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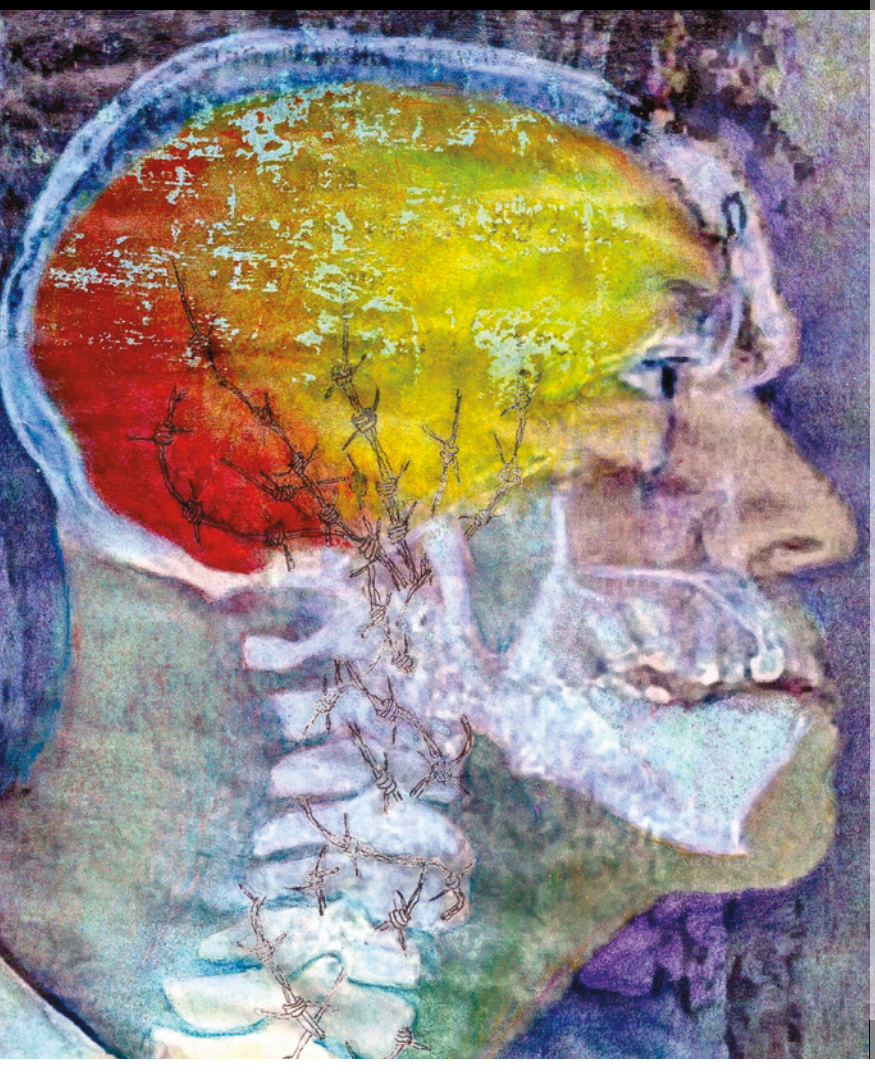
RADIOLOGIC TECHNOLOGY



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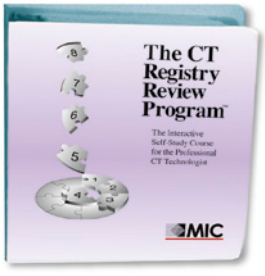

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Errata

In the print version of the Directed Reading, "Medical Imaging of Neglected Tropical Diseases of the Americas," which appeared in the March/April 2016 issue, the caption for Figure 5 incorrectly identified the medical images as computed tomography images. The article from which Figure 5 was reprinted labeled the images as magnetic resonance images. This was corrected in the online PDF file available at asrt.org/as.rt?vRrsyM.

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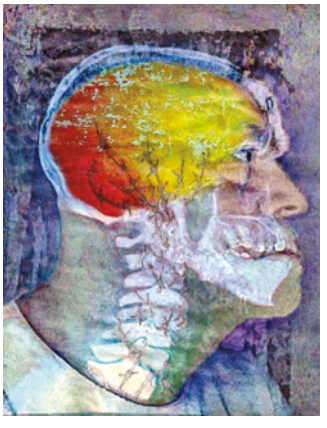

ON THE COVER

Before Ed Nicosia, R.T.(R), of Amsterdam, New York, became a radiologic technologist, he was a graphic artist. Much of his artwork reflects his personal experiences. To capture what he experiences during a migraine headache, for example, he created this mixed media piece incorporating a photograph of himself, a radiograph, paint, and pen and ink.

This symbol indicates expanded content.

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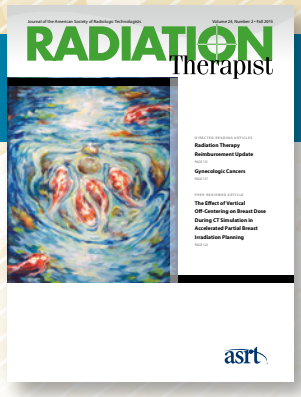
The article appeared in the September/October 2015 issue of *Radiologic Technology*.



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"The Effect of Vertical Off-Centering on Breast Dose During CT Simulation in Accelerated Partial Breast Irradiation Planning," by **Timmerie F. Cohen,** Ph.D., R.T.(R)(T), CMD; **Jeffrey S. Legg,** Ph.D., R.T.(R)(CT)(QM), FASRT; and **Melanie C. Dempsey,** Ph.D., R.T.(R)(T), CMD, FAAMD.
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WRITE FOR asrt

Contrast Media Delivery in the Assessment of Anomalous Left Coronary Artery From the Pulmonary Artery

Charbel Saade, PhD
Salam Al-Hamra
Hussain Al-Mohiy, PhD
Fadi El-Merhi, MD

Background A patient with a history of mitral valve prolapse and regurgitation that was corrected with a mitral ring repair 15 years earlier received a diagnosis of anomalous left coronary artery arising from the pulmonary artery and underwent repair.

Discussion Coronary computed tomography angiography (CTA) was employed to image the patient before surgical intervention. Synchronizing contrast media administration to opacify the right coronary artery in the arterial phase and the left coronary artery in the venous phase required a test-bolus approach.

Conclusion Matching compromised cardiovascular dynamics with patient-specific contrast media administration protocols was improved considerably with the use of a test-bolus technique during electrocardiography-gated coronary CTA.

Keywords *coronary computed tomography angiography, anomalous left coronary artery from pulmonary artery, Bland-White-Garland syndrome, contrast media*

Coronary computed tomography angiography (CTA) is a noninvasive imaging technique with greater benefits than invasive conventional coronary angiography. Coronary CTA enables accurate assessment of the entire coronary and extracardiac structures, displaying 3-D information about the structural relationships of the anomalous vessels and surrounding intraluminal and extraluminal anatomy, which contributes to clinically important prognostic information.

In this case, coronary CTA was employed to image the patient before surgical intervention. Anomalous left coronary artery from the pulmonary artery (ALCAPA) was diagnosed and subsequently repaired. ALCAPA is a rare and potentially life-threatening anomaly in which the left main coronary artery typically arises from the left inferolateral aspect of the main pulmonary artery slightly above the pulmonary valve. In most people, the left anterior descending coronary artery (LADCA) branches out of the left main coronary artery (LMCA) shaft and courses along the anterior interventricular groove.

The incidence of ALCAPA is approximately 1 in 300 000 live births, comprising 0.24% to 0.46% of congenital cardiac diseases.[1] Most patients are diagnosed in early childhood, with a few hundred cases diagnosed in adulthood.[2] Although this anomaly has been described in the literature, the contrast media delivery strategy during coronary CTA has not. Understanding this anomaly on preoperative imaging is paramount because it can affect the surgical approach. This condition also is known as *Bland-White-Garland syndrome*.

Institutional review board approval is not required for this case presentation, and all patient information remains anonymous. The authors' aim is to demonstrate the opacification patterns between the coronary artery arising from the pulmonary artery and the ascending aorta during coronary CTA.

Case Description

A 31-year-old woman who was previously healthy, except for a history of mitral valve prolapse and regurgitation that was corrected with a mitral ring repair 15 years earlier, presented to the emergency department

with symptoms of palpitations and progressive dyspnea. An electrocardiogram (ECG) demonstrated rapid rate atrial fibrillation that was cardioverted electrically to sinus rhythm. While at the hospital, the patient had recurrent dyspnea on exertion, with no symptoms of angina. Echocardiography showed moderate dilatation of the left ventricle, with mild global left ventricle hypokinesia and an ejection fraction of 45% to 49%. During diastole, evident Doppler signals were seen near the origin of the pulmonary valve, suggestive of the aberrant origin of the LMCA from the pulmonary artery.

Coronary CTA demonstrated a patent right coronary artery (RCA), with prominent vessels in the anterior mediastinum that might be related to the RCA; images were suggestive of a stenosis at the origin of the LMCA. The LMCA was arising from the undersurface of the pulmonary flow close to its origin, giving rise to an LADCA and left circumflex arteries (see **Figures 1**-**3**). Figure 3 also shows the anastomosis between the right posterior descending coronary artery and the LADCA. The patient underwent reimplantation of the LMCA to the left coronary sinus in the ascending aorta because the vessel terminated in the myocardium for the LADCA and left circumflex arteries. She was discharged 7 days after the procedure with no postprocedural complications.

Coronary CTA Technique

Imaging during the arterial and venous phase in a single acquisition in patients with congenital coronary anomalies poses a challenge for radiographers and radiologists. Synchronization of contrast media administration in the RCA (oxygenated blood) and LMCA (deoxygenated blood) with the coronary CTA acquisition requires an understanding of the scanner, contrast media, and patient cardiovascular dynamics.

Scanner Acquisition

With the patient in the supine position and arms placed above her head, ECG-gated coronary CTA was performed, employing a 256-multidetector CT scanner (iCT, Philips Healthcare). Anteroposterior and lateral scout scans were performed, with a scan range from the apex of the chest to the costophrenic angle. The detector width of the scan was 256 mm × 0.625 mm, pitch was 0.2:1, rotation time was

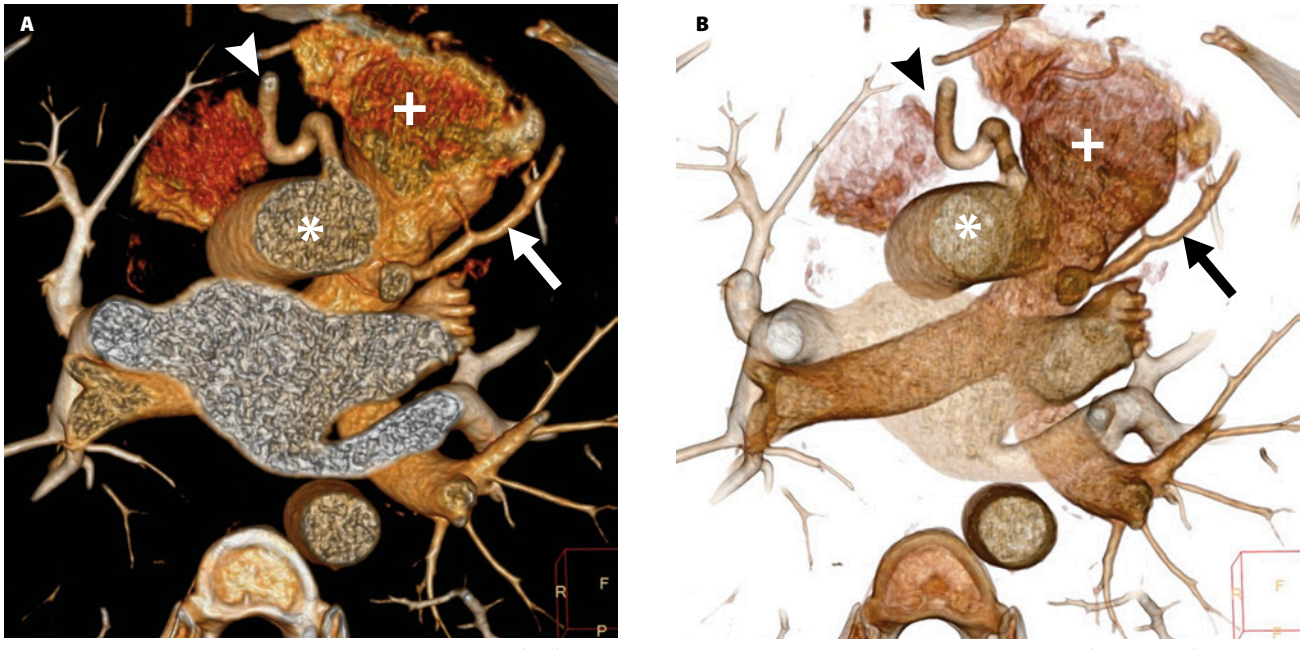

Figure 1. *A. Three-dimensional computed tomography (CT) volume rendering shows the right main coronary artery (arrowhead) arising from the ascending aorta (*). B. The arrow indicates the anomalous left main coronary artery arising from the inferior pulmonary artery (+). Images courtesy of the authors.*

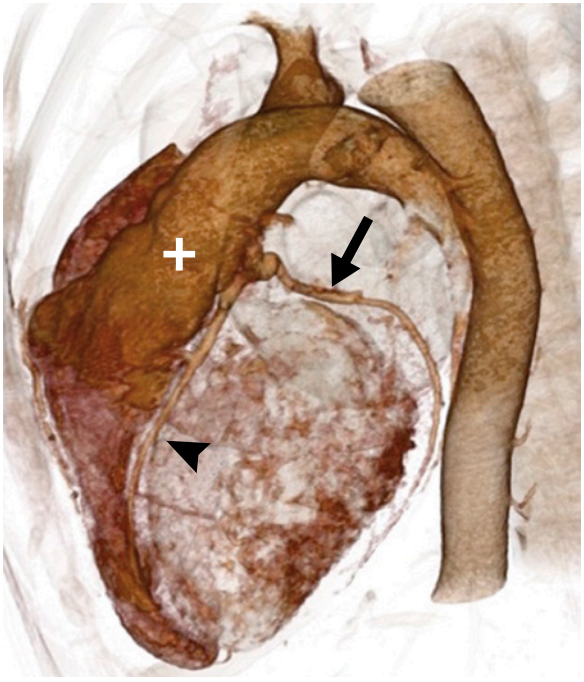

Figure 2. *Three-dimensional CT volume rendering shows the left anterior descending coronary artery (arrowhead) and left circumflex coronary artery (arrow) arising from the left inferior pulmonary artery (+). Image courtesy of the authors.*

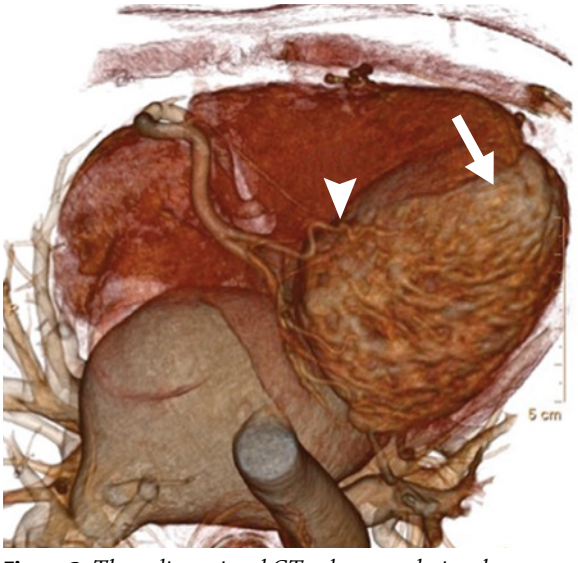

Figure 3. *Three-dimensional CT volume rendering shows anastomosis between the right posterior descending coronary artery (arrowhead) and left anterior descending coronary artery (arrow). Image courtesy of the authors.*

0.27 seconds, kilovoltage peak was 100 and milliamperage 200, with z-axis modulation, and a scanning time of 2.1 seconds.

Contrast Bolus Geometry

To predict the opacification pattern within the vessel, the region of interest was measured and plotted on a time density curve. This technique was used where one region of interest was plotted inside the abdominal aorta (at the level of aortic hiatus). One milliliter of contrast material was introduced at the same injection rate as the main contrast bolus. The region of interest determined the time to peak and the circulation time for the pulmonary and systemic circulation.

Synchronization

To synchronize data acquisition with optimal arterial and venous opacification during CTA, it has been recommended that scan direction be in the opposite direction of the contrast media flow.[3-6] During CTA, it is feasible to scan at a faster rate than that of the contrast media traversing the vessel.[7] A drawback to faster scan acquisitions is poor arterial opacification, particularly when deoxygenated blood flows from the pulmonary artery to the LMCA. Although clear limitations exist regarding the effects of fast scan times and associated contrast/blood flow dynamics, a practical solution to overcome such limitations is to measure the opacification peak of the pulmonary artery and ascending thoracic aorta. Once these data are available, the exact contrast/blood flow dynamics can be predicted, regardless of blood flow dynamics. Therefore, optimal synchronization between contrast/blood flow with a craniocaudal CT scan direction achieves peak opacification throughout the entire deoxygenated and oxygenated coronary artery blood flow (see **Figure 4**).

Image Reconstruction

The following parameters were set: standard image reconstruction of axial images at 0.625-mm slice width, a reconstruction interval of 0.5 mm, and a 180-mm × −180-mm field of view, using iterative reconstruction technique software (iDose[4]; Philips Healthcare), with a window width and level of 420 and 65, respectively. The ECG-gated scan reconstruction

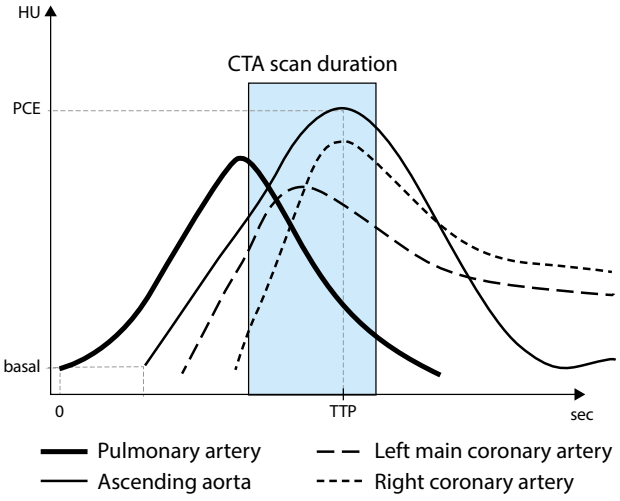

Figure 4. *Line diagram demonstrating the opacification pattern of the pulmonary artery and ascending aorta compared with the anomalous left main coronary artery and normal right coronary artery. The computed tomography angiography (CTA) duration occurs at the peak of the opacification of the pulmonary artery and ascending aorta, with contrast still being injected during the scan duration to ensure that the venous system is opacified. PCE, peak contrast enhancement; TTP, time to peak.*

interval with the fewest motion artifacts was determined by reconstructing a slice at the midsegment of the RCA in 2% steps, from 35% to 75% of the R-R interval. For diagnostic interpretation, reconstruction of the CTA images was used, with a time point with the fewest motion artifacts located at the midsegment of the ascending aorta (68%).

Discussion

An anomalous origin of the coronary arteries from the pulmonary artery usually is an isolated abnormality; it occurs in 0.4% of all patients with heart disease.[8]

Synchronizing contrast media administration to opacify the RCA in the arterial (oxygenated) phase and the LMCA in the venous (deoxygenated) phase requires a test-bolus approach. As contrast media flows into the left atrium and exits the left ventricle, the RCA is being opacified, while contrast media exiting the right ventricle is opacifying the LMCA. Therefore, a single scan acquisition that includes peak contrast media opacification in the arterial and venous phase is necessary to visualize complex coronary circulation. In this case study, complex blood flow dynamics was considered, and timing in both the arterial and venous phases was achieved in a single coronary CTA scan acquisition.

ALCAPA usually is suspected when transthoracic echocardiography shows a dilatated RCA arising from the aorta, diastolic blood flow from the LMCA into the pulmonary artery, diastolic blood flow from the inferior portion of the interventricular septum to its superior portion, and mitral regurgitation. However, findings of this nature are not specific and are shared with other diseases such as Kawasaki disease and arteriovenous fistula. Coronary CTA is a noninvasive procedure that can help in diagnosis because it can show coronary arteries with optimal image quality and high diagnostic accuracy.

For this patient, the surgeon employed a pinhole surgical correction technique of the mitral valve 15 years earlier that resulted in reduced visualization of the surface of the heart; therefore, the anomalous coronary artery was not discovered then. Multiple treatment options are suggested for adults presenting with ALCAPA, yet no optimal surgical techniques have been defined. Treatment options include LMCA ligation, reimplantation of the LMCA to its original site in the aorta, baffle creation through the pulmonary artery (Takeuchi procedure), and a combination of LMCA ligation and coronary artery bypass graft surgery. Reimplantation of the LMCA to the aorta is the first treatment choice because it restores normal anatomy and circulation; if not possible, ligation and coronary artery bypass graft surgery are preferred because they provide a dual coronary flow system.[9] In this case, reimplantation of the LMCA to the left coronary sinus in the ascending aorta was performed because each vessel terminated in the myocardium for the LADCA and left circumflex artery.

Conclusion

Detailed cardiovascular assessment, careful evaluation of the great vessel origins, their relationship to the cardiac chambers, and associated anomalies should be part of routine coronary CTA assessment. Matching compromised cardiovascular dynamics with patient-specific contrast media administration protocols is

improved considerably with the use of a test-bolus technique during ECG-gated coronary CTA.

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Minimizing the Long-term Effects of Ionizing Radiation in Pediatric Computed Tomography Examinations

Kristina Darnell, MS, R.T.(R)(CT)(MR)
Gary D Morrison, MEd, R.T.(R)

Purpose To identify methods for minimizing the effects of ionizing radiation from pediatric computed tomography (CT) examinations, including the education of medical staff, imaging staff, and patients, and dose-reduction techniques that provide the best patient care and highest image quality at the lowest possible dose.

Methods A literature search was conducted for peer-reviewed journal articles and Web-based information from professional organizations that discuss ionizing radiation in CT examinations and its effects on adult or pediatric patients.

Results and Discussion The literature indicates that dose-reduction methods, such as using appropriate technical factors and shielding, are beneficial in acquiring the best image quality for proper diagnosis at the lowest dose possible to the patient. In addition, a radiologist review of examination requisitions can help eliminate duplicate orders and unnecessary examinations, along with providing recommendations for alternative examinations that do not use radiation such as ultrasonography and magnetic resonance imaging. Education for referring physicians and other medical professionals on the importance of alternative examinations and dose-reduction methods is essential to ensure they provide adequate education to pediatric patients and their families.

Conclusion Patient education and radiation safety are top priorities for imaging professionals. Radiation exposure to pediatric patients should be minimized through the use of shielding, appropriate CT parameters, other dose-reduction methods, and education. Further research is needed in these areas to ensure optimal patient care.

Keywords *radiation safety, radiation protection, computed tomography, shielding devices in CT, pediatric CT, pediatric patients*

Computed tomography (CT) produces high-quality images to improve diagnosis, aid in selecting treatment, and eliminate unnecessary medical procedures. However, the ionizing radiation delivered during CT procedures can be harmful to patients because of its potential carcinogenic effect.[1] This is especially true for pediatric patients, who are more susceptible to the effects of radiation than are adults because of their rapidly dividing cells and immature tissues. In addition, because of children's longer life expectancies, they have a longer latent period for radiation effects to develop.[2,3] Considering the potential long-term cancer effects of ionizing radiation on pediatric patients, radiation protection methods and education are necessary.

Since CT was introduced in the 1970s, the number of CT examinations performed has continued to increase. Approximately 60 million examinations are performed annually, with an increase of 10% each year. Of those examinations, 4 million to 7 million are done on children.[2,4-6] CT examinations now account for 11% of all diagnostic radiology procedures and contribute nearly 70% of radiation dose from diagnostic procedures.[7] Although the total number of CT examinations has increased, the number performed on children in pediatric hospitals has declined in recent years because of concerns about the risk of fatal cancers associated with radiation exposure in these patients.[3,6] The as low as reasonably achievable (ALARA) principle and the Image Gently campaign have helped to create

awareness about the need for dose reduction in CT examinations and the need for education about the issue.[6] The purpose of this literature review is to discuss how the effects of ionizing radiation from pediatric CT examinations can be minimized by educating medical staff, imaging staff, and patients about dose-reduction methods that provide the best patient care and highest image quality at the lowest possible dose.

Methods

The search for this literature review was conducted primarily through CINAHL, MEDLINE, and Health Source databases. Keywords used alone or in combination included *radiation safety, radiation protection, computed tomography, CT, shielding devices in CT, pediatric CT, pediatric patients, ionizing radiation, effects of radiation in medical imaging,* and *radiation dose in CT exams.* An Internet search also was performed for peer-reviewed articles on radiation safety in pediatric patients and radiation safety in CT. Only peer-reviewed journal articles published within the past 10 years were included in the research, along with Web-based information from professional organizations. All articles used in this literature review discussed ionizing radiation in CT examinations and its effects in either adults or pediatric patients.

Results and Discussion

CT offers excellent visualization of anatomic structures and delivers high-quality images that aid in diagnosis and treatment of various diseases. Many advances in CT have made it useful in interventional procedures, trauma care, and cancer management and staging.[8] Multidetector CT scanning offers fast scanning times that help reduce the overall examination time and motion artifacts.[3] The ease and speed of CT examinations make it well tolerated by children and the imaging method of choice for many physicians. CT scanning reduces the triage time needed in emergency situations and often eliminates the need for further testing and, sometimes, exploratory surgery.[7] Although these advantages are beneficial, the modality also has disadvantages.

The ionizing radiation produced during a CT examination poses many risks for pediatric patients. Of greatest concern is the increased risk of cancer.[4] The National Research Council's Biological Effects of Ionizing Radiation (BEIR) subcommittee proposed in its BEIR VII report that there is no safe level of exposure to ionizing radiation and even the smallest dose carries a risk to the exposed person of developing cancer.[1,5] The U.S. Food and Drug Administration (FDA) has labeled medical x-rays a carcinogen, although the risk of cancer at low doses is not known.[5] Based on the number of CT examinations performed today, it is estimated that nearly 2% of all cancers could be the result of radiation from CT examinations.[5] The most common malignancies caused by this radiation exposure are leukemia, thyroid cancer, and breast cancer because of the radiosensitivity of the involved tissues. Children are most susceptible to these cancer risks because they live longer, allowing more time for cancers to develop after exposure.[1,5]

Another concern associated with CT examinations is possible missed diagnoses from low-quality images due to reduced exposure settings.[4] If the exposure is too low to produce images of sufficient quality to make a confident diagnosis, the examination might do more harm than good, causing a greater potential risk than if the radiation exposure was high.[4] Radiologists should identify their own preferences regarding CT image quality and noise level to allow for accurate diagnoses while maintaining a reasonably low dose.[4]

Processes for regulating and monitoring radiation doses received during CT scans are under development, and several approaches have been proposed. One option is to maintain a patient's dose record and make it a part of his or her permanent medical record so threshold doses can be monitored. This information could be shared with other health care facilities and insurance providers, within Health Insurance Portability and Accountability Act (HIPAA) guidelines, to protect patient privacy as well as ensure radiation safety.[5] Although generally not used by patients, the x-ray report card, available through the FDA's Center for Devices and Radiological Health, and the Image Gently medical imaging record card, available on the Image Gently Web site, can help patients and physicians keep a record of where imaging studies were performed.[7] Because radiation doses vary per examination and facility, the American College of Radiology has recommended a national registry database. This would allow facilities to upload their protocols and doses and

compare them with other facilities as a quality control measure. Such a database could lead to a national average dose value and possible nationwide protocols, which could help alleviate the problem of variable doses.[1] All of these options could help with monitoring and regulating pediatric radiation doses.

Minimizing Risks

Minimizing the risks associated with ionizing radiation from CT examinations of pediatric patients is a priority for imaging professionals. Two alternative modalities that do not use ionizing radiation are magnetic resonance (MR) imaging and ultrasonography. Because pediatric patients typically are smaller and have less intra-abdominal fat, ultrasonography often is the first choice for imaging pediatric cross-sectional anatomy.[3] Ultrasonography is ideal for imaging the abdomen, particularly the right upper quadrant and pelvic areas.[5] MR imaging is optimal for imaging musculoskeletal injuries and the central nervous system. Tumors and inflammatory processes also are well visualized on MR images.[5] Although MR imaging takes longer, pediatric patients with chronic illnesses and those who need frequent repeat head imaging should undergo MR imaging in which rapid, single-shot sequences are beneficial.[2]

Radiologists, along with referring physicians, play a part in offering alternatives to CT examinations. It might be necessary for the radiologist to consult with the referring physician regarding whether a CT scan is required and whether an alternative examination could be performed. This prompts the physician to justify his or her order and reduce unnecessary examinations.[8] In addition, radiologists can review orders and determine protocols for pediatric examinations. This prevents possible duplication of orders, helps to determine whether a CT examination is required, and prevents unnecessary exposure to ionizing radiation with alternative types of imaging. This practice could be a factor in the recent decline in CT examinations in pediatric hospitals.[3]

Several scanning parameters and techniques affect ionizing radiation exposure during pediatric CT examinations. Based on the ALARA principle, all imaging personnel should keep radiation dose and exposure as low as possible; this especially applies to the radiosensitive tissues of the breasts, gonads, thyroid, and eyes. Shielding is one option; however, the use of shields in CT departments is not routine.[9] Traditional lead shielding can be used during CT examinations and is effective for the radiosensitive organs and for imaging pregnant patients. Because of the 360° rotation of the beam, these shields must be wrapped completely around the patient. The x-ray beam incurs greater attenuation when entering laterally; therefore, lateral shielding is not as critical as anterior and posterior shielding. Anterior and posterior shielding, as shown in **Figure 1**, are acceptable when wrap-around shielding is not available. Lead shields should be placed 5 cm to 10 cm outside the scan field of view to avoid artifacts.[10]

In-plane bismuth shields, as shown in **Figure 2**, were developed specifically for use in CT. These shields decrease the surface dose to radiosensitive areas by absorbing the low-energy x-rays while allowing the beam to pass through and produce a diagnostic image.[9,10] Studies regarding the use of bismuth shields have found the dose reduction in radiation-sensitive areas to range from 18% to 74%. This reduction depends on tissue sensitivity, tube angulation, shield placement, and scanning parameters.[10] As an added advantage, bismuth shields also reduce some metal artifacts by hardening the beam when a foam pad spacer is placed between the patient and the shielding material.[9,10]

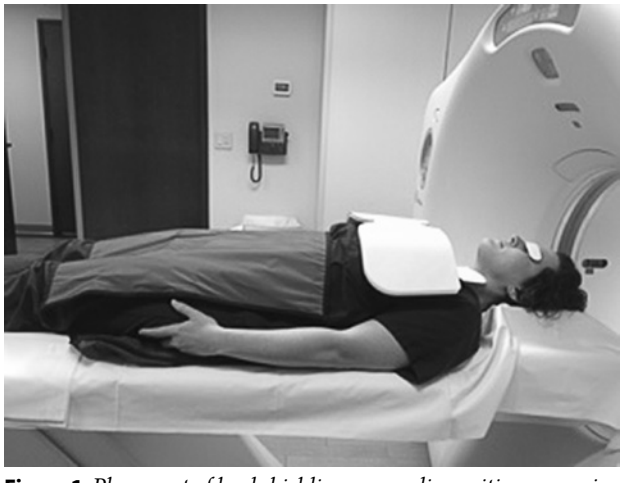

Figure 1. *Placement of lead shielding over radiosensitive organs in computed tomography (CT) scanning with 360° beam rotation. Photo courtesy of Lydia Donaldson, BSRS, R.T.(R)(CT).*

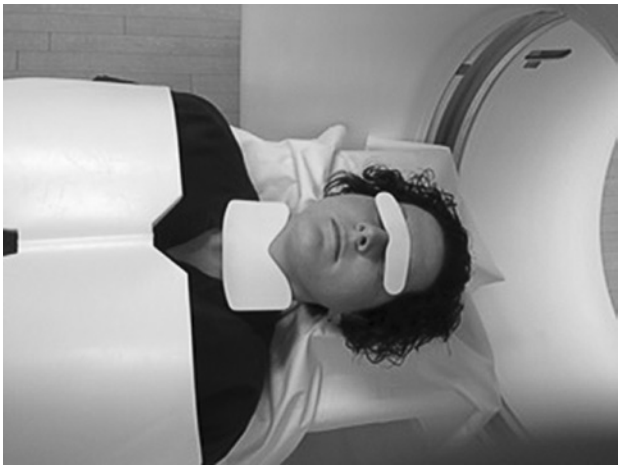

Figure 2. *Placement of bismuth shielding designed for CT use to reduce surface dose to radiosensitive organs. Photo courtesy of Lydia Donaldson, BSRS, R.T.(R)(CT).*

However, some controversy remains regarding the effects bismuth shields have on image quality. Curtis stated that these shields provide considerable dose reduction to the breasts, gonads, thyroid, and eyes with minimal effects on image quality and that because they are effective, affordable, and easy to use, they should be used every day in CT departments.[9] However, De Maio et al reported questionable effects of bismuth shielding on image quality and emphasized that other methods can provide equally effective dose reduction to patients.[10] They pointed out that the American Association of Physicists in Medicine now prefers methods other than bismuth shields to reduce radiation exposure during CT examinations, and DeMaio et al endorsed this position.[10]

Considering these conflicting views and the questionable effects on image quality, further research in this area would be beneficial. Despite strong evidence that bismuth shields reduce radiation dose to patients during CT examinations, technologists must ensure that shields are positioned properly and used in conjunction with other dose-reduction methods to provide optimal image quality and the best patient care possible.[10]

Scanning parameters that affect radiation dose to the patient include kilovoltage peak (beam energy), milliamperage (tube current), gantry rotation speed, collimation, pitch, and patient positioning. Understanding these parameters and the imaging system being used is key to reducing patient dose because one factor affects the others.[6] However, some scan protocols can be adjusted depending on the amount of radiation produced.

Overscanning, which occurs during helical scanning to obtain enough image information for image reconstruction, can increase patient dose. However, the use of collimators in newer scanners helps reduce excess tissue irradiation.[2,6] Helical scanning is preferred over axial scanning because it allows for images to be reformatted into additional planes and for the creation of 3-D models to aid in diagnosis without additional scanning. Helical scanning often is the best choice for pediatric patients because of the short time required to obtain the volume scan.[2]

Another factor affecting radiation exposure is the scout image. Scout images should be limited to the area of interest and should be taken in the posteroanterior projection, rather than the anteroposterior projection, to reduce dose to the radiosensitive breasts, gonads, thyroid, and eyes.[2,6]

When imaging a pediatric patient, it also is suggested that only a single-phase examination be performed because scanning the unenhanced and enhanced phases of the abdomen can double the dose. Typically, second-phase or delayed imaging is unnecessary and rarely provides further information.[2]

Automatic exposure control is another important technical factor that changes the tube current as the x-ray beam passes through the patient based on the patient's body size and amount of attenuation of the beam. Although it might work for adult and pediatric patients, automatic exposure control is not recommended when scanning pediatric patients unless it has been tested by a medical physicist to ensure that it has an accurate dose for pediatric scanning.[2]

Education for imaging staff, physicians, and patients helps ensure quality patient care by providing information about the risks of ionizing radiation. Education and professional development in the CT department begin with the staff CT technologists. Although the typical operator of a CT scanner is a radiologic technologist registered by the American Registry of Radiologic Technologists (ARRT), those trained before 2007 were not educated in the physics of CT equipment because it was not a curriculum requirement.[2,6] To ensure that

CT technologists are properly qualified, they must take part in additional professional development such as CT courses from the American Society of Radiologic Technologists or online education through an educational facility or the Image Gently Web site. Although Strauss et al and Zacharias et al suggested that technologists be encouraged to take the ARRT CT certification examination as a means of demonstrating commitment to their careers and providing high-quality patient care,[2,6] new requirements by the ARRT might have an effect on the role of current CT technologists and their ability to take the CT certification examination.

In addition to the clinical experience requirement, technologists now are required to complete 16 hours of structured education within 24 months before they can submit an application to take the CT postprimary certification examination. This structured education, whether it is provided by a college or university or through continuing education credit, must meet the current guidelines of the ARRT.[11] Required certification of technologists was proposed for facilities to meet Joint Commission accreditation[12]; however, the Joint Commission announced that the certification requirement will not be adopted, although sites will be required to meet safety guidelines and be current on technical advances.

Specifically, CT technologists must complete continuing education in the safe operation of their particular CT equipment, as well as in radiation dose optimization techniques and tools for pediatric and adult patients, as addressed in the Image Gently and Image Wisely campaigns.[13] These new educational requirements will help ensure facilities are equipped with highly qualified staff trained to use proper radiation safety measures to care for patients effectively.

Many health care providers, including referring physicians, emergency department physicians, and radiologists, are unaware of the increased risk of cancer from the radiation dose of CT scans; as a result, they often do not explain the risk to patients.[5] For example, a study cited by Richardson showed that only 9% of physicians were aware of this risk, which led to 3% of patients saying they were notified of the risk of cancer from CT scans.[14] Therefore, education and professional development for physicians are essential to minimize the dose to pediatric patients. Radiologists could offer consultations with referring physicians to help decrease the number of unnecessary examinations.[2,6] This would be beneficial because one-third of CT scans performed might be medically justified.[5] In addition, conferences on radiation protection and online resources, such as those offered on the Image Gently Web site, can help increase physicians' awareness of the risks of ionizing radiation to pediatric patients and reduce unnecessary examinations.[2,6]

Education for parents of pediatric patients also is essential for proper patient care and safety. Parents sometimes do not understand what is involved in their child's radiology examination or the risks associated with it. When radiologists or pediatricians discuss an examination with parents, they help parents become fully informed while showing respect for their autonomy.[7] Although parents should be informed of the benefits of the examination vs the risks of cancer induced by ionizing radiation,[5] formal informed consent is not required for pediatric CT examinations.[7] However, obtaining formal consent from parents before an examination might be considered to ensure parents have been educated properly about the procedure and radiation protection methods as well as the potential cancer risks associated with a radiation-producing examination.[7] Informational aids, such as pamphlets available on the Alliance for Radiation Safety in Pediatric Imaging's Web site and materials produced for the Image Gently campaign, educate parents about medical and background radiation and increase awareness about radiation exposure from CT scans. Providing information about the potential risks of CT examinations to parents improves communication between patients and their physicians.[6,7] These informational opportunities help all medical and imaging professionals achieve their goal of providing adequate information regarding CT scans and their risks and benefits.[7]

To view parent education materials on CT examinations, visit asrt.org/as.rt?BKugbP.

Conclusion

Radiologic technologists should be aware of ways to minimize the effects of ionizing radiation during pediatric CT examinations while maintaining image quality. Although CT has many benefits, the risk

of cancer for the pediatric population causes great concern. The need to find ways to monitor radiation exposure and minimize the risk to children is a priority for the imaging community. Minimizing the dose to pediatric patients can be done by using ultrasonography and MR imaging, which do not produce radiation, and by securing radiologist preapproval of certain examinations and protocols. Adjusting the scanning parameters and technical factors and using bismuth shields also have become valuable dose-reduction methods in CT.

However, education of staff, physicians, parents, and patients seems to be one of the most valuable ways to minimize the risk of ionizing radiation. Properly educating staff and physicians helps them pass that knowledge on to the parents of pediatric patients who can then make informed decisions about the care and treatment of their children. It is the duty of all imaging and medical professionals to provide quality care, inform patients, and keep the radiation dose as low as reasonably achievable. Therefore, because of the long-term effects of ionizing radiation on pediatric patients, these radiation dose-reduction methods are a necessary part of providing the best patient care and image quality possible.

The articles included in this literature review highlight some areas in which further research is needed such as the use of bismuth shielding during CT examinations. Although bismuth shields are affordable, effective, easy to use, and reduce radiation dose from exposure during CT examinations, their effect on image quality is unclear.[9] It also is uncertain whether technical factors can be modified sufficiently to lower patient dose and still maintain adequate image quality. More investigation is needed on whether reduced scanning factors result in incorrect diagnoses.[6] Perhaps a national registry of scanning parameters and protocols would provide an appropriate dose without the risk of misdiagnosis. Although providing information about examinations to parents and patients is an important goal for all technologists, the need for formal informed consent for pediatric CT examinations still is debated.[7] Despite the need for further research, radiation exposure to pediatric patients should be minimized through the use of shielding, appropriate CT parameters, other dose-reduction methods, and parent and provider education. Patient education and radiation safety are the imaging professional's top priorities.

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Successful Admission Criteria to Predict Academic and Clinical Success in Entry-Level Radiography Programs

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Purpose To examine successful admission criteria in health education programs.

Methods Health sciences databases were searched for admission criteria in medical and allied health education. Special emphasis was placed on radiologic technology investigations.

Discussion Many medical and health sciences programs use cognitive and noncognitive factors to predict student success. However, research has not identified common admission criteria that can be used to predict academic and clinical success of candidates in radiologic technology education programs.

Conclusion Further research is needed to investigate the use of cognitive and noncognitive factors as admission criteria for radiologic technology programs and to determine whether these factors can be used to predict student success.

Keywords | *admission criteria, allied health, standardized testing, interview*

In radiologic technology education programs, the number of applicants can far outweigh the available spaces. Therefore, reliable admission criteria is crucial. A student who does not remain in a radiography program results in an empty space that cannot be filled until the following year.[1] Thus, students must be chosen for their academic ability and also for noncognitive attributes such as communication skills and persistence. To date, no one set of criteria exists for either category.

This literature review examines successful admission criteria in health education programs including medical and allied health professions. Its purpose is to discern positive admission criteria that will help radiography programs improve retention, provide positive certification examination, and increase completion rates and clinical success.

The author expected the research to reveal that radiography programs use either a combination of different admission criteria or only cognitive criteria to predict student success, with minimal emphasis on overall grade point average (GPA). It was not expected, however, to find that programs use noncognitive criteria to predict clinical success. The author also believed that programs would use standardized testing to evaluate cognitive abilities and that interviewing would not be used to evaluate potential students because of the subjectivity of applicants' responses.

Methods

The databases used in this study included CINAHL, Proquest Nursing, and Allied Health Source. Terms used in the search were *admission criteria*, *allied health*, *standardized testing*, and *interview*. Inclusion criteria were the allied health professions; all other fields were excluded. Resources before 2004 were excluded unless they were related directly to the radiologic technology profession.

Literature Review

The quest for successful admission criteria to predict student success is important in health care education for physicians, nurse anesthetists, chiropractors,

and physician assistants.[2-7] It also is important for allied health care education including dental hygiene, medical technology, nursing, occupational therapy, physical therapy, and respiratory therapy.[8-11] The radiologic technology profession falls under the allied health care category, and determining successful admission criteria is equally important in this profession.[1,12-17]

In health care education, prior research concerning successful admission criteria has covered 2 primary categories of assessment: cognitive and noncognitive factors. Cognitive factors relate to academics, such as a student's overall and selective GPA and standardized test scores. Noncognitive factors, such as motivation, knowledge of the profession, work ethic, and interpersonal skills, can be assessed through interviews, essays, reference letters, and prior health care work experience. Although cognitive assessment has been examined to predict a student's ability to complete the program, many researchers have investigated noncognitive appraisal as a method to predict clinical success.

In addition to addressing types of admission criteria for health care education programs, this literature review addresses admission criteria used in radiography programs from 1976 to 2013 including the evolution of specific criteria.

Nonallied Health

In a nurse anesthetist education program, Burns investigated the predictive value of cognitive factors, such as GPA and Graduate Record Examinations (GRE) scores, and noncognitive assessment such as critical care work experience.[2] She found that overall GPA score was the most substantial factor, followed by GPA in science-based courses. The investigation also revealed that years of critical care nursing work experience had a reverse relationship in terms of predicting student success. She surmised that this could be because of the length of time the student was away from the educational environment, thereby leading to issues with motivation and attitude. Burns' conclusion was that a combination of cognitive and noncognitive factors could predict a student's success more accurately than either set of criteria alone.

In a physician assistant education program, Jones and Forister examined noncognitive variables by comparing the use of 2 types of interview formats to predict clinical success: the behavioral and the multiple mini-interview (MMI).[3] The results of their study indicated that the more subjective behavioral format with its unstructured questions and single interviewer demonstrated candidate ratings of "highly desirable" and "desirable" on a consistent basis. The researchers were concerned that the geniality and winsomeness of an individual was actually being ranked rather than specific cognitive and noncognitive factors. In contrast, the researchers determined that the MMI format, which was highly structured and thereby less subjective, was more adept at predicting a student's inherent and suppressed aptitude. The MMI format typically is based on comments made by candidates in response to given scenarios.

Peskun et al examined cognitive and noncognitive admission criteria in a medical school.[6] Cognitive variables in their study included GPA and Medical College Admission Test (MCAT) scores. Noncognitive variables included interviews, essays, and reference letters—all used to assess the candidate's ability to communicate as well as an applicant's level of compassion and regard for others. The researchers believed that noncognitive measurements were as important as cognitive measurements because personality traits are an important component of medical practice. The purpose of their study was not only to evaluate a student's cognitive ability to succeed in medical school but also to assess noncognitive factors for success in the residency portion of a student's education. The results of this study demonstrated that the cognitive variables of GPA and MCAT scores corresponded with academic success in medical school. They also noted that noncognitive admission factors predicted the student's residency ranking. As a result, the researchers stated that nonacademic evaluations should be valued as part of admission criteria.[6]

Stansfield and Kreiter, as well as Lemay et al, assessed the value of interviews in the admission process.[4,7] Stansfield and Krieter stated that medical schools rate noncognitive variables higher than cognitive and were concerned with inter-rater reliability.[7] Similarly, Lemay et al concentrated more on the low reliability and validity of the interview format and the subsequent effect on the fairness of the interview process to the applicant.[4]

In both studies, medical schools used interviews to complement cognitive variables such as GPA and MCAT scores. The educational institution investigated by Lemay et al used the following weighted scale to determine which applicants were accepted into the school: cognitive variables (40%), interview (48%), and an essay written under observation during the interview process (12%).[7] The researchers found that when comparing scores of applicants who were accepted with those placed on the waiting list, compelling variations in the interview scores were evident. The mean interview score for those who were accepted was higher than those of applicants placed on the waiting list.

Allied Health

Jewel and Riddle investigated admission criteria that could predict which applicants accepted into a physical therapy program might be placed on probationary status at a later date.[11] It was hoped that identifying these individuals could help prevent future probationary issues. They examined cognitive variables including overall GPA, math and science GPA, and GRE scores. They determined that students with low GRE scores tended to be placed on academic probation, thereby surmising that these applicants struggled with their approach to content covered in written examinations.[11]

In a respiratory therapy program, Ari et al explored the correlation of admission criteria to the student's success on the national board examination.[8] Their study examined criteria, such as overall GPA before entering the program, in addition to GPA while in the program. Their research demonstrated that GPA before entering the program is related to student success.[8]

Neither of these allied health studies differentiated between cognitive criteria and noncognitive variables that measured clinical success. Conversely, the radiologic technology profession always has been cognizant of the importance and value of noncognitive factors as a predictor of clinical success.

Radiologic Technology

Earlier research on successful admission criteria mentioned variables that include high school academics, whereas those factors are excluded in more recent research. However, what has not changed is the search for noncognitive factors that predict clinical success. For example, in 1976, Ballinger discussed the effect of criteria, such as American College Testing (ACT) scores, high school rank, number of math and science courses taken, and personal interview, to predict overall scores on the American Registry of Radiologic Technologists (ARRT) certification exam, focusing in particular on the radiographic technique section that might predict clinical success.[18]

Using evaluations by employers as a reference, Ballinger wanted to determine whether the exam scores could predict clinical performance.[18] To make this determination, he discussed a 1973 study performed by the ARRT to determine validity of the certification exam whereby a questionnaire was sent to the employers of individuals who passed the exam. Employees were rated on their technical ability in the workplace; this appraisal was compared with each technologist's ARRT certification exam score. He found that a relationship existed between an employee's performance on the certification exam and his or her performance in the workplace: a higher exam score correlated with a higher employer evaluation.[18]

Ballinger also compared the variables mentioned above with students' overall exam scores in what was then identified as the "radiographic technique" portion.[18] His results indicated that a student's high school class rank and their ACT English score were the best overall predictors of success on the exam. Ballinger concluded that a higher class rank demonstrated higher student motivation, thereby increasing likelihood of success on the ARRT certification exam.[18]

Cisneros-Blagg and Blagg's 1985 literature review of radiologic technology admission criteria investigated the use of noncognitive factors to determine clinical success.[19] They were concerned that relying solely on academic variables for admission might exclude individuals with the desire and positive attributes to be successful. Their summation of the research revealed that noncognitive variables related to motivation were the only ones that predicted success for individuals with below-average academic assessments. In addition to motivation, other noncognitive variables assessed included interpersonal relationships, career planning, self-concept, moral judgment, and problem-solving

ability. The authors concluded that programs should include an assessment of noncognitive variables in addition to general cognitive variables such as GPA, selective GPA, and standardized testing; however, they could not determine definitively which noncognitive variables to include.[19] They recommended that, especially during times of reduced applicant numbers, it is most important to properly assess students who are on the border of acceptance and nonacceptance.[19]

Four years later, Winkler and Bender published an examination of the admission process of their radiologic technology program.[20] In this particular program, applicants were ranked using a weighted admission point score for cognitive and noncognitive factors. The cognitive admission criteria included high school rank, GPA, and math and science grades. In addition, overall GPA and math and science GPA in college courses were evaluated along with the actual number of math and science courses taken. Noncognitive criteria were assessed using an interview, work experience involving patients, and a statement of goals. The researchers compared weighted scores to the students' performance to determine whether students with higher weighted scores performed better in the program and on the ARRT certification exam. Results indicated that although high school–related criteria had no bearing on the students' performance, weighted scores were a valid predictor of student success. Those students with higher weighted scores performed better in the program and on the certification exam.[20]

In a 1996 national study, Shehane investigated admission criteria in associate degree radiography programs to identify common criteria used to predict student success.[21] The author determined that the criteria most used by programs were math and science GPA (high school and college), a minimum GPA requirement (most used 2.5), and an interview. Other factors considered included GPA for prerequisite courses, English/speech GPA, ACT/Scholastic Aptitude Test (SAT) scores, clinical observation, and computer courses. The research revealed that most survey responses did not indicate any specific type of criteria used to predict success. In addition, the majority of programs surveyed in this study used some type of ranking or weighting system to select students.

Research of radiologic technology program admission criteria from 2004 to 2013 demonstrated a decreased emphasis on high school performance and an increased focus on cognitive variables such as standardized test scores and college GPA (both cumulative and selective). Selective GPA included either math and science GPA or grades in specific prerequisite courses. As in the earlier research, noncognitive variables included an interview to assess knowledge of the profession and communication and interpersonal skills, a statement of goals, and prior employment or volunteer experience in the health care field.

In 2004, Rutz investigated admission criteria to determine which variable or variables could predict clinical success.[16] In particular, she examined students' work ethic as a predictor of clinical performance. Like Winkler and Bender, but contrary to Ballinger, Rutz determined that high school GPA had no bearing on clinical success.[16,18,20] Her research revealed that cognitive variables did not assess the attributes and skills needed for a student's success in the clinical environment. She stated that it was difficult to assess all 3 domains (ie, cognitive, psychomotor, and affective) needed for students to thrive from a clinical perspective. Furthermore, using an interview to assess necessary attributes for clinical performance might be an option but could be time consuming and carry legal implications. Rutz suggested using the Occupational Work Ethic Inventory (OWEI), especially the initiative and dependability scores, as a method to measure a student's work ethic, which is of high importance to employers.[16] In her study, results of the OWEI taken before admission were compared with students' clinical performance evaluations. The result revealed that no single admission criteria could be used to predict clinical success and that no statistically significant relationship existed between academic achievement and clinical success. However, Rutz concluded that an admission candidate with a high score on the OWEI's initiative and dependability sections was more likely to be successful in terms of clinical performance.[16]

Kudlas explored radiography programs' admission processes in relation to student retention in 2006 to learn whether a variation existed among programs that used a competitive process and those that did not.[1]

He concluded that programs with a competitive admission process had a higher retention rate. Furthermore, selective GPA and reference letters were the only admission variables to correlate significantly with increased retention rate. His study revealed that students with clinical issues resulted in the highest departure rate (50%). Academic and discipline reasons were the second-highest reason cited for students departing (40%).[1]

Espen et al sought to identify common admission criteria used by radiography programs.[12] Results revealed criteria most often used by programs; however, no common criteria appeared to be used by all programs surveyed.[12]

Ochs and Adams' 2008 literature review investigating admission criteria in radiation therapy programs concluded that the use of GPA in a competitive process was the best predictor for student success; however, if performed correctly, the interview process could add great value.[14] They explained that it was important that the interviewer be educated and properly prepared for the task, and they cautioned relying on a student's GPA because grades could be influenced by the character and attributes of an educator. Furthermore, they determined that written or face-to-face interaction with candidates was the only authentic method to truly discern the student. Ochs and Adams concluded that GPA alone should not be the only criterion considered for admission.[14]

In 2009, Kwan et al found that prior performance in math and science courses was a predictor of academic success.[15] They also stated that the use of an interview in the admission process could better the understanding of noncognitive variables. Kwan et al, like Jones and Forister as well as Lemay et al, suggested using the MMI.[3,4,15]

Later research in radiologic technology education demonstrates a continued interest in assessing noncognitive factors to predict clinical success. Standardized testing and the use of a newer, less subjective interview process were the focus of more recent studies.

Standardized Testing

The use of standardized testing as an admission criterion also has been researched in allied health. Goodyear and Lampe investigated standardized testing in a medical technology program in combination with cumulative and science GPA, reference letters, and an interview.[9] The standardized test used was the Allied Health Professions Admissions Test (AHPAT). The researchers stated that there was a need to examine the predictability of the AHPAT because the number of applicants had been escalating, far exceeding the number of available spaces. Subsequently, the proper selection of applicants was imperative.

Goodyear and Lampe's study revealed that the biology section of the AHPAT was the leading predictor for success in medical technology education programs.[9] In addition, the researchers found that having the AHPAT as a requirement assisted with evaluation of older transcripts at their institution, as well as those from educational facilities other than their own.

Helm performed a literature review of the use of standardized testing in dental hygiene program admissions, focusing on standardized testing's effect on minority applicants.[10] The author explained that this was important because she believed an increase in minorities in the profession could improve access to dental hygiene care for more people. The literature revealed that standardized testing hindered minority and low socioeconomic applicants' ability to be accepted into a dental hygiene program.[10]

Chen and Voyler examined Elsevier's Health Education Systems Incorporated (HESI) Admission Assessment's ability to predict success in nursing programs so as to increase student retention.[22] The exam is an important component to the admission process; as the researchers stated, preadmission academic performance generally is used as admission criteria but is not always a true representation of a student's cognitive ability. Chen and Voyler further explained that this information can be ambiguous because of such factors as grade inflation and differences among grading systems.[22] Grade inflation also was a concern of Ochs and Adams.[14] The use of standardized testing might reduce some of the inconclusiveness associated with other cognitive variables. The results of Chen and Voyler's study comparing students' HESI scores with completion rates of first semester classes revealed that students with higher scores completed all first semester courses while those with lower scores tended to not finish all courses.[22]

However, demographic information given for that study differed greatly from that noted in Helm's literature review because almost two-thirds of the students in Chen and Voyler's study identified as minorities.[10,22]

Hawking et al investigated the predictability of success of the Psychological Service Bureau's (PSB) Health Occupations Aptitude Test as part of the admission criteria for a radiography program.[13] This program's admission process involved 2 phases: a quantitative measure to assess cognitive variables and a qualitative measure to evaluate noncognitive variables. Cognitive factors included evaluation of overall college prerequisite GPA. The results of this study revealed that only the natural science section in the Health Occupations Aptitude Test marginally predicted student success. In addition, a high score on the reading section indicated program completion.[13]

Interviews

Using interviews in the admission process helps to evaluate noncognitive variables.[13] This is especially important for health care programs in which a predictor for clinical success is vital. Although GPA is an important indicator of success, it cannot predict accurately an applicant's knowledge of the profession they wish to enter, nor their motivation.[5] Variables, such as a candidate's ability to communicate, solve problems, and think critically, might be difficult to judge.[12] As a result, many programs are reluctant to use interviews as admission criteria because the process can be flawed.[14] However, Kudlas and Shehane reported that interviews were being used in more than half of the programs surveyed as a method to evaluate noncognitive attributes.[1,21] Furthermore, Shehane stated that, along with math and science courses and GPA, interviews were the most commonly used criteria by the programs in her study.[21] Efforts to predict clinical performance in radiologic technology by Ballinger and Cisernos-Blagg and Blagg were inconclusive.[18,19] Only Rutz, who explained that an interview might lead to legal implications, was able to identify a method (ie, the OWEI) to predict clinical success.[16]

Winkler and Bender interviewed applicants as part of their admission process for their radiography program but chose to interview only those applicants whose scores were highest in the noncognitive variables.[20] This usually amounted to the top 35 to 40 individuals. Three committee members conducted the interview using a standardized form to rank several applicant qualities. A weighted process was used: The interview counted for 20% of the final admission criteria score and the cognitive criteria counted for 80%. Consequently, high academic scores counterbalanced poor interview scores, and strong interview scores provided students who had subpar academic scores with an improved opportunity for acceptance.[20]

Espen et al also discussed the use of standardized interviews; more than half of the participants in their study used interviews with standardized questions and multiple interviewers as part of their admission process.[12] Standardized interviews also were examined by Kwan et al.[15] The candidates in that study took part in a standardized interview with 4 distinct topics. Scores were rated and then combined for a final interview score as part of the entire admission process.[15]

Strickland and Lee investigated a relationship between interviews and scores on the Health Occupations Basic Entrance Test (HOBET) to determine whether standardized tests could replace the applicant interviews as a measure of noncognitive attributes.[17] The study compared interview scores from the researchers' program to the scores on the HOBET test. Candidates were instructed to read a scenario and respond by making choices concerning the circumstance presented. A standardized form was used to rank student replies. Although a weak correlation was found between the reading sections of the HOBET test and interview scores, the researchers determined that the results were not conclusive enough to replace the use of an interview for noncognitive assessment.[17]

O'Neill et al examined the interview as one of their chiropractic program's admission criteria.[5] Their program's interview format was semistructured. Although questions were provided for interviewers, they also were permitted to use their own questions as deemed necessary to supplement answers to the structured questions. The interview was conducted by a panel of 2, consisting of 1 faculty member and 1 student. These interviewers went through a training session on preventing bias and proper scoring methods. The investigators deemed that there was above average generalizability for the

interview component based on the flexibility of the semistructured format of the interview process.

Mercer and Puddey investigated the interview process and its effect on successful student admissions over a 10-year period in their Australian undergraduate medical school.[23] They also examined other admission criteria. The interview format was extremely structured, with all applicants receiving the same questions. It was conducted by one member of the educational institution and a member of the community. A rating scale was used to determine the score, and the final rating included a score for the applicant's overall communication skills throughout the interview process. The results demonstrated that the exceedingly structured format of this interview process made it comparable to the MMI format, which has become a feasible substitute for a conventional interview.[23]

Similar to other researchers, Grice believed it was imperative to measure the noncognitive traits of applicants to clinical programs, although using a traditional interview to do so might be too subjective, indefensible, and unfair to some applicants.[24] In addition, it is vulnerable to bias because of the interviewer's assumptions and beliefs, as well as the interviewer's perception of the applicant in terms of being "liked" or "disliked." Consequently, Grice suggested using the MMI as an alternative.[24]

To measure applicable noncognitive behaviors for candidates in a physician assistant program, Jones and Forister's study compared the MMI with the more traditional behavioral interview.[3] The MMI process is composed of several small stations, each with a separate interviewer. At each station, the applicant was given a scenario to assess a particular attribute. Conversely, in the behavioral interview format, questions were structured over 2 stations with 2 interviewers per station. The MMI permitted applicants to provide additionial information, thereby giving them an opportunity to demonstrate their ability. Although the behavioral interview format resulted in more applicants with perfect scores, the results were more proportional in the MMI format. Jones and Forister posited that the behavioral interview tended to measure "likability" of many of the applicants.[3] They concluded that the MMI was more reliable for predicting an applicant's noncognitive traits.[3]

Lemay et al evaluated the use of the MMI in a Canadian medical school to see whether it provided a valid and reliable appraisal of noncognitive admission criteria variables.[4] Similar to other research involving the MMI, the interview format included many stations, each with a different interviewer. Applicants were provided a scenario to read at 9 different stations and were instructed to discuss it with the interviewer. Interviewers were given specific standard questions to ask to prompt applicants, if needed. In addition, all interviewers took part in a training session. Results indicated that because of the extensive nature of the MMI format and the use of 9 different interviewers, it was not difficult to discern students who should be accepted from those who should be placed on the waiting list.[4]

Grice also discussed advantages and disadvantages of the MMI format.[24] One advantage was that applicants did not have the ability to anticipate questions, thus rendering them unable to practice their answers. Other advantages were that the interviewers' anxiety was reduced because admission decisions were not based on their assessment alone, and that the interviewers had no prior information about any of the applicants. Also, the MMI format was more efficient because several applicants could be interviewed simultaneously depending on the number of stations used. The only disadvantage Grice found in the MMI process was that it could be somewhat taxing for applicants because they were required to change thought processes hastily as they moved from station to station.[24]

Discussion

The literature reveals that for most education programs in medicine and allied health care, cognitive and noncognitive factors are assessed to predict academic and clinical success, respectively. For the most part, cognitive factors included selective GPA, in particular math and science courses, and overall GPA. This supports the assumption that overall GPA was not used as a primary predictor. There also was some indication that other selective courses were required and evaluated in the admission process, although specific courses were not indicated. Overall, most of the education programs were comfortable with using a candidate's GPA as a predictor of academic success.

The literature also revealed that noncognitive variables were evaluated as a predictor of clinical success for most programs. This disproved the assumption that only cognitive factors were assessed for admission. Using a variety of methods, noncognitive factors, such as interpersonal skills, communication, motivation, and work ethic, were assessed. In addition, many programs evaluated the applicant's problem-solving skills and knowledge of the profession. A common theme throughout the literature was that noncognitive factors were difficult to judge in a fair and subjective manner. Prior research indicated that the methods most commonly used to assess noncognitive factors were reference letters, student essays, previous health care work or volunteer experience, and interviews. However, some programs were reluctant to use the interview process as part of their admission process and criteria.

Despite the hesitancy to interview applicants, many education programs have used this strategy. The MMI format might be more successful and fair to applicants than the behavioral format for predicting clinical success. As a result, the assumption that interviews rarely were used as a predictor of success was only partly confirmed because many education programs incorporated this strategy as a primary method to assess and evaluate clinical success.

Conclusion

Although this literature review revealed many types of criteria used in the admission process of health care education programs, no common criteria across all programs were identified. Also, in terms of cognitive factors, an investigation of other courses used for selective GPA should be performed in addition to math and science courses. Finally, use of the MMI interview format in radiologic technology programs should be examined.

Further research is important now more than ever. It has been many years since the topic of common successful admission criteria has been researched, and it is time to re-evaluate. Additional research in radiography education using the MMI interview format should be performed to confirm its success as a predictor for clinical effectiveness based on its ability to evaluate noncognitive factors objectively. Last, an increased focus on selective, rather than overall GPA, is important because individual courses might be more closely related to the profession and, therefore, a better predictor of academic success.

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Radiation Safety Compliance

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This article discusses radiation safety programs, including the members of the radiation safety team, their roles, and the challenges they face, with a focus on the radiation safety officer's duties. Agencies that regulate radiation safety also are described. The importance of minimizing patient dose, ensuring that dosimetry badges are worn correctly, and using therapeutic radioactive materials safely are addressed. Finally, radiologic technologists' role in using radiation safely is discussed, and the principles of time, distance, and shielding are reviewed.

This article is a Directed Reading. Your access to Directed Reading quizzes for continuing education credit is determined by your membership status and CE preference.

After completing this article, the reader should be able to:

- Discuss the importance of radiation safety and summarize the early history of radiation safety efforts.
- Describe licensing for medical use of radioactive materials.
- List the objectives of radiation safety programs.
- Describe the radiation safety team, its duties, and key challenges.
- Identify compliance organizations and regulations that contribute to radiation safety programs.
- Explain the radiologic technologist's role in radiation safety compliance, focusing on time, distance, shielding, and personal dosimetry.

In the United States, approximately 400 million radiologic procedures are performed every year.[1] This number continues to rise, especially with increased use of advanced imaging modalities such as computed tomography (CT) and positron emission tomography. During the past 15 years, the number of advanced diagnostic medical imaging procedures has risen to an all-time high.[2] The increase is largely attributed to advancements in diagnostic imaging that allow physicians to obtain more pathological information in a shorter time. As a result, overall radiation dose has increased by nearly 6 times since the early 1980s.[2] In fact, more than 90% of radiation exposure from unnatural sources is from medical imaging.[2]

A proper radiation safety program is essential to ensure the safety of patients and radiologic science professionals. A comprehensive radiation safety program is required when facilities apply for a radioactive materials license. The privilege to use radiation can be revoked and fines imposed if the rules of safe radiation handling are not followed.

History

The history of radiation safety dates back to the early 1900s. Although the concepts of time, distance, and shielding evolved about a year after the discovery of x-rays in 1895, it took some time before safety practices became mandatory. The effects of beam collimation and filtration on skin dose were recognized about 4 years following Roentgen's discovery. Strategies to reduce exposure time and dose, including higher energy x-rays and intensifying screens, also were implemented at that time.[3] Twenty years later, strategies for protecting personnel were recommended including

maximizing distance, limiting occupational time, and mandatory time off. Days off were considered "radiation holidays" as a method to reduce overall dose.[4]

However, before the late 1950s, only a few radiation protection programs had been established at the state and local levels. The Atomic Energy Act of 1954 gave states authorization to regulate the use of radioactive materials. The International Commission on Radiological Protection (ICRP) was renamed the National Council on Radiation Protection and Measurements in 1964, and the as low as reasonably achievable (ALARA) principle evolved shortly after that.[4] Congress created the Nuclear Regulatory Commission (NRC) in 1974 to increase radiation protection standards, reactor safety, and environmental protection. The NRC develops policies and regulations for nuclear reactor and radioactive material safety, oversees the operations of licensees, and resolves legal issues.[4] States that agree in writing to assume the same level of regulatory authority and control of the NRC guidelines are called *Agreement States*. These states govern their own radiation control programs in agreement with the NRC (see **Figure 1**).[5]

In recent years, the NRC has adopted a more holistic, risk-informed, performance-based approach to regulations. Although in the past many licensees adopted specific guidelines, now additional "best fit" practices are encouraged that still work in the regulatory framework but allow for small variances in individual work settings.[6,7] Radiation safety teams should model their plans based on the clinical needs of the departments involved, and they are responsible for ensuring that those who use radiation-producing machines and radioactive materials comply with applicable state and federal regulations.

Radioactive Material Licensing

A medical practice or facility that intends to use medical radioactive materials must must have a specific limited scope or broad scope license from the NRC. The type of license issued depends on several factors including[8]:

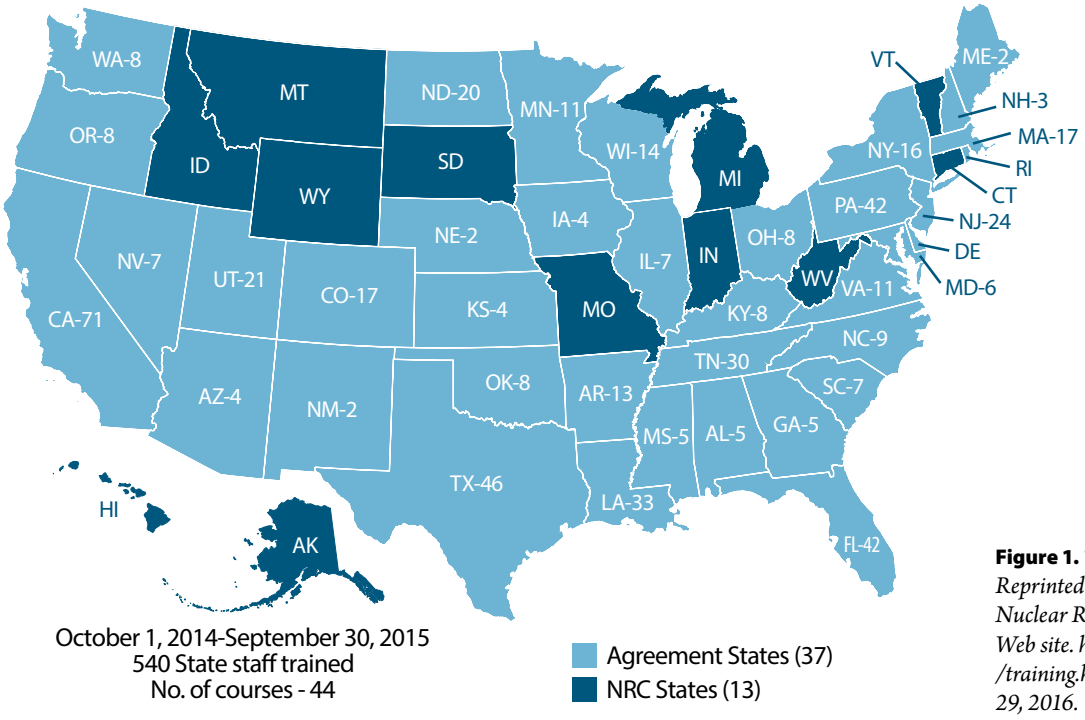

Figure 1. *The Agreement States. Reprinted from the United States Nuclear Regulatory Commission Web site. https://scp.nrc.gov/training.html. Accessed February 29, 2016.*

- Material type.
- State in which the facility is located.
- Type of facility (state or federal).
- Total type and quantity to be possessed and used.

A limited scope license is issued to small hospitals or clinics that use limited quantities of specific radionuclides. Larger medical institutions that perform greater numbers of complex procedures, including patient care and in vitro research with animal subjects, should apply for the broad scope license.[8]

Under a broad scope license, a facility is required to establish a radiation safety committee that includes an authorized user from each specific department, a radiation safety officer (RSO), a nursing professional, and a department manager.[9] The radiation safety committee must meet at least twice a year, and at least half of the members must be present at each meeting. Records of the meeting minutes must be kept until the license expires. The committee is responsible for deliberations and discussions about policies and corrective actions to stop unsafe operations in the organization. The radiation safety committee also is responsible for reviewing the facility's ALARA program and departmental audits. If research is conducted at the institution, the radiation safety committee has the added responsibility of working with the institutional review board to ensure that ionizing radiation and informed consent procedures are followed properly.[9]

Radiation Safety Program

Radiation safety programs should[7]:

- Confirm proper supervision and training of individuals working with radiation.
- Oversee safe use and control of radioactive materials.
- Limit radiation exposure in controlled and uncontrolled areas.
- Provide occupational exposure monitoring.
- Provide appropriate radiation safety equipment.
- Provide ongoing training and ensure proper radiation safety practices.
- Confirm proper licensing of radiologic technologists.

Dose minimization also is of primary concern for everyone working near radiation regularly. The ALARA principle is a well-known concept defined by the NRC as "making every reasonable effort" to keep radiation exposure as far below dose limits as is practical considering the purpose of its use, the state of technology, improvements in technology, and public health and safety.[10] Radiation safety programs are required to implement an ALARA program to keep employees mindful of occupational exposure.

In a busy hospital environment, the radiation safety team likely will be tasked with many responsibilities in addition to the ALARA program including[7]:

- Registering equipment.
- Establishing safety requirements for using medical radiation.
- Meeting licensing requirements for radioactive waste disposal.
- Providing training and documenting experience requirements for personnel.
- Verifying licensure of radiologic technologists.
- Providing training for employees who do not work directly with radiation.

An institution might have an in-house radiation safety team headed by an RSO who manages and maintains the radiation safety program for radioactive materials including materials used therapeutically and for research. In smaller institutions, the RSO could be an individual physician or a qualified radiologic technologist who handles all the responsibilities.[7] A larger radiation safety team might comprise the RSO, authorized physician users, radiologic technologists, radiation therapists, and other qualified experts, all of whom are responsible for radiation safety and protection for all radiation areas in the hospital or clinic. Medical physicists often serve as team members or consultants for unique shielding cases or construction and remodeling of facilities where medical radiation is used. They likely are to be involved in equipment calibration and evaluation. Medical physicists often are involved in radiation therapy, brachytherapy, and stereotactic radiosurgeries as well.

The goal of the radiation safety program is to develop a set of clear policies and procedures to protect everyone likely to be exposed to radiation including patients, family members, building maintenance and cleaning staff, receptionists, nursing staff, physicians, and radiologic technologists. Policies should be simple

so that those involved can meet the program's expectations.[7]

The Radiation Safety Officer

The authority and responsibilities for an RSO are outlined in 10 CFR 35.24.[11] Employees working with radiation and radioactive materials have a role in the radiation safety program that varies from institution to institution; however, the NRC requires licensed facilities to identify a responsible, qualified individual on each radioactive materials license to serve as the RSO. This individual must meet specific qualifications. He or she must have the educational background, proper training, and professional experience to meet federal and state regulations. Educational requirements include certification by a specialty board recognized by the NRC. For example, training is required before handling radioactive sources and operating the afterloader units used for brachytherapy treatments in radiation oncology.[12] Other requirements include a minimum of a bachelor's degree in science or engineering and successful completion of an examination administered by the specialty board that covers radiation physics, protection, and math related to radioactivity, radiobiology, and dosimetry. Those with a bachelor's degree also must have a minimum of 5 years' health physics experience including at least 3 years in applied health physics. An applicant with a graduate degree in physics, medical physics, physical science, engineering, or mathematics is required to have 2 years' experience working in medical physics and 1 year of experience working in radiation safety under the direction of a currently appointed RSO. He or she must be trained sufficiently in radiation safety, regulations, and emergency situations.[13]

Alternatively, an RSO in a clinical nuclear medicine facility providing diagnostic and therapeutic services can meet the qualifications by means of a different pathway. The RSO must be under the direction of an authorized physician on the institution's radioactive materials license and pass an examination in radiation physics or radiation safety, or he or she can qualify by completing a structured education program that includes 1 year of full-time radiation safety experience under the supervision of a qualified RSO on a Commission or Agreement State license plus 200 hours of classroom and laboratory training in[14]:

- Radiation physics and instrumentation.
- Radiation protection.
- Mathematics pertaining to the use and measurement of radioactivity.
- Radiation biology.
- Radiation dosimetry.

Preparation must include work environment training in regard to shipping; surveying; performing equipment checks; operating equipment for measuring radiation doses; securing and controlling byproduct material; radiation safety, decontamination, and emergency procedures; and disposal of radioactive materials.[13,14] Many radiologic technologists—mostly nuclear medicine technologists—serve as RSOs after completing this type of training.

The RSO must offer opportunities for technologists to provide input when developing procedures related to dose minimization. The RSO evaluates the feedback, and if changes are implemented, notifies workers.[15]

The RSO also is responsible for setting ALARA investigational limits for radiation workers at the institution. The RSO establishes trigger levels well below the 10 CFR Part 20 allowable occupational limits. These trigger levels, called *investigational levels,* are set by institutional policy to identify potential causes of excess radiation exposure. Investigational level 1 typically is set at about 10% of the allowable dose limit, or 5 mSv. Level 2 exposures represent a higher fractional exposure such as approximately 30% of the occupational limit. Should this limit be exceeded, the RSO notifies the worker that his or her dose limits are beyond the trigger value and provides ways for the employee to minimize exposure.[15] Level 2 also requires the technologist's signature of understanding and an explanation of his or her work practices and ways to reduce exposure. The RSO might conduct an investigation, especially if there is more than one occurrence.[15]

In addition, the RSO establishes procedures for pregnant technologists to declare their pregnancy and work safely around radiation. Pregnant technologists or therapists who are likely to receive an annual deep-dose equivalent (DDE) in excess of 1 mSv may voluntarily inform their employers, in writing, of the

pregnancy. When a pregnancy is declared, employees are provided a fetal badge in addition to the regular badge, to be worn at the waist, under shielding, to measure the DDE. A declared pregnant worker is limited to 5 mSv for the entire gestation period. If the dose to the fetus is found to be 4.5 mSv or more when the pregnancy is declared, the employee is allowed only 0.5 mSv for the remainder of the gestational period. Fetal badge readings should be monitored, and exposures should not exceed levels of 0.4 mSv to 0.45 mSv per month during the pregnancy. The RSO is required to maintain records of the dose to the pregnant worker and her fetus. If the monthly limit is reached, the RSO must notify the employee.[7]

The RSO must perform periodic testing on sealed radioactive sources to ensure there are no leaks. These types of sources often are used in clinical departments for calibration of equipment, reference dose standards, or in imaging procedures for anatomical markers and localization. Sealed sources are defined by the NRC as "any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct material."[16] The term *sealed source* can be misleading; it can give the impression that there will be no contamination on the outside of the container. However, it can leak, and wipe tests are required to maintain the integrity of a sealed source. In general, sources should be tested for leaks at least twice per year, if not quarterly. The frequency depends on the source itself, how often it is used, whether it has been used appropriately, and the age of the material. For example, testing is not required for sources with an activity of less than 3.7 GBq (100 mCi). Dated sources can exhibit deterioration, making them more likely to leak. In turn, their radioactivity could potentially contaminate health care workers and the general public.[16] The RSO must ensure that all sources are stored properly and inaccessible to employees who do not have authority to handle them. All areas in which radionuclides are handled must be identified with a radioactive symbol and designated off limits to the general public.[17]

The radiation safety team conducts annual reviews of the radiation safety program to ensure all workers are following ALARA guidelines. The RSO evaluates radiation doses received by technologists monthly or quarterly to verify they are meeting the ALARA dose limits. In addition, the RSO or authorized user provides regular education to staff about ALARA as part of the radiation safety program.[15]

Radiation safety programs are regularly inspected or audited to verify that state and federal regulations are met. Typically, an outside agency is hired to review personnel qualifications, dose monitoring devices and notifications, policies, and quality control. The agency provides a summary that describes safety violations that occurred during a previous calendar year. Violations include unusual occurrences or medical events. For example, if a radiation therapy patient received a higher total dose than prescribed, it would be a medical event and must be reported. Particular attention is paid to patient dose, number of studies or treatments performed, and calibration dates.[15] The RSO may conduct performance-based audits at the same time as the general audit to ensure personnel are following safe practices and ALARA principles. Authorized users and technologists might be asked to describe specific tasks, or they could be observed while handling byproduct material. If they do not demonstrate competency during the audit, the RSO then provides training.

Authorized Users

In radiology and oncology, an authorized user usually is a diagnostic radiologist or nuclear medicine physician, radiation oncologist, or cardiologist who has met specific requirements. To receive, use, maintain, and transfer radioactive materials, this professional must be listed on the license. The authorized user may perform certain procedures based on expertise. Other physicians, technologists, and radiation therapists may work with byproduct material under the supervision of the authorized user. For most diagnostic procedures, radiopharmaceuticals can be administered by technologists with standing orders, and direct supervision is not necessary.[9] Some therapeutic procedures that pose a higher risk to the patient require a written directive by the authorized user. The NRC requires written directives to be specific written orders that contain the patient's name, dose, radiopharmaceutical drug name, and route of administration. Another type of authorized user is the nuclear pharmacist, who must meet the qualifications found in 10 CFR Part 35.55 to be employed in commercial or in-house radiopharmacies.[14]

Compliance Agencies

Facilities using ionizing radiation must adhere to relevant laws and regulations concerning its use. Regulations ensure that radiation is used safely, and lack of compliance leaves a facility open to risk. Violations of the regulations can result in major penalties including fines, revocation of the facility's license to use, a poor reputation, and potential lawsuits initiated by employees, patients, or members of the general public.

The NRC and the Department of Transportation (DOT) regulate the transportation of radioactive materials. Preparation and packaging of materials must comply with NRC safety standards. The DOT establishes guidelines for shipping and transportation within the United States to ensure that materials are delivered safely. The International Air Transport Association (IATA) regulates international shipments of radioactive materials. Its requirements are more restrictive than those of the DOT and NRC. For example, IATA requires training for shippers every 2 years, whereas the DOT specifies training every 3 years.[18]

Losing control of radioactive material can be grounds for revocation of a facility's license; therefore, daily inventory control procedures should be part of regular recordkeeping. Only authorized users or their designees should order radioactive materials, and only from authorized vendors.[7] The RSO should train employees in the proper shipping of materials including emergency response information, methods for avoiding accidents, and proper procedures for handling packages. Packages must be checked in and monitored for measurable radiation within 3 hours of receipt or, if delivered after hours, within the first 3 hours of the following shift.

Package labels must meet federal guidelines. They are color coded to represent the overall radiation exposure risk. Most packages received in clinical nuclear medicine and radiation therapy departments are labeled with radioactive White-I or Yellow-II labels. They are surveyed by a nuclear medicine technologist or an RSO, depending on whether the radioactive materials arrive at the radiology department or at the radiation safety hot lab. They are surveyed for removable contamination by means of a wipe test using a cotton swab, and the package is monitored with a Geiger-Mueller survey meter. Packages labeled with a White-I tag cannot exceed 0.005 mSv/hr at surface level.[7] Yellow-II package surveys must be less than 0.5 mSv/hr at surface level.[7] Once materials have been checked in properly and inventoried, recordkeeping is crucial to track them. Inventory records often are kept in electronic data systems to assist in recordkeeping. The RSO can use specialized software to manage the radioisotope inventory, track orders and shipments, and receive notification when departments have disposed of decayed isotopes. For example, On Site Systems provides the Environmental Health and Safety Assistant software. It has additional features for ALARA and NRC reporting.[19] Although inventory is monitored closely, theft or misplaced materials can occur. Lost or stolen materials must be reported to the NRC.[7]

Some RSOs have oversight over nonimaging areas such as laboratories that use radioactive materials. Radioactive tissue and blood specimens must be measured using protocols established to meet the College of American Pathologists guidelines. For example, a sentinel lymph node biopsy specimen is tested in a frozen section laboratory after being injected with a radioactive substance and surgically removed. Specific protocols govern the handling, storing, and disposal of radioactive tissues. The College of American Pathologists can inspect a facility at any time to ensure proper radiation safety procedures are in place and the facility is compliant with regulations.[20]

The Joint Commission stresses the importance of the right examination and right dose to avoid unnecessary patient radiation dose. Proper use criteria should be evaluated and, if possible, examinations that do not use ionizing radiation, such as magnetic resonance (MR) imaging or ultrasonography, should be considered. If the examination is medically necessary, clinical indications for the examination must be documented.[21] The Commission also developed standards in equipment quality assurance testing, staff education and training, imaging protocols, prevention of duplicate studies, and proper follow-up for patient safety incidents. In addition, medical physicists are required to perform equipment performance evaluations for CT and MR scanners, positron emission tomography and other nuclear medicine scanners, and radiation therapy linear accelerators.[22]

The U.S. Food and Drug Administration (FDA) has implemented a range of initiatives to promote access to safe and effective medical devices for patients. The FDA's Center for Devices and Radiological Health (CDRH) initiated programs that enforce mandatory and voluntary requirements to promote the safe use of radiation-emitting equipment. The CDRH seeks to educate both health professionals and the public regarding the risks of radiation emissions and radiation-emitting products. One of its primary goals is to ensure that patients receive the benefits of radiation and the appropriate dose. CDRH programs aim to keep products safe, educate equipment users in proper and safe operating techniques, advise consumers of risks and protection concepts, and collect data and distribute information about radiation safety.[23]

In nuclear medicine, improper administration of an isotope could lead to increased patient dose. The NRC considers a medical event to be a reportable event that results from one of several combinations of events that cause an increased total body or organ dose. First, the event must meet one of the following conditions[24]:

- The dose differs from the prescribed dosage by 20% or falls outside the prescribed range.
- The dose is administered to the wrong person, by the wrong route, or involves the wrong radioactive drug.
- The dose delivered to the patient must differ from the prescribed dose by more than 0.05 Sv effective dose equivalent or 0.5 Sv to an organ, tissue, or skin.

All medical events must be reported to the NRC Operations Center within one calendar day. The ordering physician and the patient also must be made aware of the event within 24 hours. The NRC requires that a written report of the event be sent to the regional office within 15 days.[25]

Radiation Safety Team Challenges

One of the greatest challenges for the radiation safety team is maintaining a safe environment for patients and staff. Although minimizing patient dose is not a direct responsibility of the RSO, it is important in terms of the radiation safety team as a whole. Radiologists require high image quality to make an accurate diagnosis, but greater resolution results in increased radiation dose.

Minimizing Patient Dose

Diagnostic quality must be balanced with patient dose. For example, to reduce the dose from a chest radiograph, some image quality might be sacrificed. However, if a repeat image is required, the dose for that examination is greater. In CT imaging, using established protocols developed by a medical physicist or manufacturer is ideal for scanning only the organ of interest, rather than an entire abdomen, chest, or pelvis, thus keeping dose as low as possible. Scanning parameters are modified to obtain optimal images for specific cases such as renal stone visualization, orbit screening for metal, and lung nodule screening for smokers.[26] The American Association of Physicists in Medicine formed a network to establish recommended guidelines for standardizing CT protocols. Its top priority was to develop protocols for the most common procedures: perfusion; adult head, chest, and abdomen; and pelvis. Manufacturers have made protocols available with the purchase of new CT equipment.[26]

Avoiding unnecessary radiation exposure to children is most important. Considerably more pediatric CT scans are performed now than they were 20 years ago, with a 50% increase in chest scans specifically.[27] Approximately 4 million scans are performed on children annually, and these are projected to cause 4870 future cancers.[27] Although the scan time is short and images are detailed, the radiation exposure from CT scans is much higher than in radiography, resulting in 100 to 500 times greater amounts of radiation than plain radiographs.[27] Consequently, children who have undergone CT imaging have a greater chance of developing cancer later in life because their rapidly dividing cells are sensitive to radiation exposure. It takes an average of 10 to 20 years for a malignancy to develop,[15] and although it has not been proven, it has been suggested that radiation dose from CT scans could be a contributing factor to approximately 2% of all malignancies.[4]

Effective dose is a numerical value of radiation dose calculated in millisieverts and is used to predict whole-body radiation risk from a specific procedure.[15] Although effective dose originally was developed based on occupational exposure, it is useful for predicting cancer risk from cumulative radiation dose in patients.[28] The effective dose for a CT examination is based on patient

mass, the type of study, and the degree of sensitivity of the exposed organs. These doses are higher for children than for adults.[29]

A large, retrospective study of pediatric patients aged 15 years and younger was conducted to estimate lifetime cancer risk. Effective doses from CT scans were calculated for the most common pediatric studies: head, chest, abdomen and pelvis, and spine. Cancer risk models accounting for age and sex were used to associate the organ dose from specific scans with likelihood of developing cancer as an adult. Of nearly 750 cases, the authors found the highest doses were received during abdomen and pelvis scans, followed by chest and spine. Consequently, the risk of developing cancer of a solid organ was higher for abdomen and pelvis scans, with a greater risk for girls than boys. In addition, a greater risk of solid-organ cancer from chest and spine scans was noted in the girls. Although the risk for brain cancer was the lowest, head scans of children younger than 10 years were associated with a higher lifetime risk of developing leukemia. The researchers suggested that more than 40% of future cancers could be prevented by using CT protocols developed specifically for pediatric patients.[27] This is the purpose of the Image Gently Alliance, a coalition whose mission is to increase awareness of the need to reduce radiation exposure to children. Resources are available for parents, technologists, radiologists, medical physicists, and referring physicians.[30]

For more information, visit imagegently.org.

Badge Compliance

The RSO is responsible to ensure all users of radiation and radioactive material wear dosimetry badges at all times, especially during high radiation exposure procedures. Badge compliance is an issue among cardiologists, particularly cardiology fellows, and several reports document this including a study from the University of Illinois. A brief Web-based survey was sent to 2545 fellows, and 248 responded. Respondents were asked 10 questions about their radiation safety training, policy awareness, radiation exposure, use of radiation protection equipment, and awareness of personal exposure. Respondents in their fourth year reported the lowest use of radiation protective eyewear and dose monitoring badges. Their badge compliance rate was 48%, and only 24% reported wearing goggles during fluoroscopic procedures.[31] Awareness of personal exposure was low, with 17% of fourth-year fellows knowing their dose within the previous year. The level of concern about radiation exposure health effects was relatively low as well. The majority of fourth-year fellows reported being concerned "sometimes," compared with "always" or "never." The results demonstrate a gap in their knowledge of radiation exposure, indicating that training might be lacking. Cardiology fellows are exposed to greater amounts of radiation during cardiac catheterizations than the attending physicians.[31]

Badge compliance is even more important for interventional cardiologists than other physicians because they receive twice the annual dose of radiologists, or approximately 1.5 mSv to 8.4 mSv. This amount of radiation dose is equivalent to about 200 chest radiographs. The increased use of interventional cardiovascular procedures means these physicians' exposure continues to increase.[32]

One study compared a group of 10 healthy interventional cardiologists with typical exposure to a control group of health care workers who had not been exposed to radiation. Blood specimens were tested for antioxidant response markers in both groups. Although no statistically significant differences were found in reactive oxygen species or in serum antioxidant levels, the interventional cardiologists had higher levels of hydrogen peroxide. Higher amounts of lymphocytes also were found among the cardiologists. These findings indicate a measurable response to chronic low-dose radiation exposure.[32]

According to an editorial comment in the journal *Cardiovascular Interventions*, cardiologists performing interventional procedures must take the lead in starting a radiation safety program, working closely with a physicist for equipment training, purchase, and maintenance.[30] Selecting equipment that features options for decreasing dose is essential. Some options include in-pulse control, pulsed fluoroscopy, and beam filtration, which reduces patient dose by removing soft radiation beams. In-pulse control always keeps the beam at the correct power to obtain a diagnostic quality image, thereby reducing fluoroscopy time.[33] Interventional

cardiologists are responsible for maintaining the training records for the interventional team and enforcing the use of radiation badges. They also must monitor patient dose during the entire case and establish policies for follow-up should a patient receive a high radiation dose.[34]

Radiation safety awareness is low among other health care professionals as well. Jentzsch et al surveyed trauma surgeons and surgical technologists about radiation safety practices in the operating room. A questionnaire was sent to 83 participants, the majority from a level 1 trauma center. Other participants worked at a children's hospital. All were asked about their frequency of wearing dosimetry badges, thyroid shields, and lead aprons. Compliance was low. The majority (54%) reported wearing badges and thyroid shields about half of the time. However, those from the trauma center were more likely to wear badges and thyroid shields than was the orthopedic staff from the children's facility. Compliance rates for wearing aprons were greater overall. The authors concluded that consistent radiation safety education is needed for anyone using or working near x-rays.[35]

When enforcing badge compliance, it is important to distinguish between high and very high radiation areas. A high radiation area is one in which an individual could receive more than 1 mSv in 1 hour at approximately 1 foot (30 cm) from the source or from a surface that radiation has entered. In contrast, a room in which occupational absorbed dose could be more than 5 Gy in 1 hour at approximately 3 feet (1 m) from the source or irradiated surface is considered a very high radiation area.[10] Staff must be monitored with a radiation badge if they work in high radiation areas, such as fluoroscopy or positron emission tomography, or very high radiation areas such as radiation therapy. Radiation monitoring also is required if personnel are likely to receive 10% of any yearly regulatory limit or if they have declared a pregnancy. Annual occupational dose limits are as follows[15]:

- Total effective dose equivalent – 50 mSv.
- Lens of the eye – 150 mSv.
- Skin and extremities – 500 mSv.

Advances in Technology

Technological and therapeutic advancements create additional RSO responsibilities. RSOs must remain up to date on new treatments to provide education for authorized and supervised users, who can then provide information to the patient and his or her family. For example, a new injectable form of radium-223 was approved by the FDA for the treatment of metastatic prostate cancer. Specifically, radium-223 dichloride is a targeted therapy for bone metastases for patients in whom other forms of treatment have been unsuccessful. The radionuclide primarily releases alpha particles and has a half-life of 11.4 days. Clinical trials began in 2001, and pharmacologic properties, biodistribution, and dosimetry of prostate patients were evaluated. Results showed dose rates of 0.02 $\mu Sv\ h^{-1}$ at 1 m from the patient immediately after administration. Therefore, the dose to the public falls within the acceptable range of 1 mSv or less. Personnel dose is considered safe at 5 mSv. The majority of the isotope is eliminated through the gastrointestinal tract; however, residual amounts might be present in the urinary or hematologic systems. Its low penetrating ability makes it safe for others to be around the patient because the majority of the isotope is absorbed into the bone and the strength is not as high as in most nuclear medicine procedures.[36]

In radiation oncology, technological advances include higher photon energy use for treatments. In addition, hypofractionated therapy is becoming more widely used; with this treatment regimen, a patient receives a higher radiation dose per treatment to shorten the treatment course. The RSO and the radiation safety team must oversee the new treatment techniques because the potential for biological harm is greater.

Therapeutic Radioactive Materials

The use of therapeutic radioactive materials, such as iodine I 131 for the treatment of thyroid cancer, comes with its own challenges. Patients undergoing thyroid ablation using this drug must be isolated from others for several days. If their living conditions do not allow this or they cannot care for themselves independently at home, they must stay in a confined hospital room.[37] All waste generated in the room must be isolated and monitored for radioactive contamination. According to 10 CFR 35.75, the patient can be released when he or she is unlikely to expose others to a total effective dose equivalent greater than 5 mSv.[38]

This situation is fairly common and standard for the RSO and medical staff; however, some occasions can be difficult. RSOs and technologists must use problem-solving skills to deal with complex medical conditions and consult the literature describing these situations and how they were handled. One of the main challenges is measuring the radioiodine effective dose because the radioactive material is absorbed by other tissues in addition to the thyroid. There also might be residual dose to muscle and bone marrow. In addition, the biological half-life of iodine I 131 is longer in patients on dialysis compared with patients who have normal renal function. This prolonged internal exposure can damage other structures. Patients with renal failure require dialysis, which means a longer hospital stay with regular dose monitoring. Therefore, staff exposure is another concern, and dialysis nurses must be educated and properly protected while providing patient care. Ideally, they should wear a lead apron and a real-time dosimetry monitor.[39] As long as dialysis is performed 24 hours after receiving the radioiodine, staff exposure can be kept to a minimum, which is less than the dose received from a chest radiograph.[38]

The Radiologic Technologist's Role

Radiologic technologists must comply with the regulations of the radiation protection program including knowing safety requirements and applying them correctly in daily practice. In addition to being mindful of patient exposure, technologists are responsible for practicing safe use of ionizing radiation and following the ALARA principle to minimize their occupational exposure. It is important for technologists to recognize the difference between effective dose and equivalent dose. Dose to organs and tissues affects the overall risk for radiation injury, which is the effective dose. This measure is based on the specific organs involved and radiation energy. Because the degree of organ radiosensitivity varies, effective dose uses a tissue weighting factor developed by the ICRP. It is expressed as a percentage defining the relative risk for stochastic effects, based on the total organ exposure. Stochastic effects are unpredictable biological changes that might result in the development of cancer or genetic mutation. Although the risk of severity cannot be anticipated, the possibility for biological damage increases with radiation dose. Gonads have the highest weighting factor of 0.20, followed by red bone marrow. The majority of organs have a factor of 0.05.[40] Equivalent dose does not take organ and tissue dose into account. This quantity represents the harmful effects from overall absorbed dose based on radiation energy. Although the risk for biological damage is small, it exists whenever radiation doses reach a maximum limit. The effective dose strategy is currently the optimal method for evaluating exposure to radiation and estimating risk for bodily injury.

The fundamental principles of time, distance, and shielding can be applied when performing procedures associated with the highest occupational risks such as[41]:

- Fluoroscopy.
- Interventional radiology.
- Mobile radiography.
- General radiography.
- Mobile C-arm fluoroscopy.

Time

Fluoroscopy time during lengthy cases increases occupational exposure. The longer the beam is on, the greater the exposure to the patient and staff. A cumulative timer should be used and reset before each procedure so an accurate beam time is displayed. Using the image hold function helps reduce exposure to both personnel and patients, allowing an image to be viewed without emitting constant radiation as with real-time imaging. Although the radiologist controls the beam time during interventional procedures, it is the radiologic technologist's responsibility to ensure the equipment's radiation dose reduction measures are working before the procedure begins. Options to decrease exposure include low-dose imaging, beam collimation, and the last-image hold feature.[41]

Distance

To minimize dose when working in high-exposure areas, the technologist must maintain awareness of his or her body position during procedures. Mobile radiography can pose a risk to the technologist if distance between the operator and the source is insufficient. Avoiding scatter radiation is best achieved by standing a

minimum of 6 feet away from the patient, preferably at a 90° degree angle to the beam.[41] Similarly, C-arm fluoroscopy results in a considerable amount of scatter from the patient. Because surgeons often are operating the equipment, the direction of the beam might not always be consistent. However, with awareness of the x-ray tube location, the technologist can adjust his or her position accordingly. More scatter radiation is present where the beam enters the patient or at the tube position. The rate of exposure is less where the beam exits the patient, which is the image intensifier side. Knowing this, the technologist should advise surgical personnel to avoid standing near the tube when the surgeon is capturing images. In the event that optimal distance cannot be achieved, personnel should wear protective aprons.

Shielding

Wearing protective attire, such as lead aprons, prevents scatter radiation from reaching personnel. A thickness of 0.25 mm is required for those working near x-ray beams with peak energy of at least 100 kVp, as in mammography, for example.[41] Technologists working in fluoroscopy or interventional radiology are required to wear a wraparound apron with 0.5-mm lead equivalent. Those who spend a considerable amount of time using C-arm units are advised to wear thyroid shields of the same thickness.[41]

In addition, scattered radiation to the technologist can be minimized with the use of a sliding protective lead barrier. This curtain is attached to the fluoroscopy unit above the table top and must be at least 0.25-mm lead equivalent. Another attachment that limits gonadal dose during fluoroscopy procedures is a Bucky slot shielding device. Typically, the Bucky tray is moved to the foot of the table; therefore the slot is open, allowing scatter radiation to reach personnel. The shielding device must be a minimum of 0.25-mm lead equivalent.[41]

Patients often need assistance to hold still for a radiographic procedure. Although holding patients for the examination might be necessary, technologists should not practice this routinely. Lead aprons must be worn, and if the technologist's extremities are near the primary beam, he or she also should wear lead gloves. Other options are available for patient immobilization such as a device for restraining an infant for an upright chest radiograph. If an immobilization device is not feasible, then a family member can wear an apron and assist with holding the patient.[41]

Technologists should alert a department manager or lead technologist if an apron has obvious defects, especially one that is worn routinely during fluoroscopic or interventional procedures. Protective apparel should be inspected annually by a medical physicist, lead technologist, or department manager as required by the Joint Commission.

Collimation

Because scatter radiation from the patient is of primary concern in radiography, the technologist can employ methods to minimize occupational dose. Reducing Compton scatter is achieved by limiting the size of the beam through collimation. Several types of collimating features are available on radiographic equipment to protect the patient and personnel. For example, positive beam limitation helps to ensure that the image receptor size corresponds to the collimator. As long as the feature is enabled, the radiographer cannot open the collimators beyond the image receptor dimensions. This prevents exposing the patient unnecessarily (see **Figure 2**).[42]

Personal Dosimeters

Although the RSO manages radiation monitoring, it is the technologist's responsibility to wear dosimeters appropriately. These devices should be worn outside of clothing, under the apron in the same location while performing radiographic or CT procedures. In contrast, when working in fluoroscopy, the badge should be attached over the lead apron at the level of the thyroid. In addition to monitoring thyroid dose, other structures of the head and neck are exposed and must be monitored. Because a monitoring device is worn outside the apron, the dose reading closer to the body should be negligible. Abnormally high readings might indicate that the badge was misplaced. For example, forgetting the badge in a parked car or leaving it in a radiographic procedure room will result in additional heat to the dosimeter.[43]

Minimizing Patient Dose

Patient dose is reduced through proper positioning, standardized techniques, and optimal patient exposure. Minimizing dose to pediatric patients is critical. Many departments use digital radiography (DR), which allows the radiologist to view an image on a remote station such as the picture archiving and communication system. Images can be viewed in different windows to show anatomical detail. However, the technologist faces obstacles with the use of DR in pediatric patients.[44] Variations in equipment from different vendors require additional knowledge to perform examinations. Therefore, training technologists is necessary, especially because the FDA does not regulate the use of DR equipment. In addition, training documents and pediatric techniques typically are not provided with a DR unit. Manual techniques must be developed because automatic exposure control is not ideal for pediatric imaging. Often, the standard detectors are too large and are positioned for an adult, which affects image quality. Some suggest that units with smaller detectors be manufactured to optimize pediatric DR images.[44]

Another issue with DR is the inability to use positioning devices to help children remain still for an examination. The typical items, such as sponges or towels, appear on the image, obscuring important anatomy. To avoid motion and repeat examinations, technologists should use DR-compatible positioning devices. Finally, patient exposure is not apparent from the image capture information because the contrast can be adjusted after the image is acquired. This could result in some technologists not focusing on minimizing dose and a lack of awareness of the effective dose to pediatric patients.[45]

Implementing a repeat image analysis program also can help minimize patient dose. This analysis involves tracking the number of repeated studies and the reason the radiologist deemed them unreviewable. Reviewing images with positioning errors or incorrect exposure settings can be helpful for technologists and students and encourage them to make greater attempts to position correctly the first time, thereby reducing the number of repeat exposures.[40]

Conclusion

The safe and proper use of ionizing radiation entails many elements. Technologists should be aware of ways to prevent unnecessary dose exposures to patients and to minimize their occupational dose. In addition, everyone in the health care setting should be educated about radiation safety. The RSO and the radiation safety team are responsible for compliance with regulations governing the use of ionizing radiation and ensuring the safety of patients and health care professionals working with it.

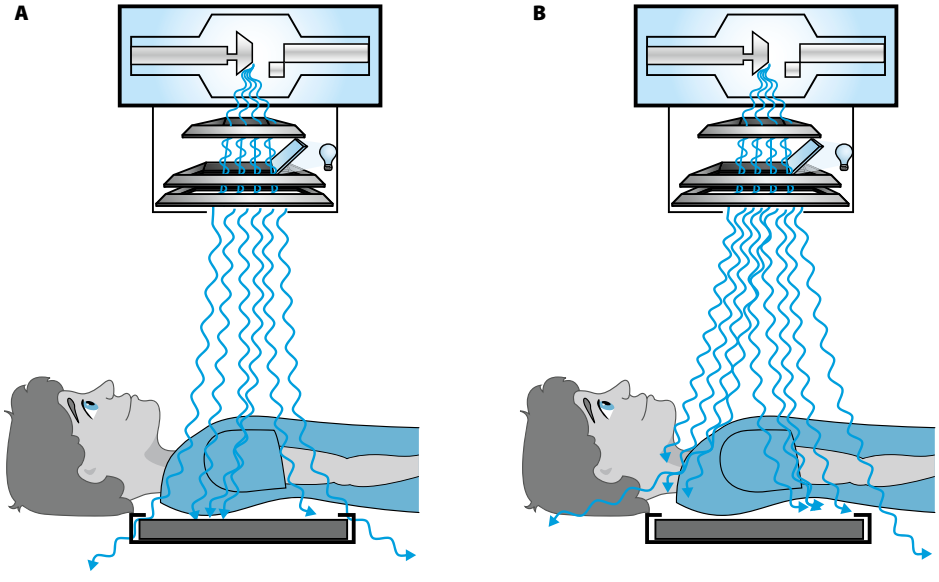

Figure 2. *Proper (A) and improper (B) collimation. © 2014 ASRT.*

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

1. Which of the following are responsibilities of the Nuclear Regulatory Commission (NRC)?
    1. develop policies and regulations for radioactive material safety
    2. oversee operations of licensees
    3. resolve legal issues

    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

2. If a medical practice or facility intends to use radioactive materials it must have a:
    a. specific license for limited or broad scope.
    b. general license for exempt distribution studies.
    c. specific license for special and commercial nuclear material.
    d. general license for source material.

3. Under a broad scope license, a radiation safety committee must include all of the following personnel ***except*** a:
    a. radiation safety officer (RSO).
    b. nursing professional.
    c. radiologic technologist.
    d. department manager.

4. Qualifications to become a medical RSO in a clinical nuclear medicine facility include all of the following ***except***:
    a. 200 hours of classroom and laboratory training in radiation protection, physics, math, biology, and dosimetry.
    b. 1 year of full-time supervised radiation safety experience under an RSO.
    c. training that includes shipping, surveying, equipment checks, measuring doses, emergency procedures, and disposal of radioactive materials.
    d. a master's degree in radiation physics.

continued on next page

5. Some therapeutic procedures that pose a higher risk to the patient require a written directive by the authorized user. Which of the following pieces of information must be included in the written directive, according to the NRC?
   a. the medical record number
   b. radiopharmaceutical drug name
   c. reason for the procedure
   d. patient's date of birth

6. Transportation of radioactive materials is regulated by all of the following organizations ***except*** the:
   a. NRC.
   b. Department of Transportation.
   c. International Air Transport Association.
   d. Office of Inspector General.

7. The Joint Commission developed standards that include which of the following?
   a. performance evaluations of imaging equipment by the RSO
   b. mandatory quarterly radiation safety presentations
   c. lowering the annual allowable total effective dose equivalent
   d. proper follow-up of patient safety incidents

8. The Center for Devices and Radiological Health initiated programs for:
   a. safe use of radiation-emitting equipment.
   b. monitoring of occupationally exposed workers.
   c. transportation of radioisotopes across state lines.
   d. safe production of byproduct material.

9. According to the article, which of the following could be a contributing factor to approximately 2% of all malignancies?
   a. failure to wear radiation badges correctly and consistently
   b. improper packaging and disposal of radioactive materials
   c. radiation dose from CT scans
   d. radiation dose from interventional procedures

10. The annual occupational total effective dose equivalent limit is _____ mSv.
    a. 10
    b. 50
    c. 100
    d. 500

11. What is the primary difference between equivalent and effective dose?
    a. Equivalent dose applies to technologists and effective dose applies to patients.
    b. Equivalent dose takes organ and tissue dose into account.
    c. Effective dose applies to technologists and equivalent dose applies to patients.
    d. Effective dose takes organ and tissue dose into account.

12. Before an interventional procedure begins, who is responsible for ensuring the equipment's dose reduction measures are working?
    a. the radiologist who will perform the procedure
    b. any authorized user
    c. the radiologic technologist
    d. the radiation safety officer

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Multiple Sclerosis: An Update

Kathryn Faguy, MA, ELS

Multiple sclerosis (MS) is the most common disabling neurologic condition in young adults and imposes high financial and quality of life costs on patients, their families, and society. Yet, developments in the battle against MS include new treatments to slow its progression and updated diagnostic criteria that can accelerate diagnosis and effective treatment. This article offers a review and update on the disease, focusing on risk factors and possible causes, symptoms, forms of MS, diagnostic criteria and tools, and the expanding array of approved treatments. It also reports on the skyrocketing cost of MS drugs, misdiagnosis, and special patient populations with MS.

This article is a Directed Reading. Your access to Directed Reading quizzes for continuing education credit is determined by your membership status and CE preference.

After completing this article, the reader should be able to:

- Define multiple sclerosis (MS).
- Discuss incidence and prevalence of the disease.
- Summarize risk factors for and suspected causes of MS.
- List common symptoms.
- Distinguish between various types of MS and how it affects certain patient populations.
- Describe MS diagnosis, focusing on the role of magnetic resonance imaging.
- Discuss various treatments and the prognosis for patients with MS.

Despite decades of research, multiple sclerosis (MS) remains an enigmatic disease. Investigators have identified many risk factors for MS, but the precise cause still is unknown. Clinicians cannot accurately predict how the disease will affect individual patients over time. Although numerous treatments are available to help relieve MS symptoms and slow the disease's progression in some cases, there still is no cure.

Disease Overview

MS is a chronic, disabling condition of the central nervous system (CNS).[1] It is presumed to be an autoimmune process and causes multifocal inflammation and destruction of the myelin sheath that surrounds, supports, and protects nerve fibers (see **Figure 1**). These areas of inflammation and destruction are called *plaques* or *lesions*. The term *sclerosis* means hardening, a reference to the CNS plaques characteristic of MS. Ultimately, MS leads to loss of axons in the brain and spinal cord.[2] The disease can progress at various rates and causes a wide variety of neurologic signs and symptoms. Symptoms can be mild, moderate, or severe; continuous or relapsing and remitting; and progressive or nonprogressive. For many patients, however, the disease causes significant disability over time including mobility challenges, pain, and cognitive difficulties.

Prevalence, Incidence, and Demographics

An estimated 2.5 million people worldwide have MS,[3] but distribution of the disease varies significantly among geographic regions. The prevalence of MS increases as distance from the equator increases[4] and is several times higher in temperate climates than in tropical ones. Inhabitants of the northern United States, Canada, Europe, New Zealand, and southeastern Australia are particularly affected.[5,6]

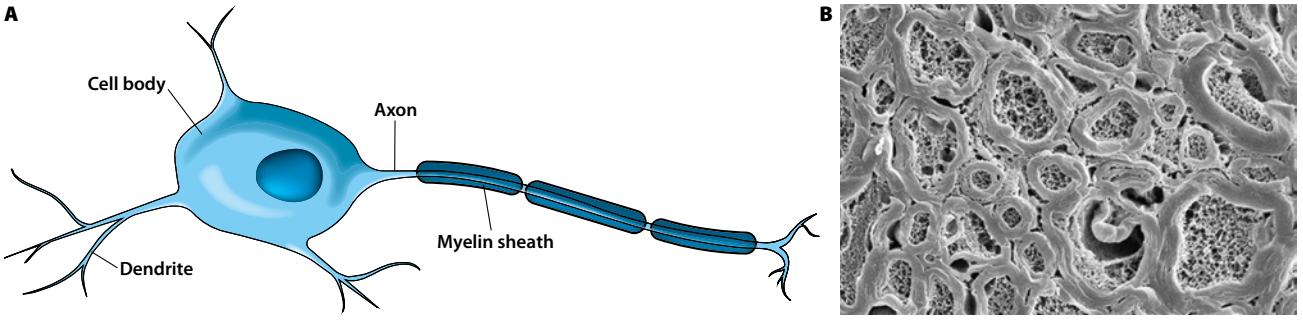

Figure 1. *A. Nerve cell. © 2016 ASRT. B. Photomicrograph of normal nerve fibers (pink) protected by myelin (green). Reprinted with permission from Ledford H. Drug that boosts nerve signals offers hope for multiple sclerosis: trialled antibody treatment thought to work by renewing the protective coating of neurons.* Nature. *2015;520(7548). http://www.nature.com/news/drug-that-boosts-nerve-signals-offers-hope-for-multiple-sclerosis-1.17367.*

MS is comparatively rare in Africa and East Asia, where the prevalence of the disease is fewer than 5 per 100 000 people. In the highest-risk areas, prevalence is greater than 100 per 100 000 people.[7] In some parts of Canada, for example, the rate is as high as 385 per 100 000 people.[8] However, there are exceptions to this geographic pattern of susceptibility. For example, the Inuit people of Canada and Alaska rarely develop MS.[9]

The geographic risk of developing MS appears to be set early in life and does not change after early adolescence. For example, if a person lives in a low-risk geographic region before age 15 years and then moves to a high-risk region, he or she retains the lower risk associated with the childhood residence, and vice versa.[9]

The estimated prevalence of MS within the United States varies significantly, from 58 to 95 individuals per 100 000. As many as 570 000 Americans are thought to have MS, approximately 0.21% of the population.[4] Whites are more affected than people of other races and ethnicities.[5] Approximately 12 000 new diagnoses are made annually in the United States.[4]

Initial symptoms of MS usually appear when patients are aged 20 to 40 years, and people in this age group account for 70% of new diagnoses.[8] It is rare for symptoms to develop after age 60 or before 15 years old,[5] but children and elderly people can develop the disease.[2] Women are approximately 3 times as likely as men to develop MS[7,8]; however, when the disease strikes later in life, the sex ratio is more even.[5] For women, the average age at MS diagnosis is 29 years; for men, it is 31 years.[1]

Causes, Associations, and Disease Mechanism

A leading hypothesis regarding the cause of MS is that it occurs in people who are genetically susceptible to the disease and who have experienced some type of environmental assault such as exposure to a particular virus or toxin.[5] For example, the Epstein-Barr virus, which causes infectious mononucleosis, has been linked to MS.[6,10] Compared with people who have not been infected with the virus, the risk of developing MS is 15 times higher for people infected with Epstein-Barr virus during childhood and 30 times higher for people infected in adolescence or adulthood.[10] Also, MS plaques express high levels of Epstein-Barr virus antigens.[9] The nature of this association is not yet understood, however,[10] and many people with antibodies for the virus do not have MS.[5]

In addition, having another autoimmune disease, such as thyroid disease, type 1 diabetes, or inflammatory bowel disease, is known to slightly raise the likelihood of developing MS.[6] Low levels of sun exposure and vitamin D have been suggested as possible contributing factors to MS development, as have cigarette smoking, obesity, and high levels of salt consumption.[2,7,10] On the other hand, several previously suspected risk factors have been definitively ruled out (see **Box 1**).

To evaluate the roles of sun exposure and vitamin D status on the risk of developing MS, Lucas et al performed a case-control study in groups of Australian adults with and without a first demyelinating event.[12] The researchers found that both factors might play a role in demyelination.[12] Specifically, higher levels of

Box 1

Disproven Suspected Causes of Multiple Sclerosis[11]

Although the exact cause or causes of multiple sclerosis (MS) remain unknown, researchers have disproven a number of previously suspected causes including:

- Using Aspartame, the artificial sweetener used in soft drinks and foods.
- Having been exposed to heavy metals such as mercury, manganese, or lead.
- Having allergies.
- Having a history of traumatic injury.
- Living with a dog or being exposed to dogs. (At one time, canine distemper was suggested as a possible cause.)

sun-related skin damage and higher serum levels of vitamin D were independently associated with decreased risk of a first demyelinating event.[12]

Although MS is not considered a genetic condition, family members of people with MS are at increased risk.[5,6] First-degree relatives of a person with MS have a 7-times-greater chance of developing the disease than do those who have no close relatives with MS.[9] For monozygotic twins, the concordance is 30%.[7] So far, the only chromosomal locus consistently associated with susceptibility to MS is major histocompatibility complex, class II, DR beta 1 (*HLA-DRB1*), which is believed to account for approximately half of the disease's genetic basis.[4,7,9] Conversely, the *HLA-C*05* allele is believed to protect against MS.

MS is considered an immune-mediated disease. It begins when various types of immune cells, such as T cells, are activated and penetrate the blood-brain barrier. These cells then secrete interleukins that allow additional immune cells to enter the CNS.[4] The invading cells produce inflammatory cytokines, proteases, free radicals, glutamate, and nitric acid that damage the myelin, ultimately leading to destruction of the nerve fibers or axons.[4,13,14]

Multiple Sclerosis Clusters

Several clusters or so-called epidemics of MS have been noted in the medical literature, and although explanations for these outbreaks have been suggested, none have been proven.[7] One of the earliest and most well known of these clusters occurred in the Faroe Islands, which are located in the North Atlantic between Norway and Iceland. Before World War II, MS had not been documented among the inhabitants of the Faroe Islands, but beginning in 1943 several waves of MS diagnoses were reported.[15,16]

British troops occupied the Faroe Islands for 5 years during World War II, and many of the occupying force came from the Scottish Highlands, where the prevalence of MS is high (90 cases per 100 000 people). One early investigator of the outbreaks, American neurologist John Kurtzke, speculated that the troops might have brought a virus with them that triggered a new susceptibility to MS in the native Faroe Island population.[15,16] He suggested that infection with the virus probably is asymptomatic and typically occurs during adolescence or young adulthood. According to Kurtzke's hypothesis, MS is a rare, late outcome of infection with the as-yet-unidentified virus.[17] However, no specific cause for the Faroe Island clusters has ever been determined.[15,16]

Additional MS clusters have been identified among residents of DePue, Illinois; Rochester, New York; and El Paso, Texas. These outbreaks tentatively were linked to high levels of exposure to zinc and other metals used in manufacturing facilities and metal smelters.[15] However, no evidence definitively links any metal with MS.[15]

Symptoms

Symptoms of MS are highly variable and can be attributed to other conditions (see **Box 2**).[5] Symptoms can occur singly or in combination and can arise as sudden attacks or progress steadily.[7]

Typical MS symptoms include[5-7,9,21]:

- Fatigue (occurs in 70% of cases).
- Unusual sensations such as paresthesia (tingling or "pins and needles"), often an early symptom.
- Muscle stiffness.
- Muscle spasms.
- Tremors.
- Numbness or weakness.
- Dizziness.
- Paralysis (usually in the legs) or gait disturbances.
- Bladder or bowel problems such as urinary urgency or retention.

Box 2

Differential Diagnoses for Multiple Sclerosis[8,18-20]

Numerous diseases and disorders mimic MS, and the diagnostic criteria for MS require that there be no better explanation for a patient's signs and symptoms. Depending on a patient's risk factors, personal and family history, and examination results, clinicians might consider and test for the following differential diagnoses:

Infectious Diseases
HIV infection
Lyme disease
Meningitis
Progressive multifocal leukoencephalopathy
Rubella encephalitis
Syphilis
Whipple disease

Other Inflammatory and Immune-mediated Conditions
Behcet disease
Sarcoidosis
Sjögren syndrome
Sneddon syndrome
Susac syndrome
Systemic lupus erythematosus
Vasculitis

Genetic Disorders
Hereditary spastic paraparesis
Leukodystrophies
Mitochondrial disorders

Spinal Cord Conditions
Cavernous malformation
Intramedullary cord tumor
Spondylotic myelopathy
Syringomelia

Ischemic Disorders
Amyloid angiopathy
Antiphospholipid antibody disease
Cardioembolic stroke
Veno-occlusive disease

Cancer
Metastatic disease affecting the central nervous system (CNS), particularly metastasis of primary cancers of the lung, breast, and kidney, as well as melanoma
Lymphoma (CNS and intravascular)

Abnormalities and Injuries of the CNS
Chiari malformation
Herniated discs
Spondylosis

Other Demyelinating Disorders
Acute disseminated encephalomyelitis
Neuromyelitis optica

Dietary Deficiencies
Copper deficiency
Vitamin B12 deficiency

- Erectile dysfunction.
- Visual abnormalities including double vision, blurred vision, or unilateral vision loss.
- Pain on eye movement.
- Slurred speech.
- Cognitive deficits such as memory problems, reduced attention span, or difficulty with problem solving.
- Depression or mood swings.

Multiple Sclerosis Types

MS takes several clinical forms and sometimes converts from one form to another. Typically, the disease begins with an acute episode but then exhibits varying degrees of remission or progression.[1]

Relapsing-Remitting

The most common form of the disease, occurring in about 85% of MS patients, is relapsing-remitting MS.[5] Patients with relapsing-remitting MS experience flare-ups of symptoms, also known as *relapses*, that develop over days or weeks and then improve spontaneously. Relapses are followed by a period of remission that can last for months or years and can be either full or partial (ie, symptoms disappear completely or improve to varying degrees).[5,6,22] However, the disease still is active even during periods when the patient is in remission.[13]

Primary Progressive

Primary progressive MS affects about 10% to 15% of MS patients and is characterized by gradual worsening of symptoms without periods of remission.[5] This disease course occurs more often in people who are older than 40 years at the onset of disease.[5] There is no effective treatment for primary progressive MS[22,23]; thus, management focuses on controlling symptoms.[23]

Secondary Progressive

Secondary progressive MS occurs when relapsing-remitting MS converts to a course of gradually progressive disease. Most people with relapsing-remitting MS eventually develop secondary progressive disease: about 50% within 10 years, 80% within 20 years, and 90% after 25 years.[7,14]

Progressive-Relapsing

In progressive-relapsing MS, the disease symptoms worsen progressively from onset, but the patient also experiences distinct attacks or relapses.[7] This type is relatively rare, affecting approximately 5% of patients.[24] As with primary progressive disease, there is no effective treatment for progressive-relapsing MS, only relief for symptoms.[22]

Clinically Isolated Syndrome

Patients with clinically isolated syndrome have a single symptomatic episode lasting at least 24 hours,[9,13] which can be a precursor to developing relapsing-remitting MS or another type of the disease. The syndrome also is sometimes described as a first clinical demyelinating event. Approximately 88% of patients with clinically isolated syndrome and CNS lesions apparent on magnetic resonance (MR) imaging develop MS within 14 years.[14] However, many patients do not redevelop symptoms or show imaging evidence of the disease for several years after an initial symptomatic episode.[2]

Benign

Benign MS is characterized by near-total remission between symptomatic episodes and little or no accumulation of disability.[9] The definition of benign MS is debated, but it is generally considered to be relapsing-remitting MS with a disability score of less than 3 on the Expanded Disability Status Scale for a period of at least 10 years.[8] On this scale, clinicians assign a score of 3 to patients who are fully ambulatory but have moderate disability in one functional system or minimal disability in 3 or 4 functional systems.[25] The function of the following 7 systems is assessed[25]:

- Pyramidal – weakness and paralysis.
- Cerebellar – control of body movement.
- Brainstem – nystagmus, ability to speak and swallow.
- Sensory – sense of touch, pain, and proprioception.
- Bladder and bowel.
- Visual.
- Mental.

Asymptomatic

Also known as *preclinical*, *subclinical*, or *radiologically isolated MS*, asymptomatic MS involves lesions that are detected incidentally on an MR examination or during an autopsy, but with no clinical indications of the disease.[7] The rate of conversion from asymptomatic MS to clinical MS is approximately one-third at 5 years after initial detection of lesions.[26] However, there is no consensus regarding follow-up assessment for individuals who have asymptomatic MS or what treatment, if any, they should receive.[26] No risk factors have been indentified to help predict which individuals are likely to convert from asymptomatic to symptomatic disease.[26]

Fulminant

Fulminant MS is a rare, rapidly progressing disease that can lead to severe disability or death within weeks or months of onset.[7,8] It also is termed *malignant MS* or the *Marburg variant* of MS, after physician Otto Marburg who described this course of the disease in the early 20th century.[27] Whereas other forms of MS affect only the CNS, fulminant MS attacks the peripheral nervous system as well.[27] Death often is due to involvement of the brainstem including herniation and mass effect from MS pathology, which is damage to the brainstem area similar to that caused by a tumor.[27]

Diagnosis

MS is primarily a clinical diagnosis based on signs, symptoms, and patient history—particularly a history of relapses and progressive disability.[8] Imaging examinations and paraclinical tests aid in diagnosis. These tests and examinations include MR imaging of the CNS, analysis of the cerebrospinal fluid, and visual evoked potentials testing to measure electrical activity in the brain.

Previously, diagnosis of MS depended on multiple symptomatic attacks, and clinicians often took a "wait-and-see" approach to diagnosis. That approach has changed, however: Clinicians now know that early diagnosis is important because early treatment can reduce the likelihood of disability and additional relapses.[28] Thus, the emphasis is on detecting MS in its initial stages and beginning treatment promptly.

History of Diagnostic Criteria

In 1965 Schumacher and colleagues proposed a means of standardizing MS diagnosis.[7] They introduced the concepts of "dissemination in time" and

"dissemination in space," which are still critical to diagnosing MS today. Dissemination in time refers to the requirement that MS flares or relapses be separated by at least 30 days. Dissemination in space requires evidence of MS activity in 2 or more separate areas of the CNS. The Schumacher criteria also specified that "The signs and symptoms cannot be explained better by another disease process," which continues to be a requirement of MS diagnosis more than 50 years later.[7] In 1983, the Posner criteria added spinal fluid evaluation and evoked potential testing to the criteria for MS diagnosis. These additional tests can document asymptomatic changes in the CNS and aid in establishing dissemination in space and dissemination in time.[7]

In 2000, an international panel of experts was convened to reassess the Posner criteria and recommend changes in light of new developments in MR imaging. W Ian McDonald served as the panel's chairman, and the criteria have since been known as the *McDonald criteria*.[7] Under the McDonald criteria, clinicians can use MR imaging of the CNS to establish both dissemination in space and dissemination in time. For example, a repeat scan performed 3 months or more after a baseline scan can demonstrate changes that confirm dissemination in time, and lesions that appear in different parts of the brain and spinal cord on MR images confirm dissemination in space.

The McDonald criteria were revised and updated in 2005 and 2010. The updates were intended to speed diagnosis without diminishing specificity and sensitivity.[7] Nevertheless, the 2010 criteria have been criticized for their complexity and relatively low sensitivity of approximately 60%.[14] A key goal of all versions of the McDonald criteria has been maximizing specificity (ie, reducing the number of incorrect MS diagnoses) rather than achieving the highest possible sensitivity (ie, identifying as many people as possible who have MS).[8] Another criticism of the McDonald criteria is that they are based on data gathered from a population of European patients and therefore might not apply as effectively to people of non-European ancestry.[8] Specifically, more study is warranted before the criteria are applied to African American and Latino patients with suspected MS.[29]

Other criteria for diagnosing MS have been developed, such as the Swanton criteria, which are reported to have comparable specificity, along with better sensitivity than the McDonald criteria. However, no other diagnostic criteria have been widely adopted by clinicians.[14]

Applying the 2010 McDonald Criteria

The 2010 McDonald criteria rely on current and previous symptomatic attacks and evidence of lesions seen on brain and spinal cord MR imaging to determine diagnosis. Under the 2010 criteria, dissemination in space can be demonstrated by clinical or imaging evidence of lesions in 2 or more of 4 key areas of the CNS: the periventricular, juxtacortical, and infratentorial areas, as well as the spinal cord.[8] Dissemination in time can be demonstrated using clinical history, sequential MR images, or a single MR scan that shows both enhancing and nonenhancing lesions, which are indicative of at least 2 separate demyelinating events.[8] The 2010 diagnostic criteria are summarized in **Table 1**.

Thus, it is possible to diagnose MS after a single symptomatic attack if MR imaging shows enhancing and nonenhancing lesions in 2 of the 4 designated areas.[8] Previously, a second MR examination of the brain was required at least 30 days after an initial or baseline scan to confirm the diagnosis. As a result of the 2010 criteria, earlier diagnosis and treatment are possible, and more patients have been shifted from a diagnosis of possible MS to definite MS. However, experts caution that the patient's clinical presentation should drive diagnostic classifications and treatment decisions[8] and diagnosis should not be made solely on the basis of MR evidence, without consideration of the clinical picture. A survey of neurologists who treat patients with MS suggested that misdiagnosis of the disease might be common (see **Box 3**).

MR Imaging's Role

MR imaging is the preferred method for confirming an MS diagnosis and monitoring disease progression.[28] MR can be used to estimate the lesion load and level of disease activity and to provide prognostic information.[7] Patients with more lesions apparent on MR images at diagnosis are known to experience greater disability later in the disease course than patients with fewer lesions at diagnosis.[13]

In addition to lesions, an MR finding commonly associated with MS is atrophy of the brain and spinal cord.[33] The rate of atrophy ranges from 0.6% to 1.35%

Table 1

The 2010 McDonald Criteria for Diagnosis of Multiple Sclerosis[30,31]

No. of Attacks[a]	Evidence of Lesions	Additional Data Needed for Diagnosis
≥ 2	Objective clinical evidence of ≥ 2 lesions or of 1 lesion with reasonable historical evidence of a prior attack	None
≥ 2	Objective clinical evidence of 1 lesion	Dissemination in space, demonstrated by: ■ ≥ 1 lesion visible on T2-weighted MR images in at least 2 of 4 multiple sclerosis (MS)-typical regions of the CNS (periventricular, juxtacortical, infratentorial, or spinal cord); or ■ Delay diagnosis until a further clinical attack[a] implicating a different CNS site occurs
1	Objective clinical evidence of ≥ 2 lesions	Dissemination in time, demonstrated by: ■ Simultaneous presence of asymptomatic gadolinium-enhancing and nonenhancing lesions at any time; or ■ New T2 and/or gadolinium-enhancing lesion(s) on follow-up MR imaging, irrespective of its timing with reference to a baseline scan; or ■ Await a second clinical attack[a]
1	Objective clinical evidence of 1 lesion	Dissemination in space, demonstrated by: ■ ≥ 1 T2 lesion in at least 2 of 4 MS-typical regions of the CNS (periventricular, juxtacortical, infratentorial, or spinal cord); or ■ Await a second clinical attack[a] implicating a different CNS site; and Dissemination in time, demonstrated by: ■ Simultaneous presence of a symptomatic gadolinium-enhancing and nonenhancing lesion at any time; or ■ A new T2 and/or gadolinium-enhancing lesion(s) on follow-up MR imaging, irrespective of its timing with reference to a baseline scan; or ■ Await a second attack[a]
0	None	1 year of disease progression (retrospectively or prospectively determined) and 2 of 3 of the following criteria: ■ Evidence of DIS in the brain based on ≥ 1 T2 lesion(s) in the MS-characteristic regions (periventricular, juxtacortical, or infratentorial) ■ Evidence for DIS in the spinal cord based on ≥ 2 T2 lesions in the cord ■ Positive CSF (isoelectric focusing evidence of oligoclonal bands and/or elevated IgG index)

Abbreviations: CNS, central nervous system; CSF, cerebrospinal fluid; DIS, dissemination in space; IgG, immunoglobulin G; MR, magnetic resonance.

[a]*An attack is a neurological disturbance typical of MS, lasting at least 24 hours without fever or infection. Attacks must be separated by at least 30 days from the onset of one attack to the onset of the second and can be either reported or observed.*

per year,[33] which is approximately 4 times greater than the normal consequence of aging.[34] The atrophy primarily affects the brain's gray matter.[34] At one time, brain atrophy was considered characteristic of late-stage disease. However, researchers now know that CNS atrophy occurs during all stages, even in early MS cases.[35] Patients with the relapsing-remitting form have the highest rate of brain atrophy,[33] and atrophy is significantly correlated with disability and cognitive impairment in patients with MS.[35]

Brain abnormalities are apparent on MR scans in 90% to 95% of patients with MS. Also, as many as

Box 3

Second Opinion: Not Multiple Sclerosis After All[32]

To explore the occurrence, causes, and effects of incorrectly diagnosed MS, Solomon et al surveyed neurologists in the United States and Canada who specialized in caring for patients with MS. They invited 242 neurologists to participate via an email message with a link to the unvalidated survey instrument. Slightly more than 50% of those invited to participate completed and returned the survey form.

When presented with the question, "Have you ever evaluated a patient who carried an MS diagnosis (given by another provider) for longer than a year who, after your neurologic examination and review of lab data, you strongly felt did NOT in fact have MS?" almost all of the respondents (95.1%) indicated yes. In fact, during the preceding year, 40% of responding neurologists indicated that they had cared for between 3 and 5 patients who they believed to have been incorrectly diagnosed with MS. Furthermore, more than one-third of the respondents reported caring for 6 or more such patients in the past year. When asked for the most likely alternative diagnoses for these patients, respondents chose nonspecific white-matter abnormalities, small vessel ischemic disease, migraines, psychiatric illnesses, fibromyalgia, neuromyelitis optica, and a variety of other disorders.

Solomon and colleagues pointed to incorrect interpretation of MR imaging examinations as a likely cause of the misdiagnoses, along with the conviction that MS should be diagnosed promptly and therapy initiated as soon as possible. Among probable harms of misdiagnosing MS, the researchers mentioned the cost of disease-modifying therapy and the possible adverse effects associated with MS treatment.

Another troubling survey finding was that some neurologists (about 13% of the respondents) indicated that they had sometimes not informed a patient when they believed a misdiagnosis had occurred. The most commonly cited reason for not informing these patients was that the patient was not currently taking a disease-modifying therapy. Risk of psychological harm to the patient was the second most commonly mentioned reason for nondisclosure of suspected misdiagnosis.

75% of patients' MR images demonstrate spinal cord plaques.[28] However, approximately 5% of patients with clinically apparent MS do not show signs of the disease on MR images at the time of diagnosis.[36] Furthermore, in people older than 50 years, normal, age-related changes in the brain can appear similar to changes caused by MS.[36]

Abnormalities seen on MR images do not always correlate well with clinical signs and reported symptoms. For example, a few patients have little impairment from MS, but show significant MS-related lesions on MR scans.[28] This phenomenon is known as the *clinicoradiologic paradox*.[33] Possible reasons for this lack of correlation have been suggested such as the brain's ability to compensate for damage by adapting and reorganizing.[14]

The Consortium of Multiple Sclerosis Centers updated its recommended MR protocols in 2015. The new guidelines recommend 3-D MR imaging over 2-D imaging whenever possible.[28] The consortium supports use of a standardized brain MR imaging protocol with gadolinium contrast for initial diagnosis and follow-up (see **Table 2**).[36] In addition, the spinal cord should be scanned with MR if initial brain imaging is nondiagnostic or if the patient presents with signs or symptoms suggesting spinal cord involvement (see **Table 3**).[29,36] T2-weighted imaging plus T1-weighted imaging with gadolinium contrast is the standard method for confirming an MS diagnosis (see **Figure 2**).[14,33] T2-weighted or fluid-attenuated inversion recovery (FLAIR) images show the total number of MS lesions and the overall disease burden.[36,37] T1-weighted images with gadolinium contrast can display new lesions that occur from breach of the blood-brain barrier and resulting inflammation.[37] T1-weighted images obtained before or after contrast administration can show so-called black holes, which are older, inactive lesions.

One way to improve the overall sensitivity of MR imaging for detecting MS-related lesions is to use higher-field equipment (ie, 3 T vs 1.5 T). This can increase the detection rate by 20% to 50% and enable earlier treatment for more patients.[34] However, higher-field imaging might not be useful for patients with an established MS diagnosis because increased sensitivity has not been shown to affect treatment decisions for this group.[34]

Several advanced MR imaging techniques help assess MS patient outcomes as part of clinical trials. These techniques, which include diffusion tensor imaging and magnetization transfer imaging, are more specific than conventional MR sequences for

Table 2

Standardized Brain Magnetic Resonance Imaging Protocol for Diagnosis and Routine Follow-Up of Multiple Sclerosis[36]

Parameter	Description
Field strength	Good quality scans with adequate signal-to-noise ratio and resolution (in-section pixel resolution of ≤ 1 mm × 1 mm)
Scan prescription	Use of subcallosal plane to prescribe or reformat axial oblique sections
Coverage	Whole-brain coverage
Section thickness and gap	≤ 3 mm, no gap for 2-D acquisition or 3-D reconstruction
Core sequences	Anatomic 3-D inversion recovery–prepared T1 gradient echo (eg, 1-mm to 1.5-mm thickness) Gadolinium single dose, 0.1 mmol/kg given for 30 seconds[a] 3-D sagittal T2WI FLAIR[b] (eg, 1-mm to 1.5-mm thickness) 3-D T2WI[b] (eg, 1-mm to 1.5-mm thickness) 2-D axial DWI (≤ 5-mm sections, no gap) 3-D FLASH (non-IR prep) postgadolinium[b] (eg, 1-mm to 1.5-mm thickness) 3-D series would be typically reconstructed to 3-mm thickness for display and subsequent comparison for lesion counts
Optional sequences	Axial proton attenuation Pregadolinium or postgadolinium axial T1 spin-echo (for chronic black holes) SWI for identification of central vein within T2 lesions

Abbreviations: DWI, diffusion-weighted imaging; FLAIR, fluid-attenuated inversion recovery; FLASH, fast low angle shot; IR, inversion recovery; SWI, susceptibility weighted imaging; T2WI, T2-weighted imaging.

[a]*Minimum 5-minute delay before obtaining postgadolinium T1. The 3-D sagittal FLAIR may be acquired immediately after contrast injection before the 3-D FLASH series.*

[b]*If unable to perform a 3-D acquisition, then perform 2-D axial and sagittal FLAIR, axial fast spin-echo proton attenuation/T2, and axial postgadolinium T1WI spin-echo at ≤ 3-mm section thickness.*

Reprinted with permission from Traboulsee A, Simon JH, Stone L, et al. Revised recommendations of the Consortium of MS Centers Task Force for a Standardized MRI Protocol and Clinical Guidelines for the Diagnosis and Follow-up of Multiple Sclerosis [published online ahead of print November 12, 2015]. AJNR Am J Neuroradiol. *doi:10.3174/ajnr.A4539.*

distinguishing demyelination and axon loss.[38] However, these techniques are not yet part of routine MS diagnosis and follow-up.

T1-Weighted Imaging

T1-weighted images with gadolinium contrast provide information about recent disease activity by showing areas of active inflammation.[36] Gadolinium enhancement occurs when there has been a breakdown of the blood-brain barrier. New MS lesions go through a period lasting from 2 to 6 weeks during which they enhance with gadolinium contrast.[7,33,39] This is the inflammatory phase of lesion development.[33]

MS lesions show 2 patterns of enhancement on T1 imaging. They can appear as nodules or rings. The ring pattern is characteristic of older lesions that have been reactivated,[14] whereas gadolinium-enhancing nodules are new lesions. Gadolinium enhancement also is useful for imaging optic neuritis (inflammation of the optic nerve) and lesions in the spinal cord.[14]

Numerous contrast media containing gadolinium are available; most are formulated at a concentration of 0.5 mol/L.[14] Standard dosing for gadolinium-enhanced MR imaging of the CNS is 0.1 mmol/kg of body weight. Studies have indicated that detection of MS lesions and certain other pathologies, such as brain tumors, might be enhanced at concentrations of 0.2 mmol/kg to 0.3 mmol/kg.[14] The higher dose can be administered for follow-up imaging in cases where the diagnosis is doubtful. Alternatively, a dose of 0.2 mmol/kg has been recommended for initial assessment. This might represent the most effective

Table 3

Spinal Cord Magnetic Resonance Imaging Protocol[36]

Parameter	Description
Field strength	Scans should be of good quality, with adequate signal-to-noise ratio and resolution (in-section pixel resolution of ≤ 1 mm × 1 mm) Closed magnets (large bore for patients with claustrophobia) preferred
Coverage	Cervical cord coverage[a]
Section thickness and gap	Sagittal: ≤ 3 mm, no gap; axial: 5 mm, no gap
Core sequences	Sagittal T2 Sagittal proton attenuation, STIR, or PSTI-IR Axial T2 through lesions
Optional sequences	Axial T2 through complete cervical cord Gadolinium[b] and postgadolinium sagittal T1 Sagittal T1

Abbreviations: PSTI-IR, phase-sensitive T1 inversion recovery; STIR, short tau inversion recovery.

[a]*Thoracic and conus coverage recommended if symptoms localize to this region to rule out an alternate diagnosis.*

[b]*Minimum 5-minute delay before obtaining postgadolinium T1. Additional gadolinium does not need to be administered for spinal cord imaging if it follows a contrast brain MR imaging study.*

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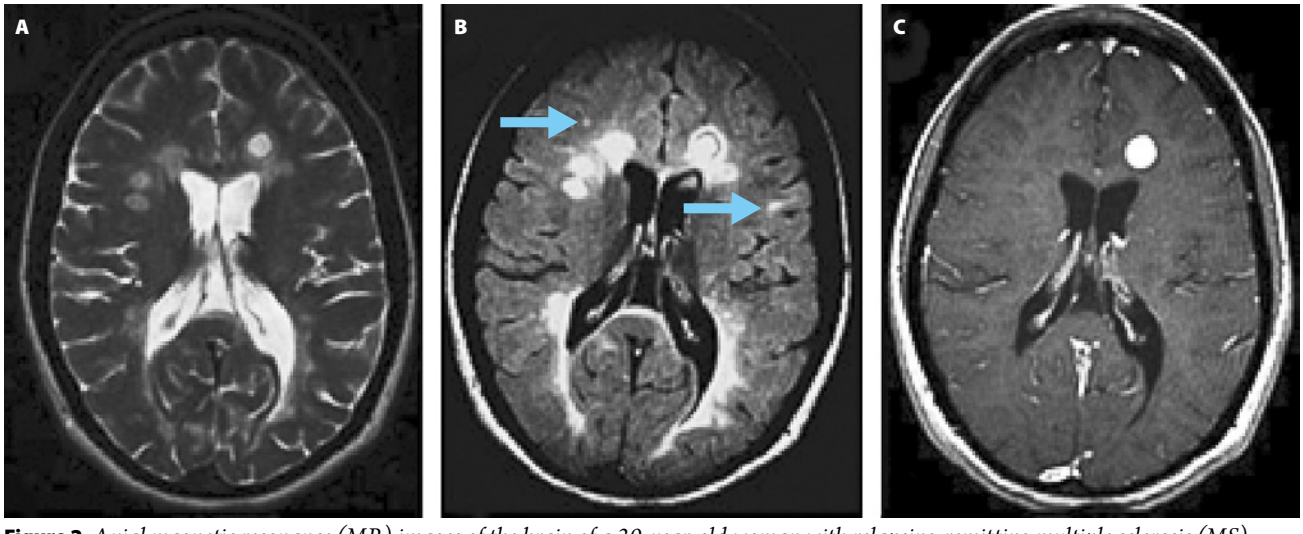

Figure 2. *Axial magnetic resonance (MR) images of the brain of a 30-year-old woman with relapsing-remitting multiple sclerosis (MS). A. T2-weighted MR image. B. FLAIR (fluid-attenuated inversion recovery) image. C. Contrast-enhanced T1-weighted image. The lesions on FLAIR usually are prominent and several small lesions are depicted only on FLAIR (arrows). Reprinted with permission from Ge Y. Multiple sclerosis: the role of MR imaging.* AJNR Am J Neuroradiol. *2006;27(6):1165-1176.*

approach in terms of balancing time, cost, and sensitivity.[14] Guidelines recommend a minimum 5-minute delay between contrast injection and imaging to optimally enhance MS lesions.[29]

Gadolinium contrast is contraindicated or should be used cautiously in patients who have acute renal failure or severe renal insufficiency. This is because of the risk of nephrogenic systemic fibrosis,[34] a rare but disabling

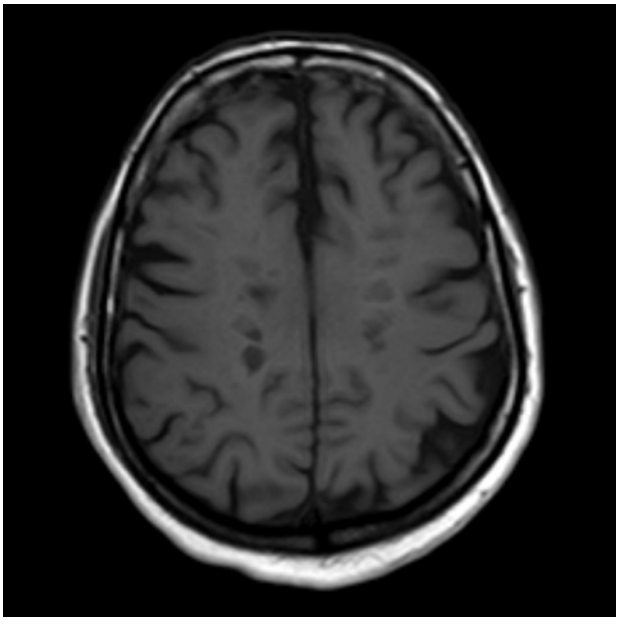

Figure 3. *Axial T1-weighted MR image showing "black holes" in the brain of a patient with MS. Image courtesy of Ahmed Abd Rabou, MD, Radiopaedia.org, rID: 35195.*

condition that involves fibrosis of the skin and internal organs. In addition, gadolinium is known to cross the placenta and should be avoided in pregnant women.[34]

T1-weighted MR images without contrast can show chronic or persistent lesions that appear hypointense or isointense compared with normal white matter. These black hole lesions are believed to be areas of permanent demyelination and axonal loss.[8,34,39,40] Studies have shown that the number and volume of black holes are positively correlated with increasing disability, but this correlation has not been conclusively proven (see **Figure 3**).[40]

T2-Weighted Imaging

On T2-weighted images, proton density, and FLAIR images, MS lesions typically appear as small round or oval hyperintensities.[8,14,33] The lesions average 3 mm to 8 mm in diameter[7] and can occur anywhere myelin is present in the CNS including the spinal cord. Some common locations are the periventricular, juxtacortical, and infratentorial regions.[33] Most MS lesions are found in the brain's white matter, but about 5% to 10% occur in gray matter, especially the cerebral cortex and basal ganglia. Gray matter lesions tend to be less inflamed than white matter lesions and might therefore be less visible on MR imaging.[33] Although most MS lesions are small, some are as large as several centimeters and thus can mimic tumors and other abnormalities.[33] Spinal cord lesions associated with MS appear more frequently in the cervical spinal cord than in the thoracic spinal cord (see **Figure 4**). Spinal cord lesions usually are less than 2 vertebral bodies long and commonly appear on the dorsolateral aspect of the spinal cord.[33] In addition, these lesions tend to be asymmetric and multifocal.[14]

One limitation of T2-weighted imaging in MS diagnosis is its lack of specificity.[38] In addition to demonstrating demyelination and loss of axons, T2-weighted images reflect inflammation and edema.[38] This lack of specificity might be part of the explanation for the clinicoradiologic paradox.[38]

Follow-up Imaging

Guidelines recommend follow-up brain imaging with gadolinium contrast for patients with MS or suspected MS to[36]:

- Demonstrate changes over time as part of the diagnostic process, if necessary.
- Assess unexpected worsening of MS symptoms.
- Reassess the original diagnosis, if in doubt.
- Establish a baseline before treatment begins or when planning changes in treatment.

In addition, patients who have relapsing-remitting MS and are taking a disease-modifying drug should have a follow-up scan 6 to 12 months after starting treatment.[38] Follow-up scanning might be indicated sooner if concerns about disease progression arise.[14]

Paraclinical Tests for MS Diagnosis

Physicians previously relied on paraclinical tests to help diagnose MS including analysis of the cerebrospinal fluid and evoked potential tests. These tests were dropped from the 2010 McDonald criteria.[8] However, a group of Canadian MS experts states that paraclinical tests still should be part of the diagnostic workup for certain patient populations and situations. These groups include[8]:

- Patients older than 50 years and younger patients with vascular risk factors, both of whom can have

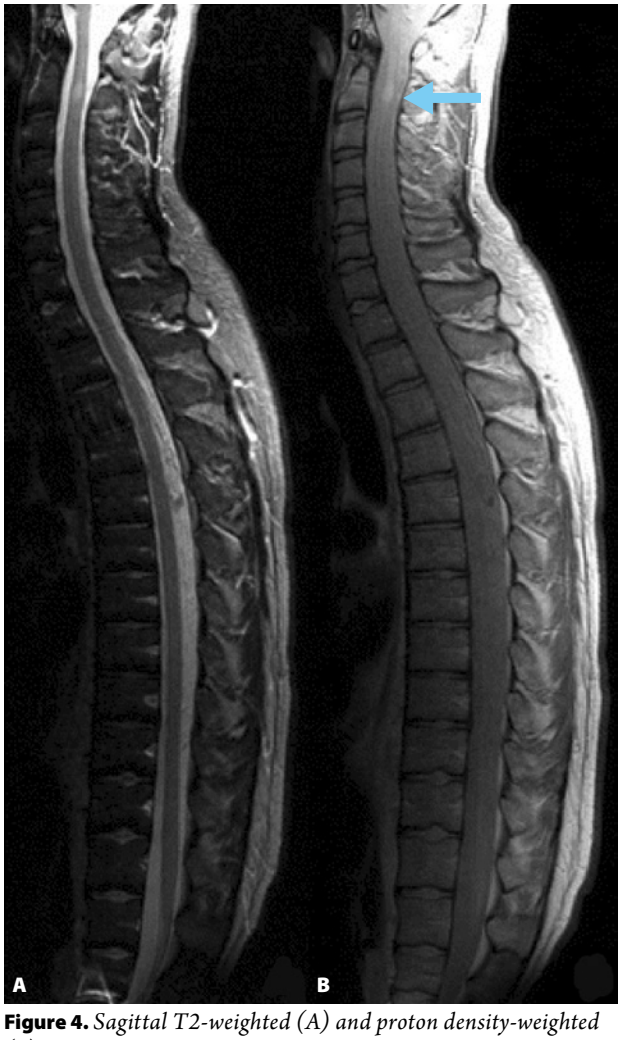

Figure 4. *Sagittal T2-weighted (A) and proton density-weighted (B) MR images of the spinal cord in a 36-year-old man with a 5-year disease course of relapsing-remitting MS demonstrate a focal lesion in the upper cervical cord (arrow). Reprinted with permission from Lukas C, Sombekke MH, Bellengerg B, et al. Relevance of spinal cord abnormalities to clinical disability in multiple sclerosis: MR imaging findings in a large cohort of patients.* Radiology. *2013;269(2):542-552. doi:10.1148/radiol.13122566.*

brain lesions on MR imaging due to aging or ischemia rather than MS.

- Patients who have migraines, as migraines also can cause white-matter lesions that are visible on MR scans.
- Patients with vague, nonspecific symptoms, in which case clinicians should use all available diagnostic tools.
- Patients for whom MR imaging is contraindicated.

One of the paraclinical tools used in the diagnosis of MS is evoked potentials. These are measurements of the CNS response to different types of stimuli including visual, somatosensory, and brainstem stimuli. In the visual evoked potential test, the most widely used in MS diagnosis, patients watch an alternating checkerboard pattern on a screen. Electrodes attached to the patient's head record electrical responses to the stimulus. A delayed latency indicates demyelination of the anterior visual pathway.[28]

Evoked potential tests are not specific or sensitive for MS, however.[21,28] In fact, visual evoked potential test results are abnormal in fewer than one-third of patients with clinically isolated syndrome and in about half of MS patients who do not have a history or indication of optic nerve damage.[18] In addition, visual evoked potential tests are not necessary if the clinician finds evidence of optic nerve damage.

Another test that can support an MS diagnosis is analysis of cerebrospinal fluid. In 90% of patients with MS, cerebrospinal fluid analysis shows an increase in immunoglobulin concentration and 2 or more oligoclonal bands.[7] However, detection of oligoclonal bands in the cerebrospinal fluid is associated with a number of other diagnoses, in addition to MS.[18]

Prognosis

The prognosis for people who have MS varies considerably among individuals and for different forms of the disease. Between 10% and 20% of patients have an indolent course of disease with minimal disability over a period of 20 years, and approximately 5% of patients have fulminant disease in which disability progresses quickly.[1,41] MS presentations in other patients fall between these 2 extremes. **Box 4** lists some factors associated with a poorer prognosis in patients with MS.

Before the development of disease-modifying therapies, the average time from diagnosis until a patient required a cane was about 15 years, and about 26 years between diagnosis and becoming bedbound.[1] The degree to which disease-modifying drugs slow the

Box 4

Unfavorable Prognostic Indicators for People With Multiple Sclerosis[7]

- Aged 40 years or older at onset of disease.
- Asian or African ancestry.
- Frequent attacks at onset of disease.
- Lesions enhance with gadolinium on initial MR examination.
- Male.
- MS-associated cognitive impairment at diagnosis.
- Oligoclonal immunoglobulins in the cerebrospinal fluid.
- Polyregional symptoms at diagnosis.
- Rapidly progressing disability.
- Short intervals between initial attacks.

progression of disability is not yet known.[1] However, most patients with MS eventually require some type of mobility assistance such as a cane, walker, or wheelchair.[7] The most disabling effects of MS continue to be fatigue, cognitive impairment, and difficulty walking.[41]

The life expectancy for people with MS is reduced by 7 to 10 years on average.[7] Approximately half of people with MS die of MS-related complications; for the other half, reported causes of death generally are similar to those for people who do not have MS such as heart disease and cancer.[7] However, suicide is significantly more common among MS patients than in the general population.[4]

Treatment

The 2 primary goals of MS treatment are to slow progression of the disease and improve quality of life by relieving the patient's symptoms.[42] MS treatment has distinct components: treatment for acute relapses, management of chronic symptoms, and treatment to modify the long-term course of the disease. Many patients also incorporate lifestyle modifications and complementary or alternative medicine into their treatment plans.

Acute Relapses

Treatment of acute relapses is necessary if the relapse affects the patient's quality of life.[1] Clinicians treat acute relapses of MS with corticosteroids such as prednisone, an oral medication, or methylprednisolone, which is administered intravenously.[1,6,43] These drugs reduce the length of the relapse but have not been shown to affect the long-term course of the disease.[1] If steroid treatment is contraindicated or ineffective for a particular patient, plasmapheresis could be an effective second-line treatment.[43] A plasmapheresis procedure involves removing plasma from the patient's whole blood and replacing it with donor plasma or a plasma substitute, thus removing antibodies attacking the immune system.[44]

Symptoms

Many MS symptoms can be treated with medication including[1,41]:

- Fatigue – amantadine or modafinil.
- Difficulty walking – dalfampridine.
- Neurogenic bladder – oxybutynin.
- Neuropathic pain – pregabalin or duloxetine.
- Spasticity – baclofen, gabapentin, tizanidine.
- Erectile dysfunction – sildenafil.
- Tremor – clonazepam, propranolol.

Lifestyle modifications might reduce MS symptoms and improve quality of life. Many of the tips suggested for people with MS are the same as for good health in general: getting enough sleep; eating a healthy, well-balanced diet; exercising regularly; and finding ways to reduce stress.[6] In one study of people with MS, clinically significant fatigue was found to be associated with a poor diet and obesity, whereas a reduced likelihood of fatigue was associated with exercise.[45] Overheating can aggravate MS symptoms, so patients might prefer exercise that allows them to avoid getting too warm. Swimming and water aerobics can be good choices. Other exercise options recommended for people with MS include stationary bicycling, walking, and low-impact aerobics. Relaxation techniques that can help reduce stress include yoga, meditation, tai chi, and massage. Joining an MS support group or talking with a counselor also can be beneficial.[6]

Primary Progressive Disease

No drugs are approved for modifying the course of primary progressive MS.[2] However, some patients with primary progressive disease have been treated with immunosuppressant drugs used off label, and randomized trials have indicated that immunosuppressants might help slow the course of primary progressive MS.[2] For now, however, treatment for this form of the disease focuses primarily on managing symptoms and disabilities.[2]

Disease-modifying Treatment for Relapsing-Remitting MS

As of January 2016, 12 drugs are approved by the U.S. Food and Drug Administration as "disease-modifying treatments" for the relapsing-remitting form of MS (see **Table 4**).[13,43] These drugs suppress or modulate the immune system in various ways.[2] They can slow the progression of MS and retard the development of plaques in the brain and spinal cord but also are associated with adverse effects that range from mildly bothersome to life threatening. Some of the drugs are injected subcutaneously or intramuscularly; others are taken orally or administered via IV infusion.[13] Disease-modifying MS drugs do not cure the disease or repair existing damage to the CNS.[22] However, these drugs can help control the disease, probably by reducing inflammation.[22] In some cases, the exact mechanism of action of the drugs is unknown or not fully understood.[13]

Reducing the rate of MS relapses is important because doing so improves patients' comfort and quality of life and reduces the number of days patients must miss work and other activities. Furthermore, fewer relapses lower the risk of residual neurological deficits in patients with MS.[13] Initiating disease-modifying treatment early in the disease process, such as after an initial attack or clinically isolated syndrome, appears to delay development of a second attack[46] and slow the long-term progression of the disease.[47]

Disease-modifying therapies are not helpful for patients with progressive MS and have shown limited usefulness in slowing the transition from relapsing-remitting disease to secondary progressive MS.[2] Another limitation of disease-modifying drugs is that their effectiveness varies among patients and over time for each patient. Some disease-modifying treatments should be used with caution in patients who have certain comorbid conditions.[1] For example, injection of interferon beta-1a (Avonex and Rebif) can worsen seizure disorders and some psychiatric illnesses; interferon beta-1b (Betaseron) should be used cautiously in patients with asthma or a history of anaphylactic reactions.[1]

Typically, the decision regarding which disease-modifying drug to choose is based on a discussion between the patient and the treating physician. The choice might depend on patient preferences, possible adverse effects, and the clinician's experience with the drugs.[43] In some cases, insurance coverage also might be a consideration. Because patients vary in their susceptibility to and tolerance for adverse effects, as well as their willingness and ability to follow dosing regimens or take drugs with different routes of administration, physicians should consider all options to find the best treatment for each patient.[13]

Some patients with MS should not be started on a disease-modifying therapy including women planning a pregnancy, people who are unlikely to follow the treatment regimen correctly, and people who might have benign MS (ie, no relapses in the previous 2 years and no MS-associated disability or disease activity evident on MR scans).[2]

The first disease-modifying drugs were approved for use in the 1990s. These included the interferon beta drugs (Betaseron, Rebif, and Avonex) and glatiramer acetate (Copaxone).[48] In clinical trials, these medications proved to reduce the rate of MS relapses by approximately 30% and to be within acceptable safety limits.[48] However, the interferons are associated with adverse effects including injection site reactions, flu-like symptoms, elevated liver enzymes, thyroid dysfunction, anemia, and depression.[20] Also, because these drugs require injection, patient compliance sometimes is problematic.[41] The first-line injectable drugs vary somewhat in terms of their effectiveness and patient tolerability; however, data directly comparing these drugs are limited.[2,13]

Oral disease-modifying drugs for MS include fingolimod (Gilenya), dimethyl fumarate (Tecfidera), and teriflunomide (Aubagio).[48] The oral medications are considered second-line treatments because of their association with more serious adverse effects.[20] For example, fingolimod causes lymphopenia and occasionally has been associated with opportunistic infections such as herpes simplex encephalitis.[49] Also, because of a case of cardiac-related death in a patient with MS less than 24 hours after beginning treatment with fingolimod, the drug is contraindicated for patients with a history of heart disease or stroke and those taking antiarrhythmia medications.[20] Dimethyl fumarate also causes lymphopenia; however, studies have not shown

Table 4

FDA-approved Disease-modifying Drugs for Relapsing-Remitting Multiple Sclerosis[2,6,13,20,43]

Trade Name; Year Approved	Generic Name	Route; Frequency	Possible Adverse Effects	Pregnancy Category[a]
Aubagio; 2012	Teriflunomide	Oral; daily	Hepatotoxicity, harm to developing fetus, potential increased risk of malignancy, nausea, diarrhea; carries a black box warning[b]	X
Avonex; 1996	Interferon beta-1a	Intramuscular injection; weekly	Flu-like symptoms, reaction at injection site, elevated liver enzymes	C
Betaseron; 1993	Interferon beta-1b	Subcutaneous injection; every other day	Flu-like symptoms, reaction at injection site, elevated liver enzymes	C
Copaxone; 1996	Glatiramer acetate	Subcutaneous injection; daily or 3 times weekly	Reaction at injection site, flushing, palpitations, chest tightness, dyspnea	B
Extavia; 2009	Interferon beta-1b	Subcutaneous injection; every other day	Flu-like symptoms, reaction at injection site, elevated liver enzymes	C
Gilenya; 2010	Fingolimod	Oral; daily	Bradycardia, hypertension, macular edema	C
Lemtrada; 2014	Alemtuzumab	IV infusion; daily for 5 consecutive days in first year, then daily for 3 days in second year	Glomerulonephritis, autoimmune thyroiditis, thrombocytopenia, infections, myalgia, arthralgia; carries a black box warning[b]	C
Novantrone; 2000	Mitoxantrone (available as a generic since 2006)	IV infusion; every 3 months	Cardiotoxicity, acute leukemia, nausea/vomiting, amenorrhea/infertility, alopecia; carries a black box warning[b]	D
Plegridy; 2014	Pegylated interferon beta-1a	Subcutaneous injection; every 14 days	Flu-like symptoms, reaction at injection site, elevated liver enzymes	C
Rebif; 2002	Interferon beta-1a	Subcutaneous injection; 3 times weekly	Liver damage, white blood cell disorders, reaction at injection site	C
Tecfidera; 2013	Dimethyl fumarate	Oral; twice daily	Flushing, diarrhea, nausea, reduced white blood cell count	C
Tysabri; 2006	Natalizumab	IV infusion; every 28 days	Hepatotoxicity, progressive multifocal leukoencephalopathy (an opportunistic brain infection); carries a black box warning[b]	C

Abbreviations: FDA, U.S. Food and Drug Administration; IV, intravenous.

[a]*The U.S. Food and Drug Administration categories for risk to fetuses are as follows: A, controlled studies show no risk; B, no evidence of risk in humans, but remains a possibility; C, evidence suggests chance of fetal harm but benefits might outweigh risks; D, positive evidence of risk from studies or post-marketing data, but the benefits might outweigh the risks; X, positive evidence of animal or human fetal abnormalities from studies or postmarketing data with risks outweighing any possible benefit.*

[b]*FDA warning designed to call attention to serious or life-threatening risks.*

an increased risk of infection with this drug.[20] Some of the potential adverse effects associated with teriflunomide include hepatotoxicity, risk of infection, possible increased risk of malignancy, and risk of teratogenicity, which increases risk of developmental malformations in an embryo or fetus.[13] Because of the risks to a developing fetus, patients are advised to avoid pregnancy while taking teriflunomide. If a patient becomes pregnant, she

should undergo rapid elimination of the drug from her plasma.[20]

Other second-line disease-modifying drugs include natalizumab (Tysabri), a monoclonal antibody given by intravenous infusion. A serious concern with long-term use of natalizumab is the possibility of developing progressive multifocal leukoencephalopathy.[48] This infection causes cognitive impairment through activation of the John Cunningham virus (JCV). Progressive multifocal leukoencephalopathy can be fatal or cause permanent disability. Therefore, an annual anti-JCV antibody titer is required for all patients taking natalizumab.[41] Any patient who develops progressive multifocal leukoencephalopathy while taking natalizumab should stop using the drug immediately and have an MR examination of the brain and a lumbar puncture to check for the virus.[41] In addition, the patient should undergo plasmapheresis to remove natalizumab from the blood.[41] The overall risk of developing progressive multifocal leukoencephalopathy in patients using natalizumab is 3.78 per 1000; however, the risk jumps to 13 per 1000 in patients who have taken natalizumab for 2 years or longer.[20]

Some clinicians opt to begin treatment for relapsing-remitting MS with one of the first-line disease-modifying drugs, which tend to be safe, moderately effective, and associated with relatively mild adverse effects. Physicians still prescribe these drugs for most patients with MS, despite the introduction of newer medications.[50] However, if the response to a first-line treatment is not sufficient, the patient might be switched to a second-line drug which, although more effective, might carry greater risks.[2] Initial treatment with a second-line disease-modifying drug might be indicated for patients with severe or frequent relapses.[2]

For example, glatiramer acetate is associated with fewer adverse effects than are the interferons and has comparable effectiveness, so it is recommended as an initial, first-line treatment by some physicians. However, use of glatiramer acetate requires daily injections. Patients who prefer not to use an injected drug might receive prescriptions for fingolimod or dimethyl fumarate.[41] Natalizumab might be reserved for patients with breakthrough disease or those who cannot tolerate the adverse effects of other therapies.[20]

Various disease-modifying drugs have different mechanisms of action, so if a particular drug does not work well for one patient, another might work better.[13] In general, it is appropriate to consider switching to a different disease-modifying therapy if the patient has not responded adequately to treatment after one year or experiences intolerable adverse effects.[2] Patients should continue with their disease-modifying therapy indefinitely, unless[13]:

- It is not controlling the disease sufficiently.
- The patient considers the adverse effects unacceptable.
- The patient cannot or will not comply with the treatment regimen.
- A better treatment for the patient becomes available.

Disease-modifying drugs should be stopped whenever the patient reports a serious adverse effect, becomes pregnant, or the disease becomes progressive.[2]

Assessing the Effectiveness of Disease-modifying Treatments

To evaluate the effectiveness of disease-modifying therapies, Tramacere and colleagues performed a meta-analysis of randomized controlled trials of these drugs in adults with relapsing-remitting MS.[51] Their analysis included interferon beta-1b, interferon beta-1a, glatiramer acetate, natalizumab, mitoxantrone, fingolimod, teriflunomide, dimethyl fumarate, alemtuzumab, pegylated interferon beta-1a, daclizumab, laquinimod, azathioprine, and immunoglobulins.[51] Some of these drugs are under investigation for treating MS and are not approved by the U.S. Food and Drug Administration for that purpose.

The researchers' objective was to rank the treatments according to their benefits and acceptability to patients. Thirty-nine trials were included in the meta-analysis, representing approximately 25 000 participants. The average length of the studies included in the analysis was 24 months. In most cases (60%), the treatment was compared with a placebo; 40% of the trials compared 2 different treatments.[51] Most of the studies included in the analysis were sponsored by pharmaceutical manufacturers; thus, results might be affected by bias.[51]

Specifically, the investigators examined the drugs' ability to prevent relapses and worsening of MS-related

disability. They concluded that alemtuzumab, natalizumab, and fingolimod were the best choices for preventing clinical relapses. However, this conclusion was based on data reflecting only the first 24 months of treatment; long-term results might differ. As far as preventing the worsening of disability in the short term, only natalizumab showed a beneficial effect based on moderate-quality evidence.[51]

Tramacere et al stressed that additional research on disease-modifying therapies is needed. In particular, more long-term studies are called for because MS affects many patients for decades. The authors noted that additional studies that directly compare treatments, as opposed to studies comparing a single drug with a placebo, would be helpful. Finally, more data are needed about the safety of these drugs, particularly their long-term safety.[51]

Adherence to Disease-modifying Treatment

Several studies have concluded that significant numbers of patients with relapsing-remitting MS either stop taking their disease-modifying drug or do not take the drug consistently. This is concerning because the effectiveness of disease-modifying MS drugs depends on long-term, consistent use.[52,53]

For example, a group of German researchers studied pharmacy data of patients who began treatment for MS with one of 4 commonly prescribed disease-modifying therapies: interferon beta-1a intramuscular (Avonex), interferon beta-1a subcutaneous (Rebif), interferon beta-1b subcutaneous (Betaseron), or glatiramer acetate (Copaxone).[52] The researchers collected medication information for 50 057 patients, focusing on the first 2 years after treatment began.[52] They concluded that between 30% and 40% of patients were consistently compliant with their prescribed drug regimen 2 years after beginning treatment.[52]

A study conducted in Alberta, Canada, examined patterns of adherence to disease-modifying treatment over a period of 18 years in a cohort of 1471 patients with MS.[53] As with the German study, all of these patients were prescribed an injectable drug, either an interferon beta-1a or beta-1b or glatiramer acetate. The Canadian researchers found that the median time until patients stopped taking the first disease-modifying drug prescribed for them was 8.6 years. However, 54% of the patients who began treatment with an injectable drug and then stopped taking it either switched to an oral or other second-line drug or resumed their initial treatment within 90 days.[53] Few patients went without treatment for extended periods of time.[53]

In this study, the most common reasons reported for stopping the initially prescribed disease-modifying drug were intolerance (48%) and inefficacy (34%).[53] Younger patients (ie, those aged 30 years or younger at the time treatment began) and patients with a higher level of disability were more likely to stop taking their first-prescribed disease-modifying drug.[53] Patients who began treatment with glatiramer acetate tended to continue taking the drug longer than did patients who were taking an interferon beta.[53]

The Health Outcomes and Lifestyle Interventions in a Sample of people with Multiple Sclerosis (HOLISM) study was an international survey of more than 2200 people with MS recruited via social media forums and MS society Web sites. The purpose of the HOLISM study was to examine health and lifestyle behaviors and their relationship to self-reported quality of life, disability, and disease activity among MS patients over 5 years.[42] In this survey, 752 participants (33%) indicated they had never taken a disease-modifying drug; 384 (16.9%) said they had taken a disease-modifying drug previously but were not currently taking one; 421 people (18.5%) reported switching disease-modifying drugs; and 719 (31.6%) were taking a disease-modifying drug and had not switched.[48] The study's lead author suggested that the large numbers of survey respondents who stopped taking a disease-modifying drug or switched to a different drug were probably attributable to a drug's adverse effects.[48]

Costs

Because MS typically strikes younger adults, it can cause significant disability over time, usually requires lifelong treatment, and is an expensive disease. By one estimate, average medical expenses and indirect costs, such as lost income, total $1.2 million over the course of one patient's lifetime.[13] A study of people filing for bankruptcy because of medical expenses suggested that MS is a greater financial burden on individuals and families than are a variety of other disabling conditions

including stroke, heart disease, and mental illnesses (see **Box 5**).[4]

Future Directions in Pharmacologic Treatment

Researchers are looking for treatments that promote remyelination or neuronal repair of MS-related damage, as well as neuroprotective agents that prevent the lesions and atrophy associated with MS.[41] For example, a sodium-channel blocker, lamotrigine, was investigated as a potential neuroprotective drug in a group of 120 patients with secondary progressive disease. However, study results were negative. After 2 years, patients on lamotrigine showed similar brain volume losses as did control patients taking a placebo.[41]

Alternative and Complementary Treatments

Many patients with MS (more than 88%, according to a 2014 pilot study at the University of Delaware) take vitamin D supplements, often at the suggestion of their physician.[56] If serum levels of vitamin D are low (< 75 nmol/L), patients often are advised to take 2000 to 4000 IU per day to raise the level to the recommended amount.[41]

Surveys suggest that significant numbers of MS patients use other types of complementary and alternative treatments as well. In many cases, however, patients do not discuss these treatments with their health care providers.[56] For example, results of the HOLISM survey indicated that many patients were taking combinations of over-the-counter, herbal, and prescription medications, as well as dietary supplements, to treat various MS symptoms. Some common examples include paracetamol (acetaminophen), St John's wort, and magnesium.[48] Specifically, more than one-third of respondents were taking at least 3 medications and 15% were taking 5 medications or more, in addition to a disease-modifying drug.[48]

Quality of Life

MS significantly reduces the self-reported quality of life for many patients. One study indicated that the average quality of life for people with MS was one full standard deviation lower than for the general population. In particular, men, older patients, those who had long-standing MS, and people with progressive disease tended to report a lower quality of life.[57] Pain or discomfort, depression, limited mobility, and difficulties with daily activities were commonly noted problems that affect quality of life.[57] Up to half of all patients with MS have depression during their lifetime, a much higher rate than for the general population.[4] In addition, the suicide rate for people with MS is 7.5 times higher than for the general population.[4]

Box 5

The Cost of Treating Multiple Sclerosis[54,55]

A group of researchers in Oregon tracked the cost of disease-modifying treatments for MS over a 20-year period and found larger than expected price hikes. During the period 1993 to 2013, prescription drug costs in general rose 3% to 5% annually, but the cost of some first-generation disease-modifying drugs, such as interferon beta-1b (Betaseron), interferon beta-1a (Avonex), and glatiramer acetate (Copaxone), increased 21% to 36% annually. The cost for a year's treatment with these drugs has reached $60 000. Similarly, the costs for more recently approved disease-modifying drugs, including fingolimod (Gilenya), teriflunomide (Aubagio), and dimethyl fumarate (Tecfidera), also increased more than for other prescription drugs, growing by 8% to 17% per year. Furthermore, these newer drugs entered the market at prices 25% to 60% higher than prices for first-generation MS drugs. As a result, MS drugs cost 2 to 3 times more in the United States than in comparable developed nations including Canada, Australia, and the United Kingdom.

The study's lead author, Daniel Hartung of the Oregon Health and Science University College of Pharmacy, noted that "The inexplicable increase in the cost of MS drugs, particularly older, first-generation drugs, is at odds with how we think the marketplace should work. A growth in the number of MS drugs should lower costs for patients. What we see here is the opposite happened: Costs have risen sharply, and at a pace that's far greater than drugs in a similar biologic class."

Special Patient Populations

Pediatric Patients

MS most often strikes young adults and is rare in children. Only about 3% to 5% of MS cases in the United States are pediatric onset.[58] However, MS is known to be more aggressive in children and adolescents, making prompt diagnosis and treatment even

more important in this age group. Almost all children and adolescents with MS (97%) have the relapsing-remitting form of the disease; primary progressive MS is quite rare in this age group.[59]

The sensitivity and specificity of the McDonald diagnostic criteria were assessed in a group of 212 pediatric patients with possible MS who were examined clinically and with MR imaging over a 2-year period. In this group of patients, the criteria demonstrated 100% sensitivity and 86% specificity.[59] In addition, the positive predictive value was 59% and the negative predictive value was 100%.[59]

During the first 3 years following MS diagnosis, pediatric patients' relapse rates are 2 to 3 times higher than relapse rates for adults.[13] Also, up to 40% of children with MS develop cognitive impairment in the first few years after diagnosis, which often affects academic performance.[13]

First-line disease-modifying drugs have been shown to be safe and effective for use in pediatric patients.[59,60] A study of 300 pediatric patients with MS concluded that the safety profile for interferon beta-1a was similar for children, adolescents, and adults. This held true even among children younger than 12 years old.[59] Also, glatiramer acetate has not been associated with any major adverse events in pediatric patients, although one incident of hepatotoxicity associated with glatiramer acetate in a pediatric patient with MS was noted in the literature.[59] However, about 30% of children cannot tolerate first-line injectable disease-modifying drugs, and many pediatric patients prefer oral medications.[59] Newer disease-modifying drugs, including the oral and infusion drugs, have not been tested in pediatric patients as of this writing, but trials are planned.[59]

Pregnant Women

In the past, women with MS sometimes were advised to avoid pregnancy because of perceived risks. However, most studies that examined the subject showed that these patients have similar pregnancy outcomes and rates of pregnancy complications as women who do not have MS.[61]

MS disease activity decreases during pregnancy, especially during the third trimester, when it drops by about 70% compared with prepregnancy levels.[1] However, the likelihood of a relapse increases after delivery. About 30% of patients have a relapse during the first few months after giving birth.[1] Decisions about when to stop and restart MS treatment in women who are pregnant, planning to become pregnant, or postpartum should be based on the individual patient's condition and her level of disease activity before the pregnancy.[1] In general, disease-modifying treatments are discontinued when a patient becomes pregnant,[61] and teriflunomide definitely is contraindicated during pregnancy because of risks to the developing fetus.[1]

Conclusion

MS is a challenging condition for patients affected by the disease and for the health professionals who care for them. Diagnosis can be challenging because many diseases mimic the signs and symptoms associated with MS. Another challenge is predicting whether, when, and how much MS-related disability eventually will occur. Identifying the best treatment for each individual is challenging because a therapy that works well for one patient might not be tolerable, effective, or appropriate for another patient. Finally, paying for MS treatment can be an enormous challenge for patients, families, insurers, and society. Nevertheless, the outlook for patients with MS has never been brighter, with refined criteria for diagnosing the disease earlier and several new drug treatments approved in recent years.

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1. Women are _____ likely than men to develop multiple sclerosis (MS) and tend to develop the disease at a(n) _____ age than men.
   a. more; older
   b. less; older
   c. more; younger
   d. less; younger

2. A leading hypothesis regarding the cause of MS is that it occurs as a result of a combination of:
   1. genetic susceptibility.
   2. exposure to a specific virus or toxin.
   3. a triggering event such as a traumatic injury.

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

3. Which of the following are possible symptoms of MS?
   1. fatigue
   2. numbness or weakness
   3. visual disturbances such as double vision

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

4. Most patients with relapsing-remitting MS eventually develop _____ disease.
   a. fulminant
   b. benign
   c. radiologically isolated
   d. secondary progressive

continued on next page

5. Patients with clinically isolated syndrome have a single:
   a. brain or spinal cord lesion detectable on magnetic resonance (MR) imaging.
   b. symptomatic episode lasting 24 hours.
   c. area of damage in the central nervous system (CNS).
   d. relative with MS or no family members with the disease.

6. Which of the following criticisms have been made regarding the 2010 McDonald diagnostic criteria for MS?
   1. They are complex.
   2. They require analysis of cerebrospinal fluid and visual evoked potential testing, which are costly and can delay diagnosis.
   3. They are based on data from European patients and might not apply as effectively to other patient populations.

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

7. Regarding MS diagnosis, experts caution that:
   a. it is only possible to diagnose MS after more than one symptomatic attack.
   b. the patient's clinical presentation should drive diagnostic classifications and treatment decisions.
   c. only MR images can confirm a diagnosis.
   d. even with McDonald diagnostic criteria, early diagnosis and treatment are unattainable.

8. The spinal cord should be scanned with MR for patients with suspected MS:
   1. in cases of benign disease.
   2. when initial brain imaging is nondiagnostic.
   3. when the patient's signs or symptoms suggest spinal cord involvement.

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

9. When do MS lesions appear nodular on gadolinium-enhanced MR images?
   a. during all stages of the disease process
   b. when they are at least 2 years old, indicating areas of permanent axon loss
   c. only when they exceed 10 mm in diameter
   d. when they are new

10. MS lesions in the brain typically appear on T2-weighted, proton-density, and fluid-attenuated inversion recovery (FLAIR) MR images as:
    a. asymmetrical hypodensities.
    b. large, irregular isointense areas.
    c. small round or oval hyperintensities.
    d. "black holes."

11. Paraclinical tests, such as cerebrospinal fluid analysis, might be helpful in MS diagnosis for patients:
    1. who have vague or nonspecific symptoms.
    2. for whom MR imaging is contraindicated.
    3. who have migraines.

    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

continued on next page

12. Disease-modifying drugs repair damage to the CNS caused by MS.
    a. true
    b. false

13. Which of the following is a serious possibility with long-term use of natalizumab?
    a. cardiomyopathy
    b. harm to a developing fetus
    c. increased risk of malignancy
    d. progressive multifocal leukoencephalopathy

14. A patient with MS should stop taking a disease-modifying drug when:
    1. he or she reports a serious adverse effect.
    2. she becomes pregnant.
    3. the disease becomes progressive.

    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

15. According to one study, on average, patients with MS have a reported quality of life one standard deviation lower than the general population. In particular, which of the following groups of MS patients tend to report reduced quality of life?
    a. younger patients
    b. patients who recently received a diagnosis
    c. men
    d. people of northern European ancestry

16. During pregnancy, MS disease activity _____, but likely will _____ after delivery.
    a. decreases; increase
    b. increases; decrease
    c. stops completely; resume gradually
    d. accelerates rapidly; slow significantly

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○ Yes ○ No

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○ Very valuable ○ Valuable ○ Somewhat valuable ○ Not very valuable

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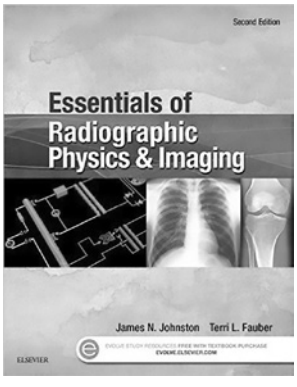
Essential Reads



***Essentials of Radiographic Physics and Imaging.* 2nd ed. Johnston JN, Fauber TL. 2016. 288 pages. Elsevier Mosby Publishing. www.elsevier.com. $111.**

Essentials of Radiographic Physics and Imaging provides the reader with the fundamental principles of radiologic physics and current imaging practices. The authors successfully combine these difficult concepts into one textbook that is easy to understand and apply to clinical practice.

The textbook, based on curriculum guidelines from the American Society of Radiologic Technologists and content specifications from the American Registry of Radiologic Technologists, is an excellent resource for radiologic science educators who want to ensure students are taught key concepts for the Registry examination. Students will appreciate the book's organization, which includes focused areas within the chapters that reinforce critical concepts and mathematical applications to help keep students on task while studying. The textbook also is a great resource for practicing radiologic technologists because it contains information on new technologies used in clinical environments.

As technology has advanced, the body of knowledge regarding digital imaging also has evolved. Although this information can be a challenge to explain, the authors did an extraordinary job of providing illustrations and explanations that simplify difficult concepts and add to the profession's body of knowledge in digital imaging.

The book's strengths include photographs of imaging accessories and equipment, radiographic images, and illustrations, as well as concise boxes throughout each chapter identifying physics and imaging connections, critical concepts, math applications, and ways to put theory into practice. These boxes are placed strategically throughout each chapter to direct the reader's focus to the key concepts presented.

This textbook also offers many extras that aid in understanding radiographic physics and imaging. Critical thinking and review questions are located at the end of each chapter to reinforce key information. Answers to review questions and a glossary are accessed easily at the end of the textbook allowing readers to assess their knowledge. Perhaps the most useful, however, is a free electronic resource with an image collection and additional quiz questions. Readers have multiple opportunities to reinforce information as they study.

The authors are commended for an outstanding job with the organization of this textbook. It is well written and enjoyable to read, with content in a logical order. Given the amount of information, the textbook is the

perfect size and well constructed. The illustrations, photographs, and radiographic images are beneficial. In chapter 12, it might have been helpful had the authors provided an additional color layer illustration of the computed radiography photostimulable phosphor imaging plate and information pertaining to its importance and use. Overall, the authors were thoughtful to provide visual elements that are easy to understand and explain. The information is accurate, thorough, and presented well.

I highly recommend this textbook. The authors have presented the history of the imaging profession while simultaneously keeping the reader abreast of current technological advancements. This one textbook, which combines radiographic physics and radiographic imaging, can be used to replace 2 textbooks teaching these separate content areas.

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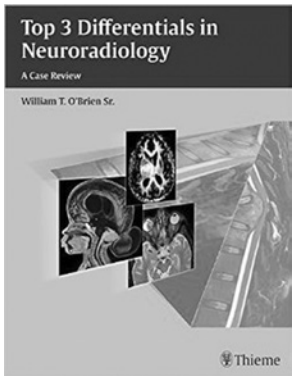

***Top 3 Differentials in Neuroradiology: A Case Review.* O'Brien WT Sr. 2015. 624 pgs. Thieme Publishers. www.thieme.com. $129.99.**

Top 3 Differentials in Neuroradiology: A Case Review describes nearly 300 disease pathologies of the neurologic system and illustrates specific conditions through medical imaging case studies. The book's prime audience is radiologists and neuroradiology students. However, radiologic technologists experienced in multiple modalities, specifically magnetic resonance (MR) imaging and computed tomography (CT), might find it useful because most neurologic diseases are best demonstrated with MR and CT.

The book is organized into 3 sections—brain, head and neck, and spine—with the content presentation similar to a radiologist's report. Every page includes a case study with images and a description of the condition.

Some cases are accompanied by numerous images, while others have only one. Some of the images were acquired with outdated technology, but the pathology is still visible. In addition, the book contains few diagnostic radiography, ultrasonography, and nuclear medicine images.

Each case study includes:

- A key imaging finding, which is a short description of the abnormality seen on the image.
- The top 3 differential diagnoses.
- Additional differential diagnoses for some case studies.
- The diagnosis.
- A brief review of key terms labeled *pearls*.

Cases have between 1 and 6 differential diagnoses. Readings related to the diagnosis appear at the bottom of every page.

Much of the brain section focuses on pediatric MR imaging, which is particularly helpful for MR technologists working with children. The head and neck section features a combination of medical imaging modalities, mostly MR and CT, and includes pediatric and adult cases. The spine section has the fewest case studies and includes mostly adult studies.

Clinical presentations listed for each case study are brief and sometimes vague. Although each case reveals the diagnosis and appearance on the image, no other information about the disease process, such as further associated imaging or prognosis and treatment for the diseases, is offered.

Radiologic technologists might not be familiar with some of the diseases presented, but their rarity might be of interest. Two case studies are accompanied by images that display normal development of myelination and preoperative images for tractography. Because these cases do not present differentials or disease, they seem out of place, but they are related to neuroradiology. Last, some studies contain undefined terms a radiologic technologist might not be familiar with.

Looking at the images and trying to determine the pathology before reading the actual diagnosis is exciting. The presentation of differential diagnoses with the correct diagnosis benefits the reader. The interesting and rare pathologies make this book a great reference in the clinical setting, especially in the MR arena. Overall, *Top 3 Differentials in Neuroradiology: A Case Review* would benefit technologists working in pediatrics, MR, CT, and neuroradiology.

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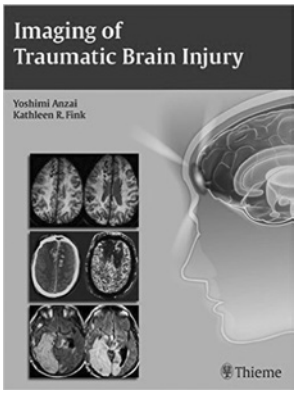

***Imaging of Traumatic Brain Injury*. Anzai Y, Fink KR. 2015. 183 pages. Thieme Medical Publishers. www.thieme.com. $99.99.**

Imaging of Traumatic Brain Injury is written for radiology residents and fellows, neuroradiologists, general radiologists, emergency medicine specialists, neurosurgeons, and neurologists. It also could help CT and MR technologists to better understand their patients with such injuries.

Each chapter presents case histories of topics that include skull-based trauma, postoperative imaging, pediatric imaging, and advanced imaging. Key points called *pearls* are provided at the end of most chapters. The high-quality medical images are clear and marked to indicate the area discussed. Color illustrations display radiographic signs that help determine radiographic imaging patterns such as a baseball appearance representing choroidal detachment. References are provided in each chapter, and an index provides quick reference to specific topics.

The chapter on epidemiology discusses risk factors, underlying causes, and management for each age group. The chapter on evidence-based imaging provides insight into considerations for CT vs MR use. Clinical evaluation criteria used to determine appropriate imaging choices is based on previous case studies.

The topics of pathophysiology, blunt cerebrovascular injury, penetrating trauma, maxillofacial, orbital, and ocular injury are presented in separate chapters. Each of these chapters contains information about the imaging best suited for an injury and provides images that correlate with the text to explain the complexities related to the injury. Some cases present 3-D reconstruction images, and all images are annotated with complete information.

The chapter on pediatric head trauma describes evaluation, radiation dose, and the need for CT in this patient population, and it covers topics that range from birth trauma and nonaccidental trauma to unique aspects of pediatric imaging, with suggestions for protocol and dose.

The advanced imaging chapter presents the changes in pathology not visualized on standard CT and MR as well as imaging techniques offered by diffusion tensor imaging, single-photon emission CT, positron emission tomography, arterial spin labeling, susceptibility imaging, functional MR imaging, magnetoencephalography, and MR spectroscopy. The authors suggest that these techniques will advance new baselines for imaging and treatment as more evidence is gathered about the long-term effects of mild traumatic brain injury.

Imaging of Traumatic Brain Injury provides concise, in-depth discussion for diagnosis of traumatic brain injury and indications for follow-up. The insightful information can help technologists be more aware of patient care aspects when imaging suspected brain injury patients.

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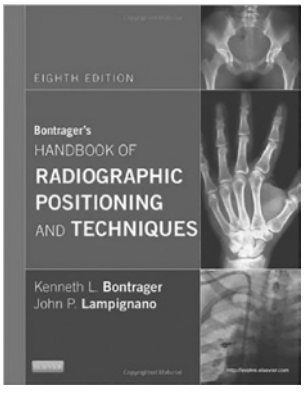

***Bontrager's Handbook of Radiographic Positioning and Techniques.* 8th ed. Bontrager K, Lampignano J. 328 pgs. Elsevier Mosby. evolve.elsevier.com. $40.37.**

Bontrager's Handbook of Radiographic Positioning and Techniques is a compact, spiral-bound guide that covers applied aspects of radiographic positioning and exposure factors. The handbook is for students and practicing technologists who would like a quick review before an examination begins to ensure it is completed correctly and with the least amount of radiation exposure to the patient. This handbook also can be used by clinical instructors and educators to reinforce classroom concepts that carry over into clinic or practice lab situations. Its small size means students and technologists can carry it into clinical situations, and it has space to write exposure factor notes for specific equipment or particular rooms throughout a clinical site. Practicing technologists might not need the chapters for common examinations, such as the chest, abdomen, and extremities, but they might find information on the less commonly ordered studies such as mandible or temporomandibular joint helpful. The handbook also contains appendices that address imaging through a cast, grid ratio changes, and source-to-image distance changes.

The handbook is well organized and comprehensive with each section containing the name of the examination, a picture of the image receptor size and orientation, blocker placement (for use with analog images), marker placement, and collimation recommendations. Also included are a photo of a patient in position with a central ray entrance point and a photo of the radiograph with image evaluation criteria. Positioning instructions are given in simple, bulleted points, which make it easy to scan quickly. Central ray placement and angles, source-to-image distance, and collimation also are found under their own headings. As an educator, I was pleased to find that the full-size text pages are referenced at the bottom of each page for the different examinations. This makes switching back to the full text simple and saves time in the classroom and lab. My students say they like the kilovoltage peak range that is given for each examination, because it aids in learning exposure setting techniques. The edges of each chapter in the book are set apart in blue that shows up on the side for easy reference, especially once the reader becomes familiar with the general layout. The front and back covers have a plastic coating that protects the book from dirt and liquids. The room provided to write notes is small, but given the size of the book, it seems adequate.

The layout and order of the content is logical with the exception of the location of the abdomen examination—specifically the adult abdomen examinations, acute abdomen series, and pediatric abdomen examinations on pages 272-280. In the full-size version, the abdomen examinations follow the chest examinations. If the publisher wanted to follow the full-size version exactly, the abdomen examinations would be in chapter 2 after the chest examinations in chapter 1. Nevertheless, I understand that the publisher included the abdomen examinations in chapter 9 with the common contrast media procedures because the area of the body being examined is the same.

I recommend this book to students, registered technologists, and educators for all the strengths stated in this review. I believe it is especially helpful for students entering the clinical portion of their education because it provides a thorough review of each examination in a sturdy, compact, spiral book.

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Ensuring Student Safety in Magnetic Resonance Educational Programs

Loraine D Zelna, MS, R.T.(R)(MR)

Conversations about magnetic resonance (MR) imaging usually include discussions on safety because of potential risks in the MR environment. The magnetic fields used in MR imaging are, on average, 30 000 to 60 000 times more powerful than the earth's magnetic field. This strong magnetic field creates a projectile effect by pulling any ferromagnetic material (ie, material with a high susceptibility to magnetization such as iron) into the center of the magnet at extremely high speeds. The magnet always is on, and the magnetic field is invisible. The risks for harm created by the strength of the magnetic field and the radiofrequency hazards extend to all who enter the scanner's magnetic field. These risks include the possibility that an implanted device, such as a pacemaker, could cease working, the magnet could pull on or create excessive heat within or around an implanted device, or a person could be struck by a projectile as it is pulled toward the magnet. These potential hazards have led to rigorous screening procedures aimed at reducing the risk of accidents involving health care providers, MR personnel, support staff who routinely work in the MR environment, and patients.

Previously, radiography, radiation therapy, MR, and medical dosimetry educational programs that provided students with clinical rotations or potential access to the MR suite might have relied on the clinical setting to inform students about MR safety. In October 2014, the Joint Review Committee on Education in Radiologic Technology (JRCERT) Board of Directors adopted new interpretations to Standard Four to help ensure student safety in the MR environment. The recent interpretations require all JRCERT-accredited programs to make available to students information regarding the potential dangers of metallic implants or foreign bodies in the MR environment.[1] Programs also are required to implement a safety screening protocol that prepares students for safe MR practices.

Incidents of Note

During the October 2014 meeting of the JRCERT Board of Directors, the board confidentially discussed an experience a student had during an MR rotation. During this particular incident, the student apparently heard the MR technologist screening a patient before the examination. The student became concerned and informed the MR technologist that she had a pacemaker. The technologist had assumed the educational program had screened the student before assigning her to an MR rotation, and the program had assumed the MR technologist would screen the student.

One of the most widely publicized MR safety incidents occurred in 2001 at a New York-area hospital. A 6-year-old boy died after having an MR examination when a metal oxygen tank was brought into the MR suite by an individual who was not trained appropriately in MR safety procedures. The machine's magnetic field propelled the oxygen tank across the

room and into the magnet, causing severe trauma to the child's head.[2] This tragedy highlighted the need to improve safety considerations in the MR environment and emphasized the unmistakable need to improve safety measures for students in educational programs.

Promoting Safe Practices and Improved Accountability

Reports of unsafe practices in the MR environment have pointed to a need for increased guidance on safety practices. The American College of Radiology developed a guidance document to provide industry standards for safe and responsible practices in MR environments. The document is updated continually to reflect changes in MR imaging best practices. Emanuel Kanal, MD, FACR, FISMRM, MRMD, AANG, the lead author of the document, has developed an MR safety training course to promote the certification of MR safety officers.[3] In addition, the Joint Commission issued diagnostic imaging requirements that require organizations to manage safety and security risks in MR environments. These requirements include restricting access to MR areas, ensuring these areas are controlled by MR safety-trained individuals, and posting signage to indicate the presence of potentially dangerous magnetic fields (see **Table**).[4] Furthermore, the Joint Commission requires facilities to document the ongoing education of MR personnel, including annual training on MR safe practices.

New Standards Interpretations

In the JRCERT's continual quest to promote quality and safety, new interpretations were adopted in October 2014 for Standard Four of the JRCERT Standards for an Accredited Educational Program in Magnetic Resonance, which deals with health and safety to ensure the safety of students in educational programs for radiography, radiation therapy, MR, and medical dosimetry.[6] The interpretations require MR programs to publish and provide information about the potential dangers of implants or foreign bodies in students to all students and the general public, as well as to establish a safety screening protocol for all students. In addition, radiography, radiation therapy, and medical dosimetry programs are required to establish a safety screening protocol for all students who have access to the MR environment.[1] To document compliance, the program must describe how it prepares students for MR safe practices and provide a copy of the screening form. A plethora of MR safety information and resources for programs to use is available (see **Box**).

Table

Magnetic Resonance (MR) Safety Zones[5]

Zone	Description
I	■ Areas are freely accessible to the general public.
II	■ Semirestricted area where patients and hospital staff can interact. ■ Area must be marked clearly with a radiation hazard safety sign.
III	■ Area is physically restricted from the non-MR personnel area. ■ Does not permit free access by unscreened, non-MR personnel. ■ Must be free of any ferromagnetic objects and equipment that can be drawn into the magnet, resulting in serious injury or death.
IV	■ The MR suite itself. ■ Individuals that have not been screened are not permitted to enter this zone under any circumstance. ■ After an appropriate screening process has taken place, patients and hospital personnel can enter the MR suite but must be accompanied by designated MR staff.

As of the beginning of 2016, the JRCERT had accredited 10 MR programs, with several more in the accreditation process. All of these programs have published information about MR safety screening on their program's Web site; whereas, an informal review of non-JRCERT accredited MR programs listed on the American Registry of Radiologic Technologists Educational Programs Web site revealed that only 1 of 4 MR programs have published information on their program's Web site about MR safety screening.[7] This indicates the need for, and value of, programmatic accreditation. Programmatic accreditation provides educational programs preparing new practitioners for the profession with an external

Box

MR Safety Information Resources

- October 2015 edition of the *JRCERT Pulse* newsletter at the JRCERT Web site – jrcert.org
- Section for Magnetic Resonance Technologists Web site – ismrm.org/smrt
- American Society of Radiologic Technologists MR Community forum – asrt.org/myasrt
- American College of Radiology Web site – acr.org

benchmark to ensure they meet the minimum standards identified by the profession. These external benchmarks help to ensure that students are screened appropriately and educated in MR safety practices to provide safe, high-quality diagnostic services to patients while maintaining their own safety.[8]

Conclusion

MR safety always will be an area of concern for imaging professionals and educational programs preparing students to enter the profession. The risks can mean life or death; therefore, it is paramount to implement safe practice standards. The MR community and various organizations work diligently to improve MR safety education and provide additional educational resources. Radiologic technologists practicing in MR must remain current on new safety information and considerations and share their knowledge and expertise. Students are the future of the profession, and they need to be prepared in the fundamental principles of MR safety.

JRCERT has developed standards that assist programs in promoting safety for students, patients, and the general public. Furthermore, these standards demonstrate the JRCERT's commitment to excellence in education and the quality and safety of patient care through its accreditation of educational programs.[9]

Loraine D Zelna, MS, R.T.(R)(MR), serves as faculty and interim department chairperson of the medical imaging department for Misericordia University in Dallas, Pennsylvania. She also serves on the JRCERT Board of Directors.

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Surgical Breast Tissue Specimen Handling and Transportation in Radiology

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In the United States, approximately 1.6 million surgical breast biopsies are performed each year. The preferred treatment of clinically nonpalpable breast masses is wide local excision by wire-guided localization.[1] Specimen radiography should be performed on the excised breast tissue of all image-detected abnormalities found during preoperative workup[2] because radiologic assessment of the margins of a nonpalpable breast mass can be used to assess the surgical procedure.[3] Furthermore, some type of specimen imaging is required as a standard of care according to the American College of Radiology guidelines for the evaluation of surgically excised breast ductal carcinoma in situ as well as invasive breast carcinoma.[4,5]

Breast tissue specimens are transported from surgery to radiology and then to pathology for final histological examination. Transportation and handling procedures vary among facilities. Some facilities place specimens in simple plastic containers, such as an emesis basin, to look for needles, wires, and previously placed markers to assist in analyzing excised breast mass margins. Some use tissue containers with alphanumeric grids to make a more precise evaluation, providing the exact location of an excised mass. Others might place additional needles in the tissue or use dye, such as India ink, to indicate the location of the lesion of concern for the pathologist.

A 2014 survey of Society of Breast Imaging members about breast tissue specimen handling revealed that almost every facility had a protocol for handling the specimen and that the protocols varied because no standardized method for storing, imaging, and transporting the specimen between the departments existed.[6] According to the study, 60% of radiologists indicated that the specimen gets transferred 2 or more times, in different containers, during transport from surgery to radiology, back to surgery, and finally to pathology. In some cases, the radiologists were unaware of the process, but they all used various types of tissue handling and transporting containers based on the physician's preference or procedure location.[7] The need to transfer the specimen several times increases the risk of spilling bodily fluids, contaminating equipment, and exposing hospital personnel to blood or to injury with needles remaining in the excised tissue. Furthermore, only 13.8% of survey respondents were aware of the costs of using several containers during specimen transfer and imaging.

Nearly all of the radiologists who participated in the survey (94.6%) agreed that a standardized method for breast tissue specimen handling would result in more uniform results and an overall improvement in patient care. This article describes a standardized method for handling and transporting excised breast tissue specimens from the operating room to the radiology department throughout several medical centers at the Henry Ford Health System in Detroit, Michigan.

Procedure and Methods

The breast tissue handling process starts with wire localization performed in the medical imaging department the day of surgery. Radiologists guide the needle

to the area of interest using mammography images or ultrasonography. They place more than one wire if a mass is large or additional nodules are present. After this procedure, another mammogram is performed, and precise measurements are made and used as a reference for surgery.

Next, a completed patient information label is attached to a tissue specimen container that includes an alphanumeric grid. This is the only container used in every step of the procedure; the specimen is not switched to another container. The labeled container is transported with the patient to surgery. The area of interest is excised, and the tissue specimen is placed within the container for transport to radiology. The operation usually is paused while the specimen is being evaluated for definitive mass margins in the radiology department.

Once the breast tissue specimen arrives in the radiology department, mammographers use 2 identifiers to verify that the label on the specimen container matches the patient. The container is opened and tissue is compressed using the alphanumeric grid. The grid is used to flatten the specimen for better image resolution. After the lid is replaced, the container with the breast tissue specimen is placed on a mammography Bucky for magnification imaging, and no further tissue handling or preparation is required (see **Figure 1**).

After imaging, the mammographer asks the radiologist to check the specimen images (see **Figure 2**). Mass margins visualized on the image confirm a successful and complete mass resection and that no additional tissue removal is necessary. The grid is removed and discarded, and the container with the tissue is transported immediately to the pathology department.

Analysis and Results

Initially, analysis of breast surgical specimen management and transportation at the different medical centers in the Henry Ford Health System revealed that 3 containers were used to evaluate breast tissue specimens at different locations. Members of the breast imaging department, with the help of the supply chain management team, sought to develop a standardized process that would improve cost efficiency and safety in handling the excised breast tissue specimens at all locations.

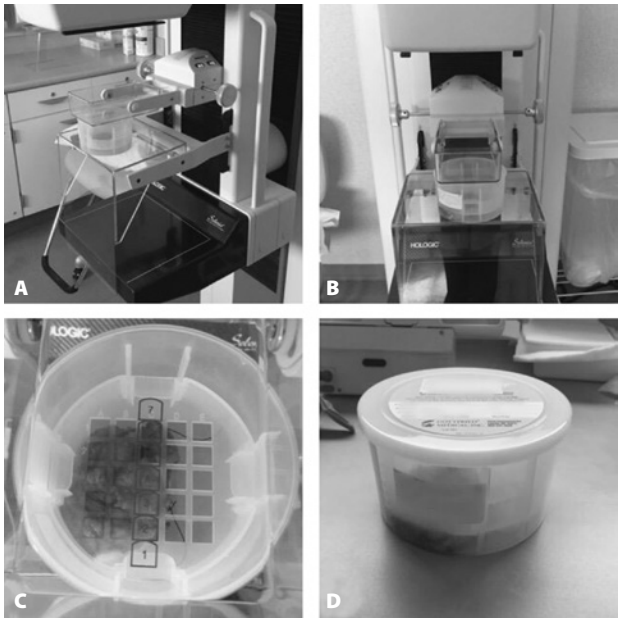

Figure 1. *A-B. Photographs of a breast tissue specimen within container C after the grid is placed. C. Superior view of the container with the compression grid in place. D. Sealed container C with specimen. Images courtesy of the authors.*

Each of the 3 containers (A, B, and C) in use had different features. Container A was a thinner, smaller plastic container containing a paper grid.[8] Container B also was made of thinner plastic and contained a coated grid.[9] Container C was made of thick, leak-resistant plastic and contained a compression grid.[10]

All 3 containers were compared to discern their safety, accuracy, ease of handling, and cost. Container A was well built and sufficiently tough to prevent needles or wires from puncturing the container. The paper grid attached inside was helpful in describing specimen size and orientation. However, the container itself was thin and could not seal tightly with a larger specimen, which increased the potential to spill bodily fluids during transport. Although container B could be sealed well, it was not sturdy enough to prevent a needle or wire sticking through and posed a risk of injury. It did, however, have the advantage of keeping the specimen in place; the special coating on the grid consisted of 2 sets of radiolucent coordinates that enabled more precise localization. Container C's thicker plastic resisted

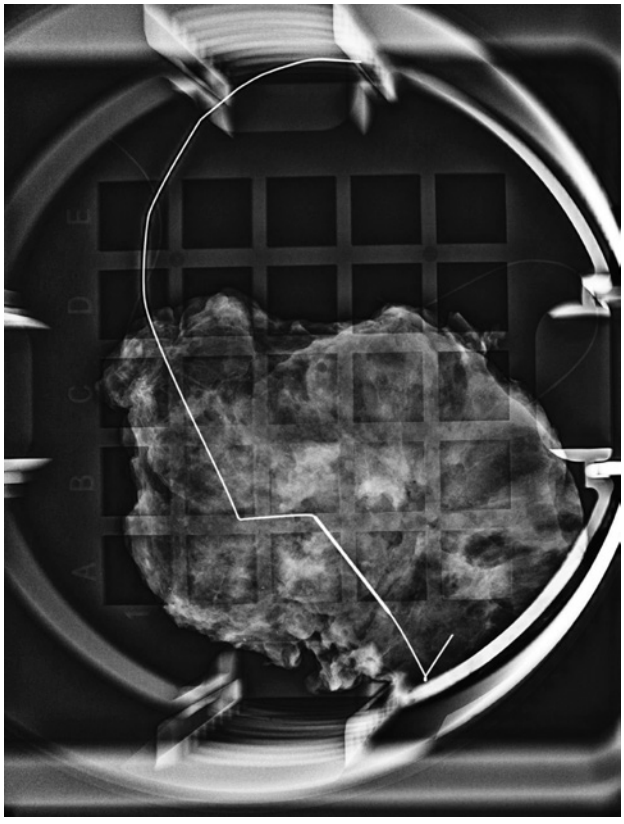

Figure 2. *Radiograph of a surgical breast specimen with a localization wire in container C with a grid. Image courtesy of the authors.*

sharp objects such as wires and needles and was able to accommodate a considerably large tissue specimen, which for the most part eliminated the need for multiple containers (see **Figure 3**). Furthermore, container C had a tightly closing lid with an inner lip that snapped into place after applying pressure. This design creates a seal and prevents bodily fluid from leaking during transportation. In addition, this container had an adjustable grid that could slide into place and provide the reference location while keeping the tissue specimen in place during transportation. The sliding grid also helped provide pressure to the excised breast tissue specimen during imaging.

A cost analysis was performed by identifying all the items used in imaging and handling surgical breast specimens among the various medical centers. In addition to the tissue specimen containers, imaging departments at some facilities used other items that contributed to increased cost and waste (see **Box**). Further analysis revealed a significant cost difference among the 3 containers. After comparing the cost of using all 3 containers as well as the additional items, container C was determined to be the most cost-effective method for handling, imaging, and transporting breast tissue specimens. Moreover, supply chain management's system-wide projective cost analysis revealed that switching to container C resulted in an overall projected savings of 27% to 28% (see **Table**).

Figure 3. *Surgical breast specimen container with grid. Image courtesy of PathProof, LLC.*

As a result of the analysis, radiologists and surgeons performing surgical breast biopsies in the system switched to using only container C for all steps of the procedure. The standardized process provides consistency and unity. Furthermore, container C's features address the safety of health care workers, minimizing the risk of spilling bodily fluids and injury.

Box

Items Used for Handling Breast Tissue Specimens at the Henry Ford Health System

Emesis basin
Chux blue pad
Filled formalin jar (90 or 250 mL)
Formalin solution (90 or 250 mL)

Table

Cost Comparison Analysis

Medical Facility	Projected Savings (%)
West Bloomfield Hospital	10-12
Henry Ford Hospital	10-12
Macomb Hospital	51
Fairlane Medical Center	25-26
Wyandotte Hospital	10-12
System-wide Savings	27-28

Discussion

Throughout the United States, there is significant variability in the way breast tissue specimens are handled. Some facilities use generic plastic containers or bags to transport and image excised breast specimens, whereas other institutions prefer one of several commercially available products.[11] The decision remains the radiologist's choice, primarily because no standardization exists. However, this preference is not always coordinated with the surgery department, and the breast tissue specimen being transported from the operating room might not remain in the same container for assessment in the radiology department. Consequently, institutions should review, evaluate, and standardize the protocol with which specimens are handled and transported from surgery to radiology and then to pathology.

Although cost is the most obvious concern when implementing new procedures, departments also must consider patient care, risk of exposure to blood-borne diseases, and injuries from wires and needles to health care workers and patients.

The Occupational Safety and Health Administration reports more than 385 000 documented needle-stick injury cases in hospitals per year.[12] According to the Centers for Disease Control and Prevention, a health care worker who incurs a needle-stick injury is exposed to hepatitis B 30% of the time, hepatitis A 1.8% of the time, and HIV 0.3% of the time in reported cases.[13] Furthermore, the Centers for Disease Control and Prevention estimates the cost of postinjury treatment and monitoring to be almost $3000 per case when taking all cases into consideration. This figure does not include inherent physical costs associated with any lost work time for the exposed employee to receive care or the emotional stress related to the postinjury anxiety. Thus, the use of a container designed to facilitate additional safety runs parallel to the Centers for Disease Control and Prevention and Occupational Safety and Health Administration guidelines that encourage the use of built-in safety.

Each facility should evaluate its needs, cost efficiency, and safety concerns before committing to changes. The most important outcome is the standardization of surgical breast tissue specimen handling and management, which can improve result accuracy, cost efficiency, procedure safety, and overall quality of patient care.

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Brave New World: Transitioning the Radiologic Sciences to Value-driven Economics

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The television series *House of Cards* follows a fictional national politician who constantly manipulates the federal political and legal system to achieve his personal goals while staying within the confines of the rules. Many of the show's plotlines are based on a political and legal system that can be manipulated or corrupted financially and operationally, with or without professional colleagues. The viewer comes to realize how fragile the system is and that any small manipulation or change can have major consequences.

Unlike the political model portrayed in *House of Cards*, the radiologic science industry has enjoyed a business model that for the past 50 years has had continuous growth and little restriction. That is, the system has been solid. Our federal health care delivery models, including hospitals and health care systems, also have enjoyed continuous growth, little restriction and oversight, and tremendous profits. Under this model, radiation imaging and oncology practices have been one of the largest income producers for health care centers across the United States. The modern U.S. health care system has grown from a $27 million industry in 1960 to a $3 trillion industry in 2015, and medical imaging and radiation oncology are significant reasons for this growth.[1]

With an initial capital investment of a building, technology, and skilled labor, most medical imaging and radiation oncology centers have demonstrated huge profits over the past 40 years, which led to increased program operations, clinical quality, and clinical staffing. The industry has flourished, with more than 2000 radiation therapy centers in the United States serving more than 1 million patients in 2014. This success also has affected higher education programs.[2]

Students view medical imaging and radiation therapy as a desirable career because of its high earning potential, the high-quality work life, and the security that the jobs will not be outsourced. However, competition to get into a program is fierce. In 2015, for example, radiation oncology residencies accepted 40% of applicants; the remaining 60%, most with 6-figure debt from undergraduate and medical school,[3] had to choose a different career in a related field. Similarly, medical physics programs accept only 25% of candidates.[4] Furthermore, the United States has only 125 medical dosimetry and radiation therapist education programs, and in 2014, the vacancy rate was low for full-time radiation therapists (1.6%) and dosimetrists (3.67%).[5]

Emerging Financial Implications

Most reimbursement in medical imaging and radiation oncology comes from 3 areas: Medicare and Medicaid, private insurance, and direct patient payments. Of these, private insurance, which for the most part covers employed people younger than age 65, reimburses the most money per charge for these services. Medicare, which pays a lower reimbursement

per charge than private insurance, has been consistent in reimbursement for many years, but percentages have decreased in the past couple of years. Cash payments from patients offer the lowest percentage of reimbursement.[4]

Despite the industry's high reimbursement and strong financial position, its business operating margins are in the 2% to 4% range.[5] In comparison, after the terrorist attacks on September 11, 2001, most airlines approached financial collapse within a period of days with operating margins at those levels. The medical imaging and radiation oncology industry has yet to experience this type of financial catastrophe. However, the model that has allowed the industry to thrive is beginning to change in both quantity of users and quality of reimbursement.[4] These changes will require radiologic science professionals to think differently about finances, operations, quality, and staffing.

Shifting Health Care Responsibility

According to the United States Department of Labor, approximately 121 million of the country's 323 million citizens are in the workforce.[6,7] In 2010, the majority of the workforce had some type of health insurance as part of a job benefits package. In 2015, this model began to change when several large U.S. companies stopped offering private insurance for their employees and instead gave them—some 3 million employees—money designated for health care services and left it to them to determine what insurance plan they will buy.[4,5,8] This number is projected to increase to 9 million employees in 2016, and 40 million by 2018. In the near future, high reimbursement private health insurance could be limited. In 10 years, health insurance might change from being a collective benefit to being each person's responsibility.[6,7]

Most medical imaging and radiation therapy workers will become more aware of the costs of the services they provide because of increased collaboration and communication from adminstrators and managers, but they still might not understand what the average person has to deal with in making health care decisions in terms of those services.[5,8] Consequently, the information gap about purchasing health care insurance could widen. This is important because when consumers receive the money for health care, they must determine how best to use it. In this new model, 3 questions arise:

- Will employees use their insurance money for health care delivery?
- Will consumers shop for the best price?
- Will consumers pay for high-cost, high-quality care?

Will Employees Use Their Insurance Money for Health Care Delivery?

If a full-time employee purchases insurance through the Affordable Care Act system at a monthly cost of approximately $500 per family, with a deductible of $2500 per year,[3-5,7] that employee, who earns $600 per week, must use a month's gross salary for the deductible to use his or her health insurance. Although the employee's employer might be giving him or her $150 to $200 per month for health care, the remaining $300 to $350 per month would be out of pocket.[3-5,7] In this scenario, nearly one-quarter of this worker's take-home pay would be used for health care. The high cost of medical insurance might cause the employee to decide against purchasing it.

Will Consumers Shop for the Best Price?

With the traditional model, a private health care insurance company paid for services, and the consumer was seldom aware of the price. Health economists are predicting that the new model with high deductibles will force consumers to begin researching services to learn the costs and shop for the best and most affordable care.[9-11] This model occurs now in the car industry. Anyone with Internet access can look up a car and find wholesale and retail prices easily. They then can use that information to make decisions about which car they want and from which dealer. In the same way, health consumers might begin to shop for prices for medical imaging and radiation therapy services, because when they are spending their own money, they might become more concerned about getting the best deal.

Health consumers also will start to look at factors other than receiving care when making their decisions, forcing medical imaging and radiation oncology facilities to make changes that enable them to stand out. For example, they might work to become known for a special type of treatment or service, or they might become

known as a facility of excellence and through volume become able to offer lower priced, higher quality care for specific conditions. A consumer in Florida might decide to travel to San Francisco for a specific type of radiation therapy based on cost and quality.

An example of this model is the television industry. Many people now have Internet TV service rather than traditional cable or satellite service. These consumers forgo some programs to pay less. As a result of this changing consumer practice, ESPN, for example, lost 7% of revenue and laid off 400 employees.[10] Because this concept of consumers desiring to pay a lower cost could happen in the medical imaging and radiation therapy industry, adapting to consumers' autonomy and adjusting the business models is critical.

Will Consumers Pay for High-Quality, High-Cost Care?

Some patients always will be able to pay for services, no matter the cost, but for the most part, much will depend on the individual's occupation, wealth, personal debt ratio, and judgment of whether the medical imaging or radiation therapy services are worth it. As a result of the new model, the number of medical imaging and radiation therapy centers offering high-cost, high-quality care might decrease. It also is unknown whether consumers will favor the large academic medical centers or the small medical imaging and radiation therapy clinics.

The Emerging Concept of Value

Radiation sciences payment system redesigns likely will include concepts of volume, cost shifting, and value-based payment schematics. For example, in radiation oncology, according to new Centers for Medicare & Medicaid guidelines, value-based payments are based on value concepts including whether[12]:

- 3-D or intensity-modulated radiation therapy treatment planning was used.
- The treatment plan was peer reviewed.
- The physician did not order a bone scan for a low-risk prostate cancer patient.

The idea of not doing something is important because it is a shift from past practices in which reimbursement was based on what was done, not what was not done. Value concepts are linked to value scores for Medicare payments and will be linked to future payment schemes. These schemes might include lower payments for lower scores and higher payments for higher scores. Patients will access radiologic science facilities' scores and use them to determine value. Providers will need to demonstrate higher value to remain in business.

The emergence of value-based payments could initiate networks of providers. In this concept, employees and providers will be paid less for their services, but by being in the network, providers will be in a volume-based group. This will be critical for radiologic science providers because of increased competition and the integration of a fluid type of health care delivery marketplace in which consumers are spending their own money. The radiation oncology industry currently operates under this concept, one whereby some medical oncologists are paid a finite amount to treat a patient.

What also might change as a result of the new model is the way metastatic disease is treated. In Canada, for example, some radiation therapy metastatic clinics follow a palliative treatment model, which provides the following based on a one-time bundled payment[13]:

- The patient is given one larger radiation dose per week.
- The clinic usually is run by one attending physician and several nurse practitioners or physician assistants.
- Patients receiving palliative treatments are treated only on Saturdays.

Medicare already has begun aligning incentives for bone metastatic patients, and another bundled type of payment system run by Medicare for breast cancer patients exists.

Discussion

Increasing evidence demonstrates that emerging concepts are leading to a transition in how radiation sciences do business and how these services fit into the greater health care delivery business models. To understand and predict what will happen in the radiologic sciences is difficult, complex, and challenging, and evidence suggests that these changes will occur quickly. Managers and practitioners therefore must learn as much as possible about these potential changes to be ready to adapt to and survive in a new economic model (see **Box**).

Conclusion

Changing reimbursement patterns and value-based practice patterns are inherent in the brave new world of health care. The radiologic sciences are about to undergo a major transition in economic practice and social culture. Managers and practitioners must be ready for change, and managers must lead their departments through new practices in health care delivery, operations, and culture.

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Box

What Radiologic Technologists Need to Know: Authors' Recommendations

Strategic thinking is critical for medical imaging and radiation therapy facilities' survival.

Learning about the new types of payment systems, business models, and emerging changes in health care delivery is critical to future radiation science managers and practitioners.

Transition is coming to all disciplines at all levels in the radiation sciences. Perhaps 50% of how we do business in 2015 could be different by 2025. We cannot predict exactly which aspects will be different, however.

Everyone will be asked to multitask more and accomplish more work in less time. The most valued radiation science employees will be knowledgeable and have multiple certifications and multitasking abilities. Now is a great time for technologists to increase their education level and certifications.

The value-based concept will not apply only to payment; it will carry over to the radiation science employees. Technologists should become more knowledgeable about billing and charges. For many in the radiologic sciences, this has not been a part of our culture. However, in the future, understanding billing and charges should become a greater part of our radiologic sciences culture. The economics will become more fluid; therefore risk will become a higher-rated metric.

The transition to a different business model might affect radiation sciences higher education. A majority of programs graduate students prepared for entry-level employment, but more midlevel provider opportunities might emerge. The current education model might continue to accommodate the same number of students. Entry-level radiologic science programs might need to consider collaborating more with other allied health professions or begin to offer a higher level of degree. Perhaps more 1-year to 2-year programs will link with major universities to offer a more advanced degree. Online education in the radiologic sciences might become a key opportunity. Technologists should consider increasing their education with more emphasis on liberal arts and other disciplines such as the humanities, social sciences, and biological and physicial sciences.

The next 10 years in the radiologic sciences might be known as moving from the operations age to the transformational age. Technology is transforming continually, but now technologists will experience the economic model's transformation and should increase their knowledge and understanding of business models.

Radiologic science professionals will be asked to become more involved with the communities they serve. For example, if radiation treatment centers follow the Canadian model and transition to providing palliative radiation oncology treatment on Saturdays, it would be a low-cost, high-quality model that would appeal to the community served.

Smarter, quicker action will be required of radiologic science professionals, and this will lead to a more fluid workplace. Rather than a technologist performing the same role for 30 years, work roles will be more varied and will shift. Increased knowledge, skills, and ability will become essential.

Cost, quality, and access will continue to drive radiologic science professionals and consumers of health care. However, the new payment paradigm will result in changes to cost, quality, and access that will be larger, of greater significance, and will transition more quickly in the workplace than ever before. A new and different language will be integrated into the workplace, changing the radiologic sciences culture, how the work is done, and how radiologic science professionals view health care delivery.

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Radiation Exposure in Pregnant and Nonpregnant Female Interventional Radiology Workers

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In the 2012-2013 academic year, 27% of radiology residents and 15% of vascular and interventional radiology (IR) fellows were women.[1] The American College of Radiology reports that 3.1% of all practicing radiologists who consider IR their primary specialty are women.[2] According to Joy Gornal, director of membership and graduate medical affairs for the Society of Interventional Radiology, the percent of female Society members is 9% (personal communication, September 16, 2013).

The American Association for Women Radiologists launched a task force in 2005 to revisit guidelines for the protection of pregnant residents from radiation exposure during training. The task force twice surveyed the Association of Program Directors in Radiology membership. Survey 1 looked at existing program and institutional policies and assessed the need for and interest in standardized guidelines that would address radiation exposure and work responsibilities for pregnant radiology residents. Based on the responses, the task force drafted program guidelines, and survey 2 then was conducted to gather opinions and determine acceptance of the drafted guidelines. The findings were published in *Academic Radiology* in 2006 and presented the proposed program guidelines for pregnant radiology residents.

The authors' concerns included the length of IR cases and that the accumulated exposure related to them can be unpredictable. Therefore, they recommended that women postpone trying to conceive until their rotation is completed or postpone the rotation in the event of a pregnancy.[3] Their recommendation was based on information regarding institutional policies rather than exposure data.

A literature review revealed no quantitative data on exposure to female IR workers to support or refute this recommendation. The purpose of the current study was to investigate radiation exposures in an academic IR and neurointerventional practice to determine whether exposures for pregnant and nonpregnant female IR workers exceed allowable values.

Methods

A 3-year retrospective review of radiation exposures to declared pregnant and nonpregnant female IR workers was performed. This study was institutional review board exempt because exposure records are collected monthly and anonymized by the radiation safety officer. Personal whole-body dosimeter data from collar and waist badges were collected and examined. Data were divided into a physician group and into a nonphysician group that included nurses and technologists. Data during pregnant and nonpregnant states were examined.

Each physician, nurse, and technologist had her own protective lead apron with 0.35-mm lead equivalent in the front of the apron and 0.25-mm lead equivalent in the back of the apron. No special maternity lead aprons were worn during pregnancy. Other dose-reducing equipment available to all IR workers to use as desired included table-mounted shields, ceiling-mounted

shields, and free-standing or rolling shields. Each angiography suite was programmed to reset to a low-dose default before the start of every case.

The attending physician was a full-time interventional radiologist who performed some neurointerventional radiology cases using biplane imaging. She acted as the primary operator in some cases and as the supervising operator working with trainee primary operators in other cases. Nurses generally sat away from the angiography table but in some cases would sit near the patient's head if they needed to be closer. A dedicated procedural computed tomography (CT) scanner was in the department, and live CT-fluoroscopy was used routinely. The nonphysician workers rotated equally through IR, neurointerventional radiology, vascular surgery's endovascular operating room, and CT-IR. Call was divided equally among all workers at each level, and no decreased call was given to pregnant workers. The declared pregnant IR physician and nonphysicians also were not assigned any alternate roles in the IR suite during their pregnancy.

Occupational radiation exposure was determined using optically stimulated luminescence technology (Luxel+, Landauer). At the studied institution, 2 dosimeters are worn by all female IR workers: one at the collar level outside of the lead apron and one at the waist level under the lead apron. Exposures to the collar and waist badges were examined for all nonpregnant and pregnant women in the IR department from 2010 to 2013.

Dosimeters provide a measure of the deep dose equivalent (DDE). When no lead apron is worn, this value is recorded as the worker's exposure. At the studied institution, special dose calculations are applied to radiation workers who wear lead aprons (resulting in nonuniform exposures to the whole body) to estimate the assigned DDE when the DDE exceeds the allowable annual exposure.[4-6] When 2 dosimeters are worn, the estimated dose equivalent 1 (EDE 1) calculation can be used: EDE 1 = 1.5(waist DDE) + 0.04(collar DDE).[4,5] The waist DDE is the value used to monitor exposure limits to the conceptus during pregnancy, whereas the EDE 1 is the calculated exposure to the worker wearing a lead apron.[4,5] The median and range of all DDE exposures across all providers were calculated as well as the median DDE for individual providers.

Results

Twelve pregnancies were declared during the review period: 10 in nonphysicians, and 2 in a full-time IR attending physician. Exposure data for these pregnancies are included in **Table 1**. Three nurses had no available collar DDE data, and the missing collar data points were excluded from the median calculations. The median collar and waist badge exposures over an entire pregnancy for nonphysicians were a DDE of 3.09 mSv (range 1.38-4.67 mSv) and 0.135 mSv (range 0-0.38 mSv), respectively. The median collar and waist badge exposures for the physician were a DDE of 25.07 mSv (17.34-32.80 mSv) and 0.475 mSv (0.32-0.63 mSv), respectively. The difference in median exposures between the 2 pregnancies for the physician is related to differing level of skill of the fellow during each pregnancy as well as changes in skill level of the physician over the 3-year period.

Table 1

Radiation Exposure Data From Pregnant IR Workers From 2010 to 2013[a]

Provider	Collar Exposure (mSv) for Entire Gestation	Waist Exposure (mSv) for Entire Gestation
1 (technologist)	4.67	0.35
2 (technologist)	4.44	0.20
3 (technologist)	3.61	0.14
4 (technologist)	2.25	0.13
5 (technologist)	1.38	0.08
6 (technologist)	3.09	0.11
7 (technologist)	2.28	0.33
8 (nurse)[b]	–	0.38
9 (nurse)[b]	–	0.03
10 (nurse)[b]	–	0.00
11 (physician)[c]	32.80	0.32
12 (physician)[c]	17.34	0.63

Abbreviations: IR, interventional radiology; mSv, millisieverts.

[a]*Gestation periods unknown and assumed to be 40 weeks.*

[b]*Data is not available either because these providers did not turn in their badges or exposure was the same as background exposure.*

[c]*First and second pregnancy in a single IR physician operator.*

During the review period, there were 10 nonpregnant female workers: 9 nonphysicians and 1 physician who was between pregancies. For nonpregnant nonphysicians, the median monthly collar and waist exposures over the review period were a DDE of 0.5 mSv (range 0.01-3.76 mSv) and 0.03 mSv (range 0.01-0.25 mSv), respectively. When the physician was not pregant, the median monthly collar and waist exposures over the review period were a DDE of 7.73 mSv (range 0.02-20.22 mSv) and 0.05 mSv (range 0.01-0.32 mSv), respectively. Because her DDE values exceeded the annual exposure limit of 50 mSv and because the physician wore a lead apron at all times, the EDE 1 calculation was used to calculate the assigned DDE. With this calculation, the median monthly exposure was an assigned DDE of 0.35 mSv (range 0.01-1 mSv), and this value falls within the annual occupational exposure limits (see **Table 2**).

Table 2

Monthly Badge Exposures in mSv for the Nonpregnant Physician and Nonphysicians[a]

Location	Provider	No. of Recordings	Mean (SD)	Median (Min, Max)
Collar	1	12	8.81 (7.56)	7.73 (0.02, 20.22)
	1	12	0.36 (0.30)	0.35 (0.01, 1.00)[b]
	2	42	1.17 (0.71)	1.01 (0.26, 3.72)
	3	28	0.97 (0.79)	0.90 (0.01, 3.76)
	4	15	0.97 (0.60)	0.87 (0.01, 2.33)
	5	22	0.62 (0.72)	0.47 (0.01, 3.45)
	6	9	0.46 (0.61)	0.27 (0.01, 1.88)
	7	12	0.16 (0.15)	0.14 (0.01, 0.57)
	8	9	0.31 (0.49)	0.08 (0.01, 1.42)
	9	30	0.05 (0.04)	0.05 (0.01, 0.12)
	10	2	0.01 (0.00)	0.01 (0.01, 0.01)
Waist	1	11	0.08 (0.09)	0.05 (0.01, 0.32)
	2	42	0.07 (0.05)	0.06 (0.01, 0.21)
	3	29	0.03 (0.04)	0.02 (0.01, 0.18)
	4	11	0.05 (0.06)	0.03 (0.01, 0.23)
	5	14	0.04 (0.02)	0.04 (0.01, 0.07)
	6	8	0.06 (0.08)	0.04 (0.01, 0.25)
	7	10	0.03 (0.02)	0.02 (0.01, 0.07)
	8	0	–	–
	9	31	0.02 (0.02)	0.01 (0.01, 0.08)
	10	2	0.02 (0.01)	0.02 (0.01, 0.02)

Abbreviation: SD, standard deviation.

[a]*Provider 1 is the only physician, and she carried 2 pregnancies during the study period. The remaining providers are nonphysicians.*

[b]*Denotes estimated dose equivalent (EDE) 1 calculated assigned deep dose equivalent (DDE) for the physician in a nonpregnant state.*

Discussion

Two exposures must be considered with pregnant workers: the exposure to the conceptus and the exposure to the worker. The potential effects of radiation on a conceptus depend on the radiation dose and the stage of development at the time of exposure. The most vulnerable time of gestation for radiation exposure to a conceptus is weeks 8 through 15, when the nervous system is forming. Potential effects include prenatal death, intrauterine growth restriction, small head size, intellectual and developmental disabilities, decreased IQ, organ malformation, and childhood cancer.[7-11]

Total fetal radiation below 50 mSv is considered negligible when compared with other risks of pregnancy.[7,8,10,12] Defects can occur at levels of 100 mSv to 200 mSv, with more severe problems occurring after higher exposures.[7-10,12] With a dose of 100 mSv, the increase over background incidence for organ malformation and the development of childhood cancer combined is approximately 1%,[7] and the risk of developing childhood cancer is highest with exposures of 200 mSv to 250 mSv between weeks 2 through 15 of gestation.[10]

The dose equivalent from occupational exposure to the conceptus during the entire pregnancy must not exceed 5 mSv, or 0.5 mSv per month, according to the National Council on Radiation Protection and Measurements.[8] The annual adult occupational dose limit is a total effective dose equivalent of 50 mSv.[6,13,14] At the authors' institution, all female IR workers, regardless of pregnancy status, wear a collar dosimeter outside of the lead apron and a waist dosimeter under the apron. Having

collar and waist exposure data from pregnant and nonpregnant workers allows a more accurate evaluation of nonuniform radiation exposure in workers who wear lead aprons. None of the pregnant or nonpregnant waist DDE data exceeded the exposure limit for a fetus. None of the pregnant or nonpregnant nonphysician DDE and pregnant or nonpregnant physician EDE 1 data exceeded the annual exposure limit for a radiation worker.

Conclusion

The main limitations of this study are its small sample size and that it reports data from only a single site. Therefore, a review of exposure records from other institutions would be an important next step. In addition, it is impossible to account for any potential differences in behavior in pregnant and nonpregnant workers. Real-time dose monitoring systems might better help reassure declared pregnant workers that their dose is minimized rather than radiation exposure data collected in a delayed fashion from film badges. Other limitations of this study include the difference in proximity to the beam for nurses, technologists, and physicians; difference in how exposure data are recorded for pregnant (exposure over the entire gestational period) and nonpregnant (monthly exposure) workers; and lack of pregnancy exposure data for residents rotating through the IR service.

This retrospective review of a single center shows that no pregnant or nonpregnant female IR workers exceeded allowable radiation exposure limits, either to the worker or the conceptus. The data suggest that IR rotations at the institution do not need to be limited for pregnant residents because of radiation concerns, because the usual length of IR rotations for diagnostic radiology trainees is 4 weeks per year, which would most certainly maintain exposures below conceptus and occupational dose limits.

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Treat All Patients With Respect

Kimberly Luse, EdD, R.T.(R)

Research on the link between smoking and lung cancer reveals a troubling pathway through history that kept crucial information about the dangers of smoking from the public. The overwhelming evidence that smoking leads to lung cancer first was exposed in the 1964 Surgeon General's Report on Smoking and Health.[1] Before then, smoking had been widely accepted, but the report increased public awareness about the dangers of smoking in relation to cancer.

Lung cancer is prevalent worldwide, with particular elevations in developing countries. In 2012, the International Agency for Research on Cancer estimated 1.8 million new lung cancer diagnoses worldwide. This translated into 12.9% of new manifestations of all cancers combined. One in 5 deaths from cancer is from lung cancer, making it the most common cause of death from cancer worldwide.[2] Reduced smoking leads to a decreased risk of contracting lung cancer; however, former and current smokers should be screened for lung cancer unless they have been smoke-free for 15 or more years.[3]

Using low-dose computed tomography screening to detect lung cancer at the earliest stages appears to be effective. A clinical trial funded by the National Cancer Institute demonstrated a 20% reduction in deaths from lung cancer among current or former heavy smokers who were screened with low-dose computed tomography vs chest radiographs. The American Cancer Society, the International Association for the Study of Lung Cancer, and the American Lung Association have endorsed low-dose computed tomography screening for lung cancer.[4] In February 2015, the Centers for Medicare & Medicaid Services added its support.[5] This progress in lung cancer detection is encouraging.

However, some health professionals show disrespect for patients who developed lung cancer after a history of smoking. Growing up in northern Kentucky, I never perceived smoking as a negative behavior. Many adults in my life smoked. In fact, smoking permeated the backdrop of my formative years, and I was smoking with friends by the time I was in high school. My public high school provided a smoking area that we used at lunch time, and we could purchase cigarettes legally. We did not attempt to hide our smoking from authority figures because it simply was not considered negative or wrong. Smoking also used to be common at work, and technologists and radiologists smoked in offices, the dark room areas, and the control rooms during patient examinations. It was light years ago with respect to what is accepted now.

What seemed to be a cool habit was very difficult to stop, and having 4 children provided the incentive for me to quit. Completing training as a radiologic technologist and interacting with patients being treated for lung cancer was another incentive. Even with this heightened awareness, some stressful events triggered occasional lapses. As a technologist who has struggled with

smoking, I believe it is important to treat all patients with respect, no matter how they became patients.

Radiologic technologists should be aware of how they respond to patients who are addicted to tobacco and other harmful substances. Whether the message is verbal or conveyed in a disapproving glance, smokers often are embarrassed and humiliated. The universal question that hangs in the air seems to be, "Why can't they stop?" There is no easy answer to this question because smoking is physically, psychologically, and emotionally addictive. For example, after my father's funeral, a close friend offered me a cigarette. I had not smoked in more than 5 years, but the cigarette felt familiar, like an old friend. It was calming and provided me a familiar way to feel normal and in control of the chaos I was feeling. I knew it was not the answer, but it provided me with comfort in that moment.

All health care professionals should be cognizant of their interactions with patients who are smokers. If smokers are embarrassed in the health care setting, they often are dishonest about how long or how much they smoke. Misinformation could result in incorrect decisions about diagnostic testing or a course of treatment once an illness is detected.

In 2015 more than 221 000 new cases of lung cancer were diagnosed in the United States and approximately 158 000 deaths were reported.[6,7] Radiologic technologists have the responsibility to be supportive, use every opportunity to educate patients to make healthy lifestyle choices, and provide for patients' emotional well-being. By the time patients receive treatment for smoking-related illnesses, they are frightened and well aware that they have contributed to their condition. Condescension, judgment, and shaming are not helpful. Health care professionals must support patients and work toward their healing. Radiologic technologists might consider examining their personal biases and becoming aware of how their words and actions contribute to the overall process of patient care.

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A Standardized Exposure Index for Digital Radiography

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Digital imaging technology has revolutionized radiology practice and has largely replaced film-screen radiography in the United States. Because of its wide dynamic range and exposure latitude, digital imaging offers advantages over film-screen radiography including reduced repeat images caused by underexposure or overexposure.[1] Digital radiography also can reduce patient dose because lower exposure factors can be used. However, if digital radiography equipment is not implemented and used properly, patients can receive excessive exposure.[1,2]

Technologists have an ethical and professional obligation to keep radiation exposure as low as reasonably achievable (ALARA) and use the lowest technical factors possible to obtain an optimal image.[3,4] However, exposure techniques used to acquire optimal digital images with minimal patient radiation dose differ from film-screen imaging techniques.[1] Depending on the vendor, digital units have varying acquisition technologies and might require different technical factors to obtain an optimal image for the same anatomical projection on the same patient. Some units have a higher absorption efficiency than others, which allows the use of lower technical factors.[5] To maintain the ALARA principle, technologists must know the appropriate exposure factors for each imaging system to produce images of optimal quality with minimal patient exposure.

The American Society of Radiologic Technologists radiography practice standards state that the radiographer must evaluate images for "optimal technical exposure factors."[4] While reviewing their images, technologists must determine whether proper technical factors were used. Unlike film-screen radiography, the technologist cannot determine whether a digital image was exposed properly by looking only at image quality. With film-screen equipment, an overexposed image is excessively dark, and an underexposed film is excessively bright. However, with digital radiography, incorrect exposure does not affect image qualities of brightness or density because computer processing automatically corrects image brightness. Therefore, it is possible to underexpose or overexpose the patient and the digital image receptor, and the system will correct the image brightness automatically.[1,2,5]

To see whether correct technical factors (ie, kilovoltage peak and milliampere seconds) were used, the radiologic technologist must check the exposure indicator value.[1,2,5] However, these values differ among the various equipment manufacturers (see **Table 1**).[1] More than 15 vendors have developed exposure indicators with different names. Some vendors use linear formulas, whereas others use logarithmic formulas. Some values increase as exposure increases, and some decrease as exposure increases (see **Tables 2-3**).[2,7] Because it is not unusual for a radiology department to have more than one vendor's equipment, these varying exposure indicators can cause confusion.[2]

In 2009, the American Association of Physicists in Medicine Task Group 116 developed a standard index

Table 1

Exposure Indicators

Manufacturer	EI Name	EI Symbol	Units	Exposure Dependence
Agfa	Log of median of histogram	LgM	bels	LgM + 0.3 = 2X
Alara CR	Exposure indicator value	EIV	mbels	EIV + 300 = 2X
Canon	Reached exposure value	REX	Unitless	Brightess = c1, contrast = c2, REX ∝ X (mR)
Canon	EXP	EXP	EXP = X	Acceptable range
Carestream (formerly Kodak)	Exposure index	EI	mbels	EI + 300 = 2X
Fujifilm	S value	S	Unitless	200/S X (mR)
General Electric	Uncompensated detector exposure	UDExp	μGy air kerma	UDExp ∝ X (μGy)
General Electric	Compensated detector exposure	CDExp	μGy air kerma	CDExp ∝ X (μGy)
General Electric	Detector exposure index	DEI	Unitless	DEI ≈ ratio of actual exposure to expected exposure scaled by technique, system parameters. Expected exposure can be edited by user.
Konica	Sensitivity number	S	Unitless	QR = k, 200/S ∝ X (mR)
Philips	Exposure index	EI	Unitless	1000/X (μGy)
Siemens	Exposure index	EI	μGy air kerma	X(μGy) = EI/100

Abbreviations: EI, exposure indicator; mbels, millibells; mGy, microgray; mR, milliroentgen.
Reprinted with permission from Herrmann TL, Fauber TL, Gill J, et al. Best practices in digital radiography [white paper]. http://www.asrt.org/docs/default-source/whitepapers/asrt12_bstpracdigradwhp_final.pdf. Published 2012. Accessed October 20, 2015.

parallel to the one completed in the International Electrotechnical Commission standard IEC 62494-1, which established common terminology to express radiation exposure to a digital detector. Use of the standardized exposure indicator is not required by law, but some vendors have begun to use it.[1,2,5,6]

The standardized exposure indicator uses the terms *exposure index* (EI), *target exposure index* (EI_T), and *deviation index* (DI).[2,6,7] EI indicates the amount of exposure to a specific area of the image receptor. The EI is determined by technical factors, computer processing (eg, region of interest, histogram analysis), patient factors, collimation, and positioning. It does not indicate patient dose because it measures radiation exiting the patient. However, if the radiation exposure to the image receptor is excessive, then the patient was exposed to unnecessary radiation.[2]

The EI_T is the ideal exposure that balances image quality and patient exposure for an image receptor.[2,6,7] If the exposure is below target, the image will have excessive mottle. If the exposure is above target, the patient will have been exposed to unnecessary radiation, a violation of ALARA. EI_T is determined by body part, projection, and image receptor sensitivity. Because the terminology is new, little information is available on EI_T values. Scientific methods to determine EI_T values objectively for common examinations should be established rather than having them subjectively determined by vendors and users.[6] Don et al suggest establishing a database or registry of appropriate EI_T values for specific examinations using digital systems.[6]

The DI is determined by the formula: $DI = 10 \times \log10(EI/EI_T)$. The DI measures how far the EI value differs from the projection-specific EI_T.[2,6,7] Therefore, the DI provides immediate feedback on the appropriateness of the selected technical factors. It shows how much above or below the actual exposure

Table 2

Selected Proprietary EIs and Vendor Recommendations[a]

Fuji S No.	Agfa LgM	Kodak/Carestream Exposure Index	Detector Exposure Estimate (mR)[a]	Action
> 1000	< 1.45	< 1250	< 0.20	Underexposed: repeat
601-1000	1.45-1.74	1250-1549	0.2-0.3	Underexposed: quality control exception
301-600	1.75-2.04	1550-1849	0.3-0.7	Underexposed: quality control review
150-300	2.05-2.35	1850-2150	0.7-1.3	Acceptable range
75-149	2.36-2.65	2151-2450	1.3-2.7	Overexposed: quality control review
50-74	2.66-2.95	2451-2750	2.7-4.0	Overexposed: quality control exception
< 50	> 2.95	> 2750	> 4.0	Overexposed: repeat if necessary

[a] *This column provides the range of detector exposures that each vendor's exposure indicator represents.*
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Table 3

Manufacturer, Corresponding Symbol for EI, and Calculated EI for 3 Incident Exposures to the Detector[a]

Manufacturer	Symbol	5 µGy	10 µGy	20 µGy
Canon (brightness = 16, contrast = 10)	REX	50	100	200
IDC (ST = 200)	F#	-1	0	1
Philips	EI	200	100	50
Fuji, Konica	S	400	200	100
Kodak/Carestream (CR, STD)	EI	1700	2000	2300
Siemens	EI	500	1000	2000

[a] *These are approximate relationships because of different calibration conditions for the various manufacturers.*
Reprinted with permission from Seibert JA, Morin RL. The standardized exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population. Pediatr Radiol. *2011;41(5):573-81. doi:10.1007/s00247-010-1954-6.*

is from the ideal. With an ideal exposure, the EI and EI_T will be equal and the DI will be zero. A positive DI means overexposure, and a negative DI means underexposure. A DI value of 1.0 equals a 26% increase in exposure, and a DI value of −1.0 equals a 20% decrease in exposure relative to the target. A DI value of 3.0 is equal to a doubling of the target exposure, whereas a DI value of −3.0 corresponds to a halving of the target exposure. One DI value is approximately equivalent to a single milliampere seconds step on a standard generator.[6] **Table 4** shows the relationship of DI values to the ideal exposure, or EI_T.[2] **Table 5** states the Association of Physicists in Medicine recommendations on how to use the DI for image quality control.[6]

Because many factors affect EI (eg, computer processing, collimation, positioning, and shielding), the DI for 2 images on the same patient with the same technical factors can vary. The technologist should not rely only on the DI and should visually evaluate the image for appropriate grayscale, detail saturation, and mottle. Images should not be repeated solely on the basis of a number.[1,2]

The DI, EI, kilovoltage peak, and milliampere seconds should be displayed with the image for review by the technologist and radiologist.[4] That information also should be retained as part of the data embedded in the Digital Imaging and Communications in Medicine header and used in a departmental quality assurance (QA) program.[1]

Table 4

Deviation Index Values With Percent of Change from the Target Exposure Index

Deviation Index		% Change From EI_T
Overexposure	+4	160
	+3	100
	+2	60
	+1	26
Optimal exposure −.5 to +.5	0	0
Underexposure	−1	−20
	−2	−40
	−3	−50
	−4	−60

Reprinted with permission from Image Gently. Back to basics: ten steps to help manage radiation dose in pediatric digital radiography. http://www.imagegently.org/Portals/6/Procedures/10%20Steps%20-%20Back%20to%20Basics%202-27-13.pptx. Accessed October 20, 2015.

Table 5

Exposure Indicator Deviation Index Control Limits for Clinical Images

Deviation Index	Range Action(s)
> +3.0	Excessive patient radiation exposure: Repeat only if relevant anatomy is clipped or "burned out." Require immediate management follow-up.
+1.0 to +3.0	Overexposure: Repeat only if relevant anatomy is clipped or "burned out."
−0.5 to +0.5	Target range
< −1.0	Underexposed: Consult radiologist for repeat.
< −3.0	Repeat.

Reprinted with permission from Shepard SJ, Wang J, Flynn M, et al. An exposure indicator for digital radiography: AAPM Task Group 116 [executive summary]. Med Phys. *2009;36(7):2898-2914.*

Although using a standardized exposure indicator should minimize confusion, it will have a much greater effect on optimizing patient radiation exposure when used with a QA program.[5,7] A QA program is necessary to minimize patient exposure and reduce exposure creep, which is likely to happen when a department converts to digital imaging.[2,7] The lower exposures possible with digital radiography produce noisy images with increased quantum mottle. Increased exposure reduces quantum mottle, and even exposing an image 5 to 10 times more than usual will create an image that appears properly exposed because of the digital detector's compensation.[7] To reduce quantum mottle, technologists might increase exposure settings, which increases patient exposure.[2,5] Lack of a feedback indicator, such as a DI, and a misunderstanding of what a vendor's exposure indicator means can lead to exposure creep and needless patient dose.[7]

Exposure creep is a serious problem with digital imaging. Don et al reported that up to 40% of digital radiographs obtained from one adult center were overexposed. In addition, 43% of radiographs in a pediatric center using computed radiography were found to be overexposed.[5] The authors suggested that facilities control and reverse exposure creep by recording and monitoring exposure indicators.[5] To reduce exposure creep, a QA program should include an analysis of the percentage of images that fall within and outside of an acceptable exposure range. The information should then be used to educate technologists so that patient exposure is decreased while image quality is improved.[5,7]

Exposure data including exposure indicators and technical factors used should be collected and reviewed routinely by management as part of a QA program.[8] Use of a standardized exposure indicator will make this process simpler and easier. Standardized exposure indicator terminology also could be used to establish national databases "to help provide diagnostic reference levels for radiology departments to compare their digital radiographic techniques."[5] The American College of Radiology has a dose index registry program for computed tomography, and a registry for digital radiography is under development.[5,7] Don et al indicated that diagnostic reference levels based on detector type, body part, and thickness can be developed from data collected in such a registry.[5]

Standardized terminology has been developed but has not been implemented fully. To realize its benefits, professional societies, vendors, and technologists must work together to improve consistency in using the common EI values provided by IEC 62494-1.[1] Consumers can insist on equipment that uses the new terminology

when purchasing equipment and request software updates for older units.[7] Technologists are obligated to be familiar with their equipment and its exposure indicators and evaluate images for proper exposure.[1,4] Use of standardized exposure indicator terminology will help technologists fulfill their professional and ethical obligations.

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Service Learning

Tina Griffith, BS, R.T.(R)(CT)
Kevin R Clark, EdD, R.T.(R)

As higher education institutions re-examine their commitment to service and community involvement, one emerging trend requires students to embrace community service projects as part of their learning experiences.[1] Service learning, also known as *experiential learning*, is an innovative teaching method that integrates community service with academic learning to enhance knowledge, teach civic engagement, and strengthen communities.[2,3] The service experience is integrated into a discipline-based academic course in which students complete written and verbal reflection activities about their insights, experiences, and benefits during the service learning opportunity.[4]

Collaborative efforts among the community or organization of interest, the academic institution, the course instructor, and the student are essential in a service learning project. The service organization has a need met while the academic institution builds a partnership with the organization and surrounding community. The instructor provides meaningful, often challenging, learning experiences, and the students interact with individuals from diverse and disadvantaged backgrounds.[3] For students, service learning improves critical-thinking and leadership skills and promotes civic engagement.[3,4]

Project Preparation

Organizing a service learning project is time consuming for an instructor, especially if the academic institution does not have a central office that assists with site placement, student orientation and debriefing, and logistical support.[4] Even without those resources, an instructor can implement a service learning project with careful planning and consideration. First, the instructor should structure the service around specific learning goals that address real community needs.[1-5] These goals should relate directly to course objectives. The instructor then must identify a service organization of interest where the students can accomplish these goals. Once an organization or community is identified, becoming familiar with the service setting, understanding the needs, and establishing a person of contact are important next steps.[4]

Next, the instructor must decide on a set of activities students will undertake to satisfy the project goals, course objectives, and needs of the organization.[4] Students could conduct research that serves an agency or organization or provide essential services to an organization's clients whether they be homeless, people dealing with domestic violence, children from single-parent homes, or immigrants adjusting to their new country.[4]

The instructor also must create written agreements listing the organization's responsibilities to the students including requirements for supervision and evaluation and descriptions of the work students will perform.[4] Some organizations might have existing volunteer contracts the instructor can use or modify for the project agreement. Other items to include in the agreement are start and end dates, number of hours students will spend in their placement, transportation and parking arrangements, orientation procedures, special

considerations (eg, background checks or tuberculosis screening), and transition and closure procedures.[4] In general, experienced faculty recommend a service commitment of 2 to 3 hours per week depending on the credit hours and student course load.[4]

Finally, the instructor must decide how to evaluate students when the project is complete. Central to service learning are thoughtful written reflections in which students relate their service engagement to the course content.[4] Instructors must decide whether the reflective pieces will include writing an essay, journaling in the learning management system, or submitting a discussion post and collaborating with peers. Ultimately, the instructor evaluates students' academic work in the service environment, not the service project itself. A grading rubric might include accuracy, thoroughness, thoughtfulness, originality, mechanics (ie, spelling, grammar, and punctuation), and range of issues addressed.[4] The instructor might choose to focus on students' acquisition of knowledge about the community, improvement in personal skills, self-discovery, or exploration of career options.[4] In addition, the instructor should check in with the organization's supervisor to discuss students' performance and suggestions for improvement.[4]

Students' Roles

The students should have clear expectations of what they will do throughout the service learning project. The instructor should address the concept of service learning and explain why it is part of the course so students are prepared to participate.[4] The students should be aware of the number of required service hours, service assignment descriptions, how they will integrate service learning with course content, and the evaluation criteria. In preparation for the service learning project, students should identify the skills they will bring to the organization.[4] This self-assessment builds students' confidence and identifies weaknesses they need to work on to be effective in the service environment.[4] The students also should be encouraged to keep a log or journal of service activities to use as a reference for writing their reflective pieces.[4]

Instructor's Role

In addition to preparing the service learning opportunity, the instructor has many responsibilities during implementation. It is crucial for the instructor to provide adequate guidance to students.[4] The amount of guidance needed depends on the students, the complexity of the activities, and the length of the service project.[4] The instructor should give students information that describes the scope and purpose of the project, organization and instructor expectations, activities, and deadlines.[4] Other instructor responsibilities include discussing academic integrity, keeping in contact with service organization supervisors, monitoring students' performance, providing time for students to discuss their service, and developing contingency plans as needed.[4]

Interdisciplinary Service Learning

Health care providers are expected to work in multidisciplinary teams to optimize patient and community health; however, many health professions students have limited exposure to each other during education and training.[5] For example, physicians and nurses work together daily, but their education is separate, and opportunities to interact during medical and nursing school are minimal.[5] A 2015 study provided health professions students the opportunity to work together in a service learning project under faculty supervision.[5] Dental, dental hygiene, medical, and nursing students worked as interdisciplinary teams to develop health and wellness plans for transitional homeless families.[5] Presurvey and postsurvey data measured changes in the participants' perceptions of working in interdisciplinary teams, and a focus group session identified strengths and weaknesses of the service learning project.[5]

Results revealed positive predispositions among the participants, and after completing the service learning project, substantial improvements were seen in student confidence with respect to being part of a multidisciplinary team and understanding the training requirements of different health care professionals.[5] This study suggested that interdisciplinary education and community service learning was a powerful combination for demonstrating the value of clinical teamwork to health professions students.[5] Similar studies involving radiography and other allied health professions students are warranted.

Conclusion

Service learning is an instructional approach that emphasizes academic work and community service equally. With regard to radiography curricula, a service learning project could be implemented in a patient care or introductory research course, and the objectives and goals could be achieved easily. Providing students with hands-on service experience in the community can enhance the quality of a teacher's instruction. Service learning also can improve students' critical-thinking and leadership skills while promoting civic engagement. These actions work together to strengthen community partnerships between the service organization, the academic institution, the instructor, and the students.

To learn more about alternate ways to encourage civic engagement in students, visit asrt.org/as.rt?9MlcsT.

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Publishing Columns in *Radiologic Technology*

Ben D Wood, MSRS, R.T.(R)
Daniel N DeMaio, MEd, R.T.(R)(CT)

Do you have an interesting idea you would like to share with other imaging professionals? Perhaps you have considered submitting an article for publication but are intimidated by the peer-review process. You are not alone in feeling that trepidation, but there is good news: Every issue of *Radiologic Technology* includes columns that are not subject to peer review. The columns vary in scope and length, and they all are excellent avenues for first-time and experienced authors to publish and add to the body of knowledge for our profession (see **Table**). Presenting your idea or work experience in a column is a great way to share expertise and improve outcomes for many more patients. You can publish, and we'll show you how.

Work Experience

Case Summary, In the Clinic, and Technical Query columns present practical clinical information by sharing solutions to technical problems and case studies. For example, you might have adapted positioning skills originally learned from a textbook or developed shortcuts that increase efficiency. Your summary of such an adaptation would make an excellent In the Clinic column, and when your idea is showcased in print, technologists everywhere will benefit. You also might recall that case summaries were an important part of your education as a radiologic science student. Preparing a patient's case summary might be the easiest way to publish your first article. Most importantly, case summaries make a significant contribution to your profession, and learning more about a case and sharing that information with others in the medical imaging or radiation therapy professions is rewarding.

Often, the most difficult part of writing a Case Summary column is choosing the right study. Ask yourself:

- Would this case be of interest to other readers?
- Did the case require modification from the typical procedure?
- Did the case require critical analysis on the part of a technologist?
- Was this case unusual, rare, or does it demonstrate an emerging problem?
- Did the case result in a change in clinical practice?

If you have answered yes to any of these questions, you probably have a suitable case to write about and submit for publication.

Another popular area for a first attempt at publication is to write about an aspect of practice that is useful in your work environment such as a new or innovative positioning technique that is not in textbooks. Perhaps you have encountered a technical problem or image quality problem and successfully solved it. Writing a Technical Query column is an ideal way to share this valuable information so others can implement it in their work. All 3 of these columns offer the perfect introduction to publishing and allow you to share your technical

Table

ASRT Journal Columns

Column Name	Description	Word Count	Example
Advances in Technology	Presents new radiologic science technology and equipment	600-2000	Description of new treatment equipment and how it is used in the clinic
Bookshelf	Briefly reviews new medical imaging and radiation therapy texts	300-500	A review of *The Physics & Technology of Radiation Therapy*
Case Summary	Presents an unusual or challenging patient case or imaging assignment	1000-2000	Special techniques for imaging the augmented breast
Focus on Safety	Provides current information regarding quality and safety in the radiologic sciences	600-2000	Proper technique for lifting patients
Global Outlook	Reports on education and practice of radiologic technology in other nations	600-2000	Advanced practice for radiologic technologists in England
In the Clinic	Provides practical technical information for on-the-job use	600-3500	A new or unusual positioning technique
Management Toolbox	Focuses on practical issues concerning department management and professional growth	600-3500	Factors to consider when redesigning a department
My Perspective	Provides a personal opinion on a topic related to or experience in medical imaging or radiation therapy	600-1500	Advice for new technologists entering the profession
Patient Care	Provides tips on caring for patients including effective communication strategies	600-1500	The importance of considering patients' emotional needs
Practice Fundamentals	Reviews basic practices and procedures to refresh technologists' skills	300-500	Creating a technique chart
Professional Review	Summarizes existing knowledge regarding a specific disease or addresses an issue of concern to the radiologic science profession as a whole	600-2000	Discussion of alternative medicine and radiation therapy practice
Setup Solutions	Discusses innovative solutions to patient setup or patient care problems encountered in the radiology department	600-2000	Unique immobilization device used for a complicated imaging or treatment setup
Teaching Techniques	Focuses on teaching and learning in the radiologic sciences	600-3500	Innovative teaching strategies
Technical Query	Covers troubleshooting image acquisition and processing	300-500	The cause of a halo effect on a radiograph and how it was corrected

expertise directly with colleagues nationally and internationally.

Administration and Teaching

Managers, administrators, and educators publish often in *Radiologic Technology*. You can join their ranks by writing about your experiences for the Management Toolbox or Teaching Techniques columns. Maybe you have successfully navigated a complicated personnel issue or implemented a quality management process that yielded positive results in your department's outcomes. Publishing your idea as a Management Toolbox column in the journal shares the information with many others, increasing its effect on professionals and patients. Educators constantly seek new tools, techniques, and pedagogical approaches to improve student learning. The Teaching Techniques column has long served as a storehouse of the latest information on innovative educational

tools and techniques. Share your educational expertise and innovative teaching strategies in the journal so that many more instructors and students can benefit.

Staying Current

From a review of basic concepts learned in school to the latest information on the most advanced new technology, Practice Fundamentals, Advances in Technology, and Professional Review columns offer a great deal of flexibility. Many technologists can benefit from a refresher of what they learned in their medical imaging or radiation therapy program. The Practice Fundamentals column is a great place to share your knowledge of a fundamental concept or procedure. In addition, if you are an educator, you might consider making writing a Practice Fundamentals column an assignment for your students as a way for them to demonstrate knowledge and learn about academic publishing. Conversely, an Advances in Technology column can provide a valuable update on the latest state-of-the-art equipment or practices in our profession. A detailed review of a current topic in the radiologic sciences also can serve as an interesting subject for discussion in a Professional Review column. The range of subject matter for these columns is nearly endless, and you are a subject matter expert.

Caring for Patients

We all are aware of the increased focus on patient care and safety in today's health care environment. Your colleagues can learn from your experiences with safety programs, innovative techniques, and other initiatives designed to optimize the services patients receive under your care. By writing a Focus on Safety, Patient Care, or Setup Solutions column, you can share your experience implementing a patient safety initiative within your institution or review an empirically supported technique that enhances patient care in the radiologic sciences. Knowing that your success could result in positive outcomes for a much larger number of patients is tremendously rewarding.

Fresh Perspectives

Global Outlook and My Perspective columns offer you the opportunity to share opinions and worldviews on topics that touch the lives and influence the practice of radiologic science professionals. Through Global Outlook, your global expertise or personal experience in the radiologic sciences outside the United States can provide a healthy dose of perspective and be quite informative. Moreover, your opinion in a My Perspective column might resonate with readers and help them feel that they are not alone in facing the challenges of working in the radiologic technology profession.

Getting Started

Sometimes the hardest step toward publishing is the first one: getting started. If you have an idea that you think is valuable and want to explore its potential for publication, start by discussing it with your peers. Determine whether others think the subject is interesting and might be suitable for publication. In addition, you can get in touch with a member of the *Radiologic Technology* Editorial Review Board, whose contact information is found near the front of every issue. We would love to hear from you and discuss your idea for publication. You will find a great deal of support from the Editorial Review Board members and from the *Radiologic Technology* editorial staff, who are available to discuss your topic, answer questions, and offer advice (see **Box**).

The next step is to find time in your busy schedule. Although allocating large blocks of time to sit down and focus on writing your article might sound like the best approach, your hectic professional and personal life might not allow for this luxury. Instead, you might find it easier to write in small chunks, coming back to your article routinely to add to it, revise, and edit. Even with writing sessions lasting 15 to 20 minutes, an article can

Box

ASRT Writer's Resources

To learn more about how to write and submit your first manuscript to *Radiologic Technology*:

- Visit asrt.org/authorguide.
- Contact Lisa Ragsdale, managing editor for *Radiologic Technology,* at lragsdale@asrt.org or by phone at 800-444-2778, Ext. 1250.
- Join the ASRT Writers Community at asrt.org/myasrt.

come together easily as long as you are consistent. Once submitted, the editorial staff is eager and willing to help revise the work and polish it for publication.

With each issue of *Radiologic Technology*, many of your colleagues demonstrate that it is possible to become a published author, even in the midst of a busy career in the radiologic sciences. With just a little perseverance and determination, your idea can blossom into a timely and informative column that helps educate our peers and improve medical imaging or radiation therapy services to patients everywhere. Get started today!

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Year One: Transitioning From Student to Staff Technologist

Sebastian Ramirez, BS, R.T.(R)

The last month of my radiologic technology program was a roller coaster ride. One week, I was a second-year student who had all my competencies completed and could run an x-ray room by myself. The next week, I was filling out a tedious online application and worried about job competition. When I attended my graduation ceremony, I felt confident and proud. Next, I felt the pressure of taking my American Registry of Radiologic Technologists examination, although the anxiety quickly lifted once I passed. After that was the interview; I prepared for every question I could think of but still doubted myself. Finally, I was offered a position and started work as a per diem technologist for a big city hospital.

I thought my confidence as a student would carry over to my professional employment, but when I began working with my first patient, everything I learned in school seemed to escape me. Suddenly, I realized I was responsible for everything: the patient's safety, sending the image to the picture archiving and communications system, transporting the patient back to his or her room, completing the study, and getting the next patient. The independence I craved as a student came with the realization that the "I'm a student" safety net was gone. I had to run a C-arm without direct supervision and navigate a big hospital alone. In addition, I was the newest and youngest member of the radiology team, a 22-year-old new hire. Sometimes new employees are treated more harshly because they are new to the organization or just entering the workforce. Although we often go to great lengths to care for patients, some hospital staff are not always tolerant of inexperienced workers. I love being a technologist, but there is a lot to learn and take in when you first begin to work. There are many different people and personalities in a large hospital setting. Unsure of how to manage it all, I had to remain steadfast and determined.

Finding My Way and My Place

Initially, it was simply a matter of "practice makes perfect." The more I worked and the more studies I performed, the better technologist I became. The less I complained, the less stress I felt. I performed any examination, worked any shift, and trained in any department possible. I was happy to have a job in a field with stiff competition, and I realized I had to act like it.

I was an important member of a health care team. I helped everyone I could and learned as much as I could from them. I learned that people give you respect when you show you are willing to help others. So I helped a nurse move her patient, helped the front desk person answer phones, and helped environmental services staff restock the linen closet. By showing I was capable of handling the hospital environment, I gained respect from my peers and confidence in myself.

After 2 months of employment, I felt in control of things. With time and dedication, work was easier, and I felt less like a student. I worried less about making

errors as performing studies became second nature. Just as it became easier for me, it will become easier for the next generation of graduating students.

Advice for the Graduating Student

Remember that patients are not "textbook." This was the best piece of wisdom I received from my former program director. Every patient is an individual, and because of this you cannot predict the ease of a study. When you have a patient in the x-ray room, take your time. Efficiency is important, but that includes getting the study right. Going too fast increases the chance for error.

Train in every department with every machine. Become a "go-to" technologist your team can rely on. Furthermore, become an expert in one thing that no one else knows, so you can help when needed. Our education in digital equipment, digital processing, and computer science prepares us for emerging trends in the imaging profession.

Retain as much knowledge as possible from school so you can better teach students you might instruct in the clinical setting. Within my first month of employment, I was teaching second-year students. Your students will probably ask about the radiation physics that you thought you would never use again, so pay attention. Remember that establishing credibility with your students is just as important as establishing credibility with your coworkers. You are, after all, educating the next generation of technologists.

Transitioning into a professional technologist can be overwhelming, but functioning on your own and finding your place at work is worth the challenge. Every day brings new opportunities to learn. The initial transition will change you, but you will never stop growing. That, in itself, is one of the most exciting parts of beginning a career. As long as you commit to overcoming the challenge, you can shake off that "student" feeling and find the rewarding feeling of being a full-fledged technologist.

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Off-Level Grid Use Error

Thomas G Sandridge, MS, MEd, R.T.(R)

Radiographic grids are necessary to intercept scattered radiation emerging from a radiographed object. Excess scatter reaching the image receptor results in an impaired level of visible image contrast as it contributes no useful information to the resulting image. The use of a radiographic grid is necessary whenever the anatomy of interest is thicker than 10 cm or if a kilovoltage peak above 60 is used.[1,2]

A 55-year-old man presented to the trauma center complaining of right distal extremity pain following a construction site accident. After physical examination, the physician ordered several studies including a mobile forearm radiograph, which was performed in the trauma bay.

Scatter is minimal when imaging distal extremities because of their relatively small thickness and lower kilovoltage peak settings. Therefore, the amount of scattered radiation produced typically does not warrant the use of a radiographic grid. In this case, the technologist elected to use a linear focused grid while performing anteroposterior and cross-table lateral projections. The technologist used exposure factors of 60 kVp and 12 mAs with a computed radiography image receptor. Although proper technique was used, taking into consideration the use of a grid, the image appeared light and underpenetrated (see **Figure 1**). An exposure index number of 1572 was calculated, which is within the appropriate range for the facility.

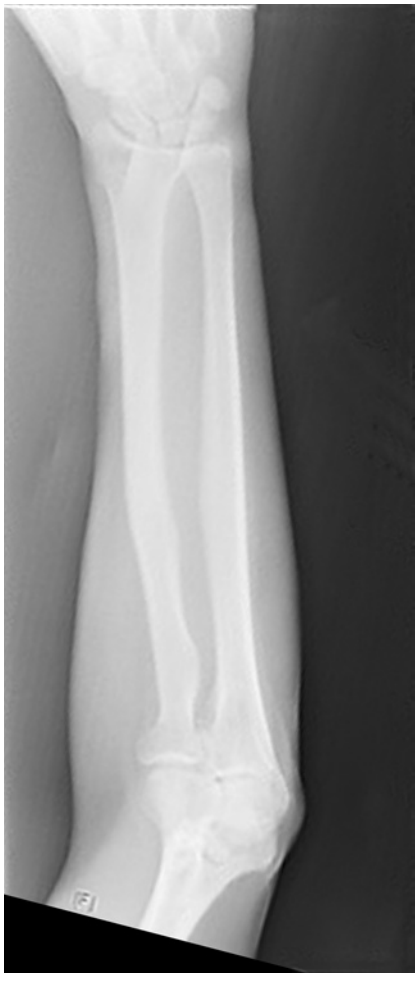

Figure 1. *Portable radiograph of the patient's right forearm obtained using a radiographic grid. Notice the loss of image detail due to an off-level grid error. Image courtesy of the author.*

Image Interpretation

The radiologist report stated, "Details of the exam limited due to underpenetration." Upon closer inspection of the image, grid lines were visible with pronounced grid cutoff. Grid cutoff results from improper alignment of the grid and central ray. Whenever primary beam photons are directed across the grid lead strips, excess absorption will occur, resulting in a uniform loss of image resolution and diagnostic quality.[1,2] Incidentally, some grid damage also is visible in the image (see **Figure 2**).

A subsequent exposure made without a radiographic grid clearly demonstrates a nondisplaced fracture of the distal radius with extension into the radiocarpal joint (see **Figure 3**). This fracture is barely visible on the first image and could have been missed by the radiologist.

Whenever radiographic grids are used, it is essential to ensure proper alignment of the grid and central ray to avoid off-level grid cut-off. The proper alignment of the body part and grid is achieved when both objects are parallel. In some cases, creative approaches are necessary to ensure proper part and grid alignment. In this case, the grid was not level, resulting in the loss of image detail.

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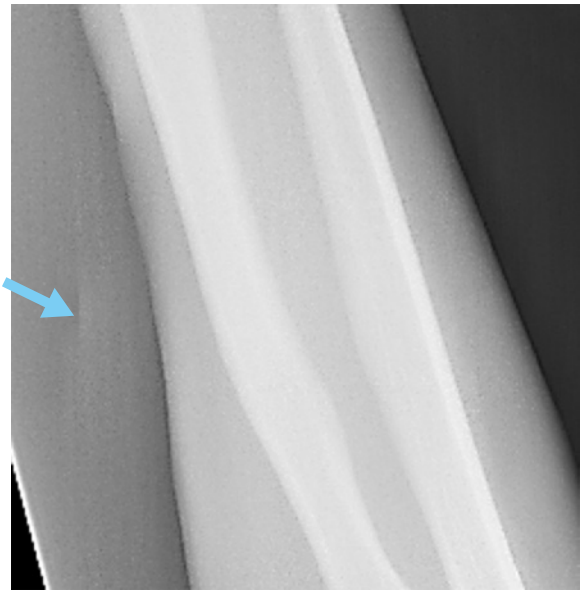

Figure 2. *Magnified image demonstrating an area of grid damage. Note the prominence of grid lines across the image indicating previous grid damage (arrow). Image courtesy of the author.*

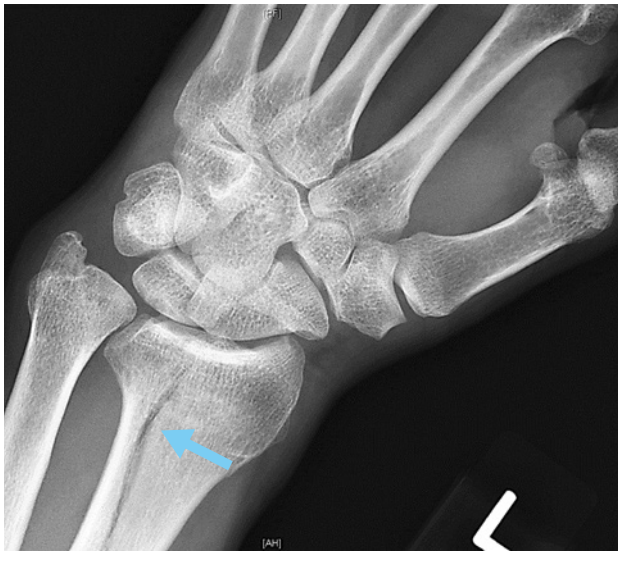

Figure 3. *A subsequent exposure made without a radiographic grid demonstrates a distal radial fracture (arrow) not visualized in the original mobile study. Image courtesy of the author.*

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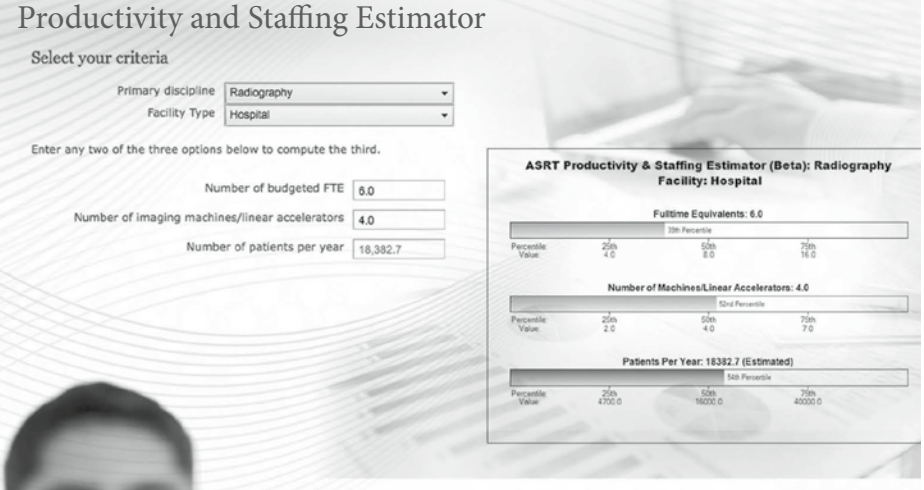

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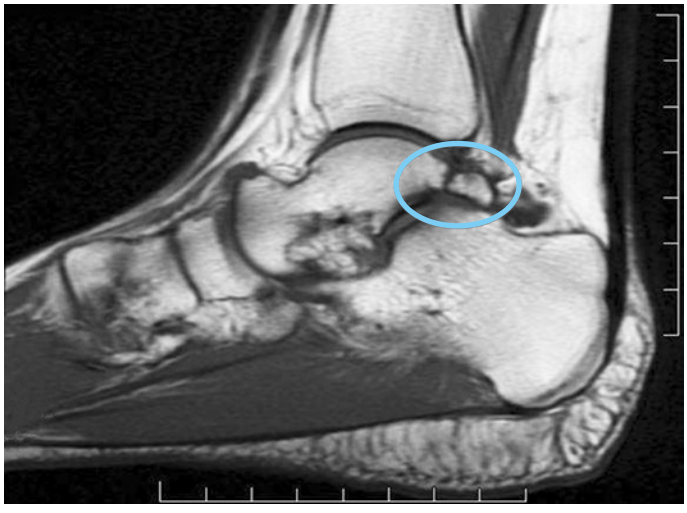
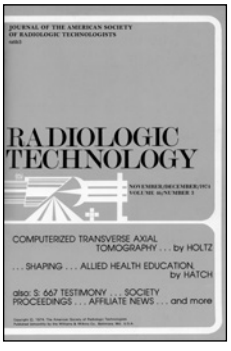


The talus bone is one of several bones forming the ankle joint and allows the ankle's upward and downward motion. A 36-year-old woman presented with pain in her ankle similar to a severe sprain. Initially diagnosed as a tendon tear, the patient proceeded with physical therapy but received little relief. A magnetic resonance image taken 4 years later revealed a talus bone fragment floating in her foot (oval) and surrounded by inflamed tissue. Because the fracture was displaced and could not be treated with a cast, the patient underwent surgery to remove the fragment. Image courtesy of Laura Mueller.

Archive



Computerized Transverse Axial Tomography in Brain Disease: A New Challenge for Technologists. *Radiologic Technology*, November/December, 1974.

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