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* Pena. BCVI 2011

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ON THE COVER

“Stormy Cerebral,” a painting by Lizzy Rainey, R.T.(R), of Lafayette, Indiana, is the first cover of Radiologic Technology’s 86th volume year. This piece depicts the vessels of the brain from a cerebral angiogram reimagined as the kinked trunk of an old tree. Illustrated “in a tempestuous expression of color,” the painting demonstrates the brain’s vessels tangled and blowing sideways, “creating a pattern of branches bent by the wind on a stormy day.”
On a certain level, publishing in a journal such as *Radiologic Technology* is all about sharing. This issue shares research findings about the gluten content of barium sulfate suspensions used by patients who have celiac disease and a continuing education article about caring for patients with spinal cord injuries, to name 2 examples.

As we begin the journal’s 86th volume year, it also is time to share a new collection of cover artwork by Lizzy Rainey, R.T.(R), of Lafayette, Indiana. Each inspired by a radiologic image, Rainey’s acrylic on canvas paintings transform anatomical features into tangled branches, gnarled tree trunks, and a cluster of snow-white birch trees. The seasonally inspired anatomy landscapes artfully combine the distinctive shapes of radiologic imagery with the dynamic forms of trees in nature.

Rainey, who has been a radiologic technologist for 33 years, finds artistic inspiration in her work as an R.T. “While I am at work seeing images of bones and the patterns of the human body, I can see similar patterns in the nature of our created world,” Rainey said. “It is just enjoyable for me to bring them together on canvas.”

A self-taught artist with a lifelong interest in art, Rainey began focusing more closely on her artwork in 2004. Her work first graced the cover of the journal in 2008, when her painting was selected as a winner in the first *Radiologic Technology* Cover Art Contest. After that, her series of anatomy landscapes appeared on the cover of *Radiologic Technology*’s 83rd volume year. Since then, Rainey has created paintings for clinics, hospitals, and doctors nationwide.

More than 5 years have passed since Rainey submitted her winning entry to that first *Radiologic Technology* Cover Art Contest, and now it is time, once again, for you to share your creative vision.

Between now and December 31, 2014, we encourage you to enter a piece of artwork inspired by medical imaging or radiation therapy for the chance to be featured on a future cover of *Radiologic Technology*. Six winners will receive $500 and a free one-year membership to the American Society of Radiologic Technologists.

You can upload your original artwork online at http://www.asrt.org/covercontest or e-mail your submission to covercontest@asrt.org. The winning artwork will appear on the covers of *Radiologic Technology*’s 87th volume year in 2015 and 2016.

In the meantime, we hope you enjoy each of Rainey’s volume 86 covers, as well as the content inside.

Alicia Kellogg, MA, ELS, has 10 years of publication editing experience and serves as managing editor of *Radiologic Technology*.

Gluten Content of Barium Sulfate Suspensions Used for Barium Swallows in Patients With Celiac Disease

Jennifer G Chiu, EdD, MBA, R.T.(R)  
Yoona Shin, PharmD  
Priti N Patel, PharmD, BCPS  
Robert A Mangione, EdD, RPh

**Purpose** To determine the availability and accuracy of information provided by hospitals, imaging centers, and manufacturers regarding gluten in barium sulfate suspensions.

**Methods** A total of 105 facilities were contacted via telephone to determine the gluten content of the contrast media used in those facilities. Manufacturers were contacted and their Web sites reviewed to determine the gluten content of their barium products.

**Results** Thirty-nine percent of the hospitals and 52% of the imaging centers were not aware of the gluten content of the contrast media they used. Twenty-nine-and-a-half percent of the respondents provided the correct gluten content. The manufacturers noted that 5 products were tested and confirmed gluten free, 1 product was not tested but described as gluten free, 1 product’s gluten content depended upon its flavor, and 1 product was reported to contain gluten.

**Discussion** Clinicians caring for patients with celiac disease or patients who choose to restrict their gluten consumption must ensure that the barium sulfate suspension ingested is gluten free.

**Conclusion** It can be difficult to determine the gluten content of barium sulfate, as a majority of radiology departments and imaging centers did not know whether the product they use is gluten free. Educating staff members and improving product labeling would benefit the quality of care provided to patients with celiac disease.

Celiac disease is a chronic autoimmune disorder that affects an estimated 1% of the U.S. population. The disease also is known as a hidden epidemic because an estimated 97% of affected patients have symptoms that have not been diagnosed as celiac disease. Patients with celiac disease have a genetic intolerance to gluten, a storage protein found in wheat, barley, and rye. When these patients ingest gluten, a wide range of clinical manifestations can appear, including gastrointestinal problems, vitamin and nutritional deficiencies caused by malabsorption, systemic inflammatory reactions and other autoimmune diseases, serious forms of cancer, and other maladies. Patients with celiac disease must maintain a strict lifelong gluten-free diet and avoid ingesting gluten found in nonfood items such as medicines, vitamins, and lip balms.

As little as 10 mg to 50 mg of gluten per day can be enough to cause damage to the intestinal mucosa. It is difficult to conceptualize what 10 mg of gluten looks like because it is such a small amount; however, it is estimated that this quantity would be approximately the size of 1/100 of a peanut. Although the goal of following a gluten-free lifestyle is to avoid ingesting all gluten, even strict diet-adherent patients with celiac disease occasionally unknowingly ingest gluten from overlooked or gluten-contaminated sources. Because of the potential cumulative effect on these patients, all known sources of gluten, even in small or trace amounts, must be avoided at all times.

Barium studies play a major role in the evaluation of patients with known or suspected gastroesophageal reflux disease (GERD), a common complication of celiac disease. The barium examination requires the patient to ingest a contrast agent called barium sulfate. The barium sulfate enables visualization of the esophagus and gastric structures that aid in diagnosis. Barium that contains gluten, even in small amounts, can adversely affect the health of a patient with celiac disease.
Several challenges might be encountered when caring for patients with celiac disease. Drug product manufacturers are not required to include gluten content on labels of contrast agents, making it difficult to assess their gluten content. As a result, the labels often do not provide sufficient information to determine whether products are gluten free.7,8 Patients and members of the health care team might not recognize that the manufacturing process and inactive ingredients included in barium contrast can alter its gluten content. Although patients with celiac disease can contact the manufacturer regarding the gluten content prior to ingestion, the health care team should assist patients with these inquiries.

Literature Review

Gastrointestinal symptoms and complications of celiac disease include diarrhea, flatulence, pain, bloating, and GERD. It has been suggested that changes in gastric motility associated with celiac disease increase the tendency for patients with this disease to develop heartburn—the most commonly reported symptom of GERD—because the stomach does not properly empty, and its contents tend to reflux back into the esophagus.7 Although the precise incidence of GERD in celiac disease remains to be established, researchers recently concluded in a study of 133 patients that GERD symptoms are common in classically symptomatic untreated patients with celiac disease.9 Although the study involved a relatively small number of patients and additional study is needed, the authors anticipate their results will lead clinicians to reconsider the relationship between heartburn, acid regurgitation, and celiac disease.10

Barium studies play a major role in the evaluation of patients with known or suspected GERD. In the past, single-contrast barium studies were the primary method for evaluating evidence of GERD and detecting complications such as ulceration and strictures. However, the use of double-contrast radiographic techniques allows for greater radiographic detail while evaluating the esophageal mucosa.11 Superficial ulcerations and mild esophagitis present in patients prior to the development of ulceration and strictures are detectable on double-contrast studies.9 Double-contrast esophagography is useful for determining the need for further evaluation with endoscopy and biopsy.

The barium swallow is a dynamic imaging study used to evaluate the oral and pharyngeal function by use of double-contrast spot images in frontal and lateral projections.11 Spot images allow for evaluation of abnormalities in the pharynx and esophagus. This procedure is commonly used to determine the cause of dysphagia, abdominal pain, blood-stained vomit, or unexplained weight loss.12,13 After the patient swallows a barium sulfate suspension, a radiologic technologist obtains single images, a series of radiographic images, or performs fluoroscopy.13 Some of the disease states for which the barium swallow is used as a diagnostic measure include hiatal hernia, diverticulitis, strictures, polyps, esophageal varices, muscle disorders, achalasia, GERD, ulcers, and cancers of the head, neck, pharynx, and esophagus.14 Barium swallows also can show inflammation or changes in the lining of the upper gastrointestinal tract that might explain the poor absorption of food, which might be caused by Crohn disease or celiac disease.15 Patients with celiac disease presenting with GERD symptoms also might be referred for a barium swallow study. When used to assess GERD, the boluses of ingested barium are administered and evaluated under fluoroscopy to assess esophageal motility.7

When a barium swallow is required for patients with celiac disease, those patients must know the gluten content of the barium sulfate used.15 Barium sulfate is a radiopaque contrast media used to clearly delineate the gastrointestinal tract during radiography examinations, fluoroscopy, or computed tomography (CT) scans.16,17 It is available as a tablet, powder, or an enema solution.17 The dry white chalky metallic powder is mixed with water to create a milkshake-like drink.18 Although often flavored, it still has an unpleasant taste.19 Barium sulfate absorbs x-ray beams and appears white on radiographs.18 When swallowed, it coats the esophagus, stomach, and intestines so diseased areas are visualized more clearly.19

Even minimal amounts of gluten (10-50 mg/day) can damage the small intestinal mucosa of patients with celiac disease.2,4 Therefore, the gluten content of the barium sulfate used in imaging these patients should be confirmed by the radiology department and imaging centers, the manufacturers, or both before patients ingest it. Technologists also should assist patients who have celiac disease with their inquiries. Questions about gluten
content in barium sulfate likely will increase as the number of patients diagnosed with celiac disease rises.

Methods

A comprehensive list of hospitals and imaging centers was obtained from the U.S. Food and Drug Administration (FDA) certified mammography facilities database. The mammography FDA database was the only comprehensive public database that included both hospitals and imaging centers in the study population. The database was filtered to include only hospitals and offices located in the 5 boroughs of New York City (the study population). Furthermore, all dedicated mammography and breast centers were omitted. Using the contact information provided on the list, all remaining hospitals and imaging centers were contacted by phone. A uniform script was used for the inquiry. The responses provided were recorded, and information was categorized into the following 5 groups:

1. Title of the person providing the information.
2. Whether the facility performed barium swallow studies.
3. Brand name of the contrast agent used for the studies.
4. Contrast agent manufacturer’s name.
5. Whether the contrast agent contains gluten.

The manufacturers of the products were then contacted regarding the gluten content of their products. For Covidien Pharmaceuticals (now called Covidien) and GE Healthcare, the contact information was obtained via their Web sites. For E-Z-EM Inc, the contact information was found on the product label. (The E-Z-EM products involved in this research were manufactured by E-Z-EM Canada Inc, a subsidiary of E-Z-EM Inc.)

All 3 companies were contacted by telephone and asked about the gluten content of their products using a uniform script. The responses provided were recorded, and information was categorized into the following 4 groups:

1. Name of the person receiving the call.
2. Time spent on the phone.
3. Time required for a response.
4. Gluten status of the product.

All manufacturers were asked to provide written documentation of their products’ gluten status.

The manufacturers’ Web sites were further reviewed for other relevant information. Responses regarding gluten content were categorized into 4 groups:

1. Gluten free.
2. Gluten free, but not tested.
3. Gluten status depends on the flavor of the suspension.
4. Product contains gluten.

Results

A total of 105 facilities (44 hospitals and 61 diagnostic imaging centers) were contacted within the New York metropolitan region. Eighty-two percent of the hospitals contacted performed the barium swallow study, 11% did not, 4% did not return messages, and 1 hospital had closed. Of the 36 hospitals that perform the barium swallow examination, 39% were not sure whether the product they use contains gluten, 58% stated that the product they use does not contain gluten, and 3% were unable to answer the question and advised the caller to contact the primary care physician. Two hospitals verified the information with their pharmacy, 1 responded that the product was gluten free, and the other replied that all were gluten free except for the vanilla smoothie flavor. Most of the responses provided were communicated after responders reviewed the product packaging.

Sixty-one percent of the imaging centers contacted do not perform the barium swallow examination, 38% do, and 1 was unreachable. Of the imaging centers that conduct the examination, 52% were unsure whether the barium sulfate used contains gluten, 44% reported that the product they use is gluten free, and 4% stated that a contrast agent is not used. Table 1 demonstrates both hospital and imaging center responses regarding the gluten content of the contrast agent used at the facility.

All facilities using a contrast agent reported using barium or a barium sulfate suspension. Three manufacturers—Covidien Pharmaceuticals, GE Healthcare, and E-Z-EM Inc—were contacted. The first 2 companies reported using gluten-free barium sulfate suspensions; the third reported stocking gluten-free barium sulfate suspensions and barium sulfate suspensions containing gluten. None of the manufacturers’ Web sites had definitive information about the gluten content of their products. However, Covidien Pharmaceuticals and GE
Vanilla Smoothie 7550 and 7650) contained a small amount (0.1%) of caramel color that might contain gluten. When manufacturers were asked to provide the gluten content information in writing, 2 of the 3 were unable to send this information. It was difficult for Covidien Pharmaceuticals to send written documentation because the product had been discontinued for 2 years. However, the company mentioned the availability of the material safety data sheet and package insert online. GE Healthcare also referred to its material safety data sheet and package insert online. E-Z-EM did not have information online but sent the package insert and written documentation for the gluten content of its products via e-mail.

After reviewing the manufacturers’ confirmation of the gluten content in their products, the researchers found that 29.5% of responses received from the radiology departments and imaging centers contained the correct information about the gluten content of the barium sulfate suspensions they use. Three responses regarding the gluten content were incorrect, and 19 respondents stated they did not know the gluten content of the product. In fact, 21 respondents did not know which brand of barium sulfate suspension they used; either no information was provided or only the manufacturers’ name was provided. Of the 8 products studied, the manufacturers confirmed that 5 were tested to be gluten free, 1 was not tested, but the manufacturer stated that no barley, wheat, oats, or spelt was used in the formulation of that product. Two products had gluten content depending on the flavor of the suspension. E-Z-EM reported that its barium suspensions with vanilla flavoring (Maxibar L150, Liquid PolibarPlus L168 and P650PPS, and Readi-CAT/2

Limitations
This study was limited to hospitals and imaging centers that were certified mammography facilities and might not represent all hospitals and imaging centers in

Table 1

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<th>Facility Type</th>
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<th>Unsure Whether Contrast Contains Gluten (No. of Responses)</th>
<th>Products Do Not Contain Gluten (No. of Responses)</th>
<th>Contact Primary Care Physician (No. of Responses)</th>
<th>Contrast Is Not Used (No. of Responses)</th>
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the sample population. Although a variety of hospitals and imaging locations were included in the study, the relevance of the results obtained is limited to facilities with similar demographics. In addition, the study population was narrow and limited to the 5 boroughs of New York City.

**Discussion**

Although information concerning the gluten content of barium sulfate was easily obtained from manufacturers, it was not as easy to obtain the information from the radiology departments of hospitals and imaging centers. The brand name or manufacturer name of the barium sulfate product used was not provided by the radiology departments unless it was specifically requested, which often required multiple transfers to different individuals and many responses that required return calls. Therefore, it took a substantial amount of time to receive the requested information from the radiology departments, which would make this process inconvenient for inquiring patients and could result in patients' frustration and dissatisfaction. Educating radiologic technologists about the importance of knowing the brand name and gluten content of barium sulfate suspensions used in the department will enhance their potential to assist patients who want to avoid ingesting gluten. Having this information can help patients make important health care decisions, as well as increase their satisfaction.

**Conclusion**

Patients with celiac disease must exercise caution whenever ingesting a substance that might contain gluten, including medications, nonprescription drugs, and vitamins, and should be advised not to ingest any
Gluten Content of Barium Sulfate Suspensions

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References


Dense Breast Notification: Anatomy, Imaging, and Patient Awareness

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**Purpose** To review the current literature pertaining to dense breast anatomy, imaging considerations, and patient notification laws.

**Methods** The literature for this review was obtained by searching for peer-reviewed articles about breast density and breast density notification for the years 2009 to 2012 using Google Scholar.

**Results** The research regarding dense breast anatomy, imaging options related to dense breasts, and notification laws yields important considerations for patients, physicians, and imaging science professionals performing the procedures.

**Discussion** Dense breast anatomy can hinder the accuracy of screening mammography. Breast density notification laws inform patients about the density level of their breasts and introduce them to additional imaging options. The laws raise questions about whether notification is necessary and beneficial or whether it leads to increased radiation exposure, health care costs, and stress to the patient.

**Conclusion** Dense breast notification laws serve to inform patients about their anatomy and provide them with the knowledge to make informed health care decisions.

It has been suggested that women aged 40 years and older should undergo yearly mammograms. Mammograms detect breast abnormalities in varying types of breast tissue. The normal breast is composed of both dense fibroglandular tissue and fatty tissue. Fatty tissue appears dark on mammograms, whereas fibroglandular tissue appears white, much like a tumor. Many factors (eg, age, genetics, and hormones) can cause the breast to be denser, making diagnosis of breast cancer difficult. In an attempt to overcome this challenge, doctors might suggest that additional diagnostic imaging be performed using ultrasonography, magnetic resonance (MR) imaging, breast tomosynthesis, or a combination of these technologies. In addition, patients with dense breasts should be aware of their breast anatomy.

It is well known that dense breast anatomy can hinder the accuracy of screening mammography. To help remedy this problem, breast density notification laws serve to inform patients of their unique breast anatomy and introduce them to additional imaging options.

**Purpose** When patients know about their breast anatomy, they are better informed to make decisions regarding whether to undergo further screening. For example, patients might decide to continue with additional testing if they come from a family with a history of breast cancer, while patients without that history might choose to save the cost and exposure of more examinations.

New laws are being proposed to inform patients about their degree of breast density. Specifically, these laws state that after a mammogram, the patient must be informed about the density level of her breasts. This point raises a controversial discussion regarding whether notification is truly necessary and beneficial and whether it leads to increased radiation exposure, health care costs, and stress to the patient. The purpose of this study was to examine the current literature on dense breast anatomy, imaging options for patients with dense breasts, and dense breast notification laws.
Methods
An article by Kathy Hardy in *Radiology Today* regarding notification of dense breasts sparked the initial interest in this subject. Further research was conducted by searching Google Scholar for articles that were published between 2009 and 2012, using the search terms *dense breast* and *dense breast notification*. General Google searches were performed to find broad information regarding dense breast knowledge.

Results
Anatomy
The normal breast is composed of 2 types of tissue: dense tissue and fatty tissue. Dense tissue is composed of glandular and connective tissue, which appears white on a mammogram, much like a tumor. The fatty tissue appears black. When a patient is said to have a “dense” breast, it means that the breast contains very glandular breast tissue to the point that it looks mostly white on a mammogram. These images make identifying a tumor difficult.

When reading a mammogram, radiologists are advised to describe the composition of the breast anatomy using the American College of Radiology Breast Imaging Reporting and Data System (BI-RADS). This system categorizes the composition of the breast according to the volume of glandular tissue in the breast. BI-RADS category A characterizes breast anatomy as being almost entirely fatty. The fatty composition of the breast tends to be more radiopaque in appearance as compared to the areas of opaque density that might be suggestive of a cancer. BI-RADS category B suggests scattered areas of fibroglandular density. BI-RADS category C characterizes breast anatomy as being heterogeneously dense, which might obscure small masses. With category D, the density of the breast is considered extreme and ultimately hinders the sensitivity of mammography (see Figure 1).

Dense mammograms manifest as brighter or more radiopaque in description because the x-ray beams are unable to penetrate the fibroglandular tissue because of the low peak kilovoltage levels used. Cancerous tumors could be hidden behind the white areas, leading to a false-negative mammogram. Approximately 20% of breast cancers are missed because of this factor.

Factors Affecting Breast Density
Many factors affect the density of a woman’s breast. Ziv and colleagues noted age, hormones, reproductive history, genetics, and diet (body habitus) as the top contributors to breast density. One of the main determining factors is age. When a woman is young, the breast is much more dense because the tissue is mainly glandular. As she ages, this glandular tissue becomes less active and progressively changes into fatty tissue. The amount of density remaining depends on hormones, genetics, and diet. In addition, hormones greatly affect density throughout the menstrual cycle. For example, the breast is densest in the later portion of the cycle, when estrogen levels are highest. For this reason, it is recommended that mammograms be scheduled in the first 2 weeks of the menstrual cycle.

Pregnancy is another hormonal factor that can influence the density of the breast. One study showed that women who bore children at a younger age had less breast density than did women who had no children or reproduced later in life. According to the study, 63.8% of women who bore their first child under the age of 20 had predominantly fatty breast tissue. This percentage was nearly half that of women who had not borne children.

Menopausal women often undergo hormone replacement therapy. It has been shown that their breasts are denser after these treatments. A study by...
Ziv and colleagues showed that most women who underwent such treatment ranked in the second and third BI-RADS levels (B and C), demonstrating the degree to which hormones can affect the density of breasts on mammograms. When a woman is post-menopausal and estrogen levels are consistently low, the breast loses some density, making the diagnosis of cancer easier. Genetics also plays a role in influencing the density of a woman’s breast. Studies have shown that the breasts of women with a first-degree relative (ie, a mother or a sister) who previously had cancer have greater breast density on mammograms.

Body habitus also influences breast density, mainly when taking body mass index (BMI), a weight-to-height ratio, into account. In one study, those with a lower BMI were more likely to have denser tissue than were those with a higher BMI. Along with habitus, general diet also affects breast density. Women with a higher caffeine intake at the time of their mammograms received a higher score on the BI-RADS scale, as well.

**Imaging Modalities**

**Mammography**

Mammography has been the primary imaging modality used to detect breast cancer. This examination often consists of 2 images of both breasts: the craniocaudal (CC) and mediolateral oblique (MLO). The CC image shows the horizontally compressed breast from above, and the MLO image is taken from the side (from the center of the chest toward the outer chest) at an angle of the diagonally compressed breast. The 2 projections allow a radiologist to determine where an area of interest might be, both horizontally and laterally.

Although mammography has been used for many years, the equipment has several limitations. The images often are not of the best diagnostic quality. False positives and false negatives are common. A false positive occurs when the radiologist determines the mammogram to be abnormal, but no cancer is present. This is common when breast compression is not enough to spread out the tissue sufficiently. A false negative occurs when the radiologist assesses a mammogram as normal when there is a cancer present. This often is caused by a breast that is very dense, resulting in an image with a small degree of variation between adjacent densities, making it difficult for the radiologist to differentiate between regular glandular tissue and tumor masses.

**Whole Breast Ultrasonography**

The most popular complementary diagnostic screening technology to mammography is ultrasonography. It is cost-effective, it images the whole breast without overlapping or superimposing tissue, it is portable, and it does not expose the patient to radiation. A sonographer scans a transducer over the patient’s entire breast, which allows masses to be identified and their locations to be marked. Physicians often use ultrasonography to double check an area of interest. Masses appear as dark, shadowy shapes. In addition, the technology has the ability to measure the size of lesions. However, the image’s diagnostic quality is not much better than a mammogram, making it difficult to differentiate between malignant and benign masses.

**Magnetic Resonance Imaging**

Since the 1980s, MR imaging gradually has become more popular for the diagnosis of breast cancer. It was first used without contrast solely for breast implant evaluation. In the late 1980s, contrast agents, particularly gadolinium-based and typically gadolinium-diethylenetriamine pentaacetic acid, were used in the imaging of breasts. MR imaging was helpful in distinguishing malignant from benign lesions caused by high vascularity. In recent years, multiple studies have been conducted to evaluate making contrast-enhanced MR imaging the primary breast imaging option. These scanners now detect up to 37% of lesions in patients with negative mammograms.

The benefits of this modality are undeniable. According to Johnson, “Enhanced breast MR can provide detailed information about lesion morphology and the pathologic vasculature of potentially malignant lesions.” High-resolution MR images are created without compressing the breast, allowing for visualization of pathology or other abnormalities that some modalities might not detect. The differences between malignant tumors and benign masses are obvious with contrast-enhanced MR imaging. A malignant tumor exhibits angiogenesis, or new blood vessel growth. With the aid of contrast material, the tumor is demonstrated with
prompt uptake and uneven borders of the lesion, followed by quick washout of the contrast.9

Breast Tomosynthesis

Breast tomosynthesis, a newer technology, gives radiologists a better look at the breast in 3 dimensions. Much like regular mammography, the breast is compressed during imaging, although not as forcefully, and instead of one image, multiple images are acquired from many different angles in a short scan.10 These different angles allow for objects at various levels in the breast to be visualized differently by producing 1-mm slices that are reconstructed into a 3-D image that provides more data, layer by layer, than a regular mammogram (see Figure 2).11 Breast tomosynthesis not only provides more information by reducing the overlapping of breast tissue, but the dose received by the patient also is comparable to or lower than that of conventional mammography. The technology allows for earlier detection of breast cancer that might be overlooked when performing a regular mammogram and is more effective at distinguishing the position, size, and shape of the lesion.12 Breast tomosynthesis reduces the number of unnecessary call-backs for negative mammograms, unneeded biopsies, and additional testing.13 In addition, multiple masses can be identified, which is challenging with mammography.

Breast tomosynthesis offers many advantages, but several disadvantages were identified. Technologists must be adequately trained in the use of this equipment because of the large detector used. In addition, there is a chance of distortion from patient motion because the exposure is longer. Large calcifications can lead to artifacts on the image. Tomosynthesis is not a stand-alone technology but is used in conjunction with mammography, leading to a higher cost to the patient.14 These factors must be considered when contemplating the use of tomosynthesis.12

Discussion

Breast Density Notification Legislation

With increasing knowledge about breast density and the threat it might pose, laws are being introduced to help women become more aware and to act as their own advocates. In 2009, Connecticut passed a breast density notification law. Texas, Virginia, New York, California, Hawaii, Tennessee, Alabama, Nevada, Oregon, and Maryland followed suit, and other legislation is pending, including a federal bill in the U.S. House of Representatives.15,16 On July 1, 2014, Massachusetts became the 18th state to enact a breast density law.17 These laws require mammogram facilities to inform patients of their breast density when sending out the report of findings from the mammogram. New York’s law requires that the following quote be included in the report for those with dense breasts:

Your mammogram shows that your breast tissue is dense. Dense breast tissue is very common and is not abnormal. However, dense breast tissue can make it harder to find cancer on a mammogram and may also be associated with an increased risk of breast cancer. . . . Ask your doctor if more screening tests might be useful, based on your risk.18

Pros and Cons

New York state law informs the patient that she is at increased risk and supplemental testing might be warranted. It also places the decision in her hands. No one

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Physicians also worry that there will be an increase in orders for sonograms and are concerned about the associated possibility of more false-positive examinations. In the American College of Radiology Imaging Network 6666 study, the combined screenings of mammography and ultrasonography resulted in 4 times the number of recalls, biopsies, and recommendations for short-interval follow-up than mammography alone.\textsuperscript{21} The study participants included women with dense breasts and an increased risk of breast cancer.\textsuperscript{12} The results raised concerns about whether this method should be used for the general population and whether it is beneficial.\textsuperscript{13} Therefore, patients are urged to speak with their doctors before further testing.

Conclusion

Breast cancer is a threat to women all over the world. Yearly mammograms have been the primary imaging tool for early detection. In recent years, however, this modality has shown some restrictions because of breast anatomy. Through the use of ultrasonography, MR imaging, and breast tomosynthesis, some of these uncertainties have been alleviated. Nevertheless, breast density consistently interferes with the accuracy of imaging. New laws are being passed in an effort to keep women informed about their unique physical characteristics and what they might need to do to protect themselves from delayed detection. Evidence suggests that providing patients with the knowledge to make informed health care decisions is important and is viewed as a patient right.

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Integrating Technology Into Radiologic Science Education

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**Purpose** To review the existing literature pertaining to the current learning technologies available in radiologic science education and how to implement those technologies.

**Methods** Only articles from peer-reviewed journals and scholarly reports were used in the research for this review. The material was further restricted to those articles that emphasized using new learning technologies in education, with a focus on radiologic science education.

**Results** Teaching in higher education is shifting from a traditional classroom-based lecture format to one that incorporates new technologies that allow for more varied and diverse educational models.

**Discussion** Radiologic technology educators must adapt traditional education delivery methods to incorporate current technologies. Doing so will help engage the modern student in education in ways in which they are already familiar.

**Conclusion** As students’ learning methods change, so must the methods of educational delivery. The use of new technologies has profound implications for education. If implemented properly, these technologies can be effective tools to help educators.

Technology continues to play an increasing role in people’s lives. The current generation of students is accustomed to using technology for entertainment and communication. This same technology can be used to assist students and teachers in an educational setting. Increased diversity in today’s student population makes it less likely that students in a class will be similar in background and capability. Using technology in an educational setting is important because it uses tools and methods with which students are already familiar, which helps engage students, facilitates lifelong learning, and creates cohesion among the students, instructor, and course content materials.

Only recently have educators begun to use popular technologies to assist in an educational setting. Martino and Odle wrote that the driving force behind using technology in new educational delivery methods has been student demand. They also found that educational institutions, faculty, and administrators traditionally have been slow to fully embrace these developing methods. These new methods can be applied to the field of radiologic technology. Because imaging professionals must continually learn and use new technology, it is reasonable to believe that integrating technology into the education of radiologic technology students would be beneficial.

A number of technologies are available to assist in the educational process, ranging from Web technologies such as wikis, instant messaging, blogs, social bookmarks, online instruction, and podcasts to software and hardware technologies such as Microsoft PowerPoint presentations and mobile electronic devices. To increase interaction among students, educators are encouraged to use new technologies.

Properly integrating the available educational technologies into radiologic science education is critical to promote effective learning. New technologies can facilitate learning but ultimately depend on the underlying pedagogy, learning methods, and strategies used to integrate the technologies. This literature review
integrating specific forms of technology was not only possible but also effective in assisting educators in the delivery of education. According to the literature reviewed, the most commonly used applications were mobile electronic devices, podcasting, online education, and social media.

**Mobile Electronic Devices**

Today’s students use mobile electronic devices for numerous activities in their daily lives, and because of the devices’ Internet capabilities, their use is increasing. Mobile electronic devices include personal digital assistants, iPods and iPhones (Apple), BlackBerrys (BlackBerry Limited), smartphones, laptops, and tablet computers. Students use these devices to store and retrieve audio recordings, photos, videos, books, presentations, and other files. Because students are already comfortable using these mobile electronic devices and the devices are a portable, convenient way to store and retrieve data, educators should consider integrating them into the educational setting.

Some software companies have developed programs that allow for individualized customization of data collection and storage that can be used for academic fields. This software can aid both students and instructors in data collection as well as the organization and storage of information that can be retrieved at a later time in a portable format. These programs could be valuable in the field of radiology for instruction and information gathering. Students could log competencies, clinical time, and professional notes through software on mobile devices, allowing instructors access to continuously updated information. Such devices and programs also could allow students access to positioning guides and technique charts. These resources could give students extra confidence by helping them to make clinical decisions, allowing them to easily retrieve Digital Imaging and Communication in Medicine (DICOM) images, and providing information at the point of care.

Similarly, educators can employ mobile electronic devices as instructional aids and clinical assessment tools. Mobile electronic devices can be used as an effective method for transferring data to students in the classroom. File exchanges can be used instead of paper,
thus reducing material and service costs for the department and the university. Educators also can give quizzes and assignments via mobile electronic devices in lieu of paper-based formats.3

Some mobile electronic devices have the ability to download medical texts and professional journal articles.7 Martino and Odle stated that mobile electronic devices “supported the development of strong student organizational skills and empowerment, enhanced just-in-time learning in the clinical setting and allowed for reinforcement of core knowledge for practice.” A study of nursing students by Williams and Dittmer showed similar results.4 The authors tested the effectiveness of mobile electronic devices in clinical practice compared to traditional methods of educating with textbooks and concluded that students quickly mastered the technology and effectively used the device. The nursing students also liked the concise and portable nature of the device, and “no students expressed dissatisfaction or regret at being in the experimental group.” Mobile electronic devices that contain textbooks and positioning guides, although expensive, are quickly becoming commonplace for radiology students.3,7

Mobile electronic devices also are being used as polling devices and to provide podcasts. The use of mobile electronic devices as polling devices allows the educator to deliver quizzes and assessments, to quickly collect and organize data, and to create an interactive learning environment. Podcasts are video or audio recordings that are stored as media files. Teachers and students can download these files to mobile electronic devices or other computing or audio delivery devices. Using such formats, educators can record presentations and lectures before or during class so students can access these files to study the material at a later time.3

All the articles reviewed showed that mobile electronic devices are a valuable resource in health care education, but one study revealed negative feedback from students. In a study of nursing students using mobile electronic devices in clinical settings, Fisher and Koren found that some students believed that mobile electronic devices presented them in a negative light to patients.7 The study used qualitative investigation to examine the integration of mobile electronic devices at the point of care in undergraduate nursing programs. Students used mobile electronic devices equipped with medically relevant software for 7 weeks.7 At the end of the study period, the students participated in a discussion group to share their thoughts about the use of mobile electronic devices in the clinical setting. Although the majority of students found the integration of mobile electronic devices helpful and effective, a few stated that they thought the mobile electronic devices made them look inept or unprofessional when they were used in front of patients. Other students found it difficult to use mobile electronic devices in front of patients, reporting that it was more difficult to navigate the devices while the patient watched, as if they were under scrutiny.7

Podcasting

Podcasts are downloadable multimedia files that can be stored on MP3 or MP4 portable media player devices and can be listened to or viewed at one’s convenience. Originally exclusive to and named after the Apple iPod, podcasts now are available to access on desktop computers, laptop computers, and tablets using the Internet.1,4 Some podcasts may be accessed for free, while others require a subscription or a payment for each podcast.1 Podcasting provides an innovative way for students to improve collaboration and communication.4

Podcasting technology can deliver training specific to a learner’s needs. Known for their portability and on-demand capabilities, podcasts are available at any time and anywhere an MP3 or MP4 device can be used. The use of podcasts is expected to continue to grow as a resource for educational delivery, and podcasts’ potential as an effective delivery method is being recognized by educators in the medical field.1,4 Educators can develop content for and self-publish podcasts to better meet the specific needs of their students.

Several studies have evaluated the effectiveness of podcasting as an educational delivery method.1,4,9 One study by Lorimer and Hilliard focused on replacing a traditional classroom lecture with podcasts and small group seminars.2 Students were given podcasts with associated PowerPoint presentation files before class and were expected to come to weekly small group seminars ready to ask questions and discuss the information. A multiple-choice activity using an electronic voting system also was employed in the seminars. This study
showed that this combination of teaching methods was an effective revision to the established lecture-based teaching pattern. The use of the electronic voting system in combination with the small group seminars and independent study via podcasts was beneficial to students and faculty alike.3

A study by Saeed et al showed similar results.4 The authors studied the use of podcasts and other electronic delivery methods in relation to students’ different learning styles. They found that students who preferred podcasts were sequential learners who preferred understanding in linear steps, repeating the material, and continuing at their own pace. Both Lorimer and Hilliard2 and Saeed et al4 stated that well-balanced academic performance was achieved among all groups and the learning technologies did not pose barriers to students’ education. Instead, “students’ engagement with their learning and level of classroom interactivity were both increased when compared with the previous traditional delivery format.” The benefits of incorporating podcasts into educational delivery methods included increased flexibility in the time and place of study and a positive influence on academic performance.1,4 Students stated that possible reasons for the positive influence on academic performance included an ability to pause or stop lectures and a lack of peer pressure during question-and-answer portions of the lecture.2

Only one study showed negative results from integrating podcasts into educational delivery. Daniel and Woody compared one group of students that read a lengthy article from a book with a second group that listened to the same article via podcast.9 The group that listened to the article via podcast did significantly worse on a quiz about the material than did the group that read the article. According to Daniel and Woody, students in the podcast group:

“[P]erformed relatively poorly on the quiz and reported that they knew less, understood less, experienced more difficulty with the material, and, marginally, learned less than did students in the text condition.”9

Students who listened to the podcast initially reported that they preferred this method instead of reading, but after taking the quiz and even before receiving their scores, they stated that the podcast was not an effective method for their learning.9

Because of the recent innovations in educational technologies, the educational system is currently undergoing a fundamental change, a shift away from traditional classroom lecture delivery methods.3 Podcasting is an effective tool for educators in traditional classroom courses as well as in online courses. Integration of podcasts in radiologic science education can draw staff and students closer together, both physically and virtually, by allowing cohesion and dialogue for in-person and distance-learning formats.2

Online Education

The Internet has become the predominant format for delivering distance education. Many institutions offer online courses that address the diverse distance and time needs of today’s students who might not be able to attend traditional university classes.10,11 Higher education has increasingly tried to reach more students in recent years, and as of 2013, more than 6.7 million college students were enrolled in at least one online course.11-13

According to Brit, “Online education can be defined as any course that is mediated via the Internet.”11 Online courses permit off-campus students to access quality education through the use of a course management system such as WebCT, Blackboard, Desire2Learn, and Moodle. These course management systems allow students to contact the educator and fellow students through e-mail and message boards and provide open communication and dialogue to help develop critical-thinking skills.10,12

For online education to be successful, the educator must encourage students to become autonomous and take responsibility for their own education.14,15 This helps students to develop their knowledge and professional skills and to emphasize a student-centered learning approach.13,14 Online education at the professional and postprofessional levels also can help students to engage in continuing education and lifelong learning.12,14 This method of learning can help radiologic technology programs provide opportunities for students to assume responsibility for their own learning14,16 and “reduce their level of dependence on staff and prepare them for the rigors of the workplace by developing high level cognitive and transferable skills.”14 Of the studies reviewed, most
supported online education as long as it is incorporated and implemented properly. 

Online education has been implemented into educational programs in varying degrees. Some institutions use online technology to enhance traditional learning in classrooms, known as the supplemental model. Conversely, the replacement model, which also is referred to as blended, hybrid, or mixed online instruction, integrates interactive online technology with or to replace some of the traditional classroom lecture instruction. Students might be taught fully online or might have varying degrees of virtual and classroom time.

Two studies by Johnston and Britt show examples of integrating online technologies into radiologic science undergraduate programs. Johnston examined the instructional effectiveness of 2 radiologic science courses—patient care as well as radiation biology and protection—which previously were taught face-to-face and converted to a fully online format. The study compared the students’ grade-point average for the courses and the students’ performance on a national certification examination in the areas covered by the courses. The results were mixed. The grades for both courses were higher for the online courses compared with the face-to-face instruction, although the difference for the patient care course was not statistically significant. In contrast, the national certification examination results for students in the patient care class were higher for the face-to-face delivery class than for those who received online instruction. No comparisons from the national certification examination could be made for the radiation biology and protection course because the standard deviation for both groups was zero. When it was time for the students to take their board certification examinations, it appeared that the students in the online classes did not remember the information as well as those who had taken classes in the face-to-face format.

The objective of Britt’s study was to determine the attitudes of students and faculty about online instruction. Surveys were sent to faculty members in the radiologic technology and nursing departments at a university. Similar surveys were sent to radiologic technology students in the clinical phase of their education and to graduate nursing students. The survey gathered information about the subjects’ attitudes toward online teaching and learning. Overall, the results were negative. Educators expressed that they experienced a lack of preparation time, a lack of contact with students, and that they were unfamiliar with the technology for online courses. However, they did consider the difficulty level of the online courses to be equal to or more difficult than traditional instruction. Students also expressed that the classes being taught online were as difficult as or more difficult than traditional classes. Fifty-two percent of the students reported no difference in their online course grades compared with classroom instruction, and, of the 48% who did report a change, 23% suggested that their grades were higher in the online classes. No quantitative data were collected about course grade-point averages or performance on national certification examinations.

Despite the mixed results of these 2 studies, more studies are showing that online courses can be effective. Evidence-based outcome studies regarding the effectiveness of online education showed no significant differences in outcomes between online and traditionally taught classes, but studies published after 1998 are more heavily in favor of online education’s ability to provide an effective student-centered learning environment.

Although there is not one correct method for delivery, online education will continue to improve as educators adapt their teaching style, course content, and educational philosophy. As educators adjust, online instruction will continue to improve and promote a more learner-centered environment.

The greatest appeal of online education is the potential to meet the needs of all students. However, like every new model of instruction, challenges exist because online education is not a mass-produced product. It differs greatly from face-to-face instruction and must focus on learning material and activities that engage students in the physical absence of a teacher. Preparation for an online course is difficult and mentally challenging for both the teacher and the student.

Success with instructional technology has led to more exploration of delivery methods. Educators who have taught online courses have reported an enhanced ability to involve or link to experts or external Web sites and improve self-directed learning, critical thinking, and the quality of student work. Other positive
features of online education are increased flexibility in schedules for students and faculty, a reduction in travel expenses, alleviation of classroom space problems, and an ability to more flexibly meet the needs of all students.\textsuperscript{11,12}

Some drawbacks to online education still exist. Sometimes, there is a limitation in the technology used for this delivery method.\textsuperscript{12} A study by Kliger and Pfeiffer suggested that narrow bandwidths can be an obstacle to using dual media when communicating with students (eg, speaking to students while showing a video online).\textsuperscript{12} In hybrid environments, students are still required to spend money on travel and other expenses to attend face-to-face classroom activities.\textsuperscript{12} There also might be an unwillingness of educators to adapt to new technologies because of the time and extra work required to implement them.\textsuperscript{11,12}

Because of the lack of face-to-face interaction in online education, it seems that increased learning could result from a more engaged effort through collaborative activities.\textsuperscript{17} The power of online learning can be enhanced by collaborative learning through the ability to discuss problems, share ideas, reflect, and review, either synchronously or asynchronously.\textsuperscript{17} Most current course management systems (eg, WebCT, Blackboard, Desire2Learn, or Moodle) incorporate tools such as e-mail, discussion boards, wikis, and live chats to encourage students to work together.\textsuperscript{10,11}

Social Media

One popular avenue for collaborative online activities is social media. The past 10 years have seen a vast increase in social networking sites and software\textsuperscript{18,19} and growing user participation in these technologies, known as the \textit{social media revolution}.\textsuperscript{6,19} \textit{Social media} can be defined as an online space or technology that allows people to establish or maintain contact with others, interact with social networks, and share ideas about any topic at any time.\textsuperscript{18,19}

Many social media platforms exist, including Facebook and Twitter, which allow people to share information about anything at any time; wikis such as Wikipedia and blogs that promote continuous information sharing within interested user communities; Skype and Ventrilo, which use audio-visual devices to enable face-to-face communication through the Internet; and video sites such as YouTube, which allow video sharing with anyone in the world.\textsuperscript{5,6,17,20} The research showed that Facebook and Twitter are the most commonly used social media tools.\textsuperscript{5,6,17,20}

Facebook

Facebook is an international Web site that allows users to easily build a personalized Web page, display photos and thoughts, and send messages to other users.\textsuperscript{5} Users can join or set up interest groups to communicate about any subject.\textsuperscript{6,11} Facebook has the potential to be a great tool for educational programs because its target demographic is so compactly gathered in one place, and it is dynamic enough to allow educators to create a communication channel of their own.\textsuperscript{6} Educators can create such channels for students to interact with the instructor in interest groups for each course or for each student cohort.

A study by Giordano and Giordano showed that health professions students prefer to obtain news, weather, sports, entertainment, and social information online, with a majority of them heavily relying on Facebook.\textsuperscript{6} It also showed that graduates often use Facebook to stay connected to their fellow alumni. This would suggest that Facebook spans both professional and personal bounds.\textsuperscript{6} Such common use of a technology would indicate that it could be adapted to education. According to Freishtat and Sandlin:

Socially oriented digital media produce a habitus within digital spaces; meaning youths’ experiences with technological culture influence the ways in which they will interact with technology.\textsuperscript{21}

This information about Facebook use by health professions students is helpful for faculty and administration.\textsuperscript{6,16} According to Giordano and Giordano:

[Facebook] is a no-cost, viral way of getting the word out about school events and programming and can be used to keep students informed of new classes, special lectures, holiday hours, special events, and even emergency notices. Above all, it is about being social, allowing students a virtual meeting space to connect with alumni, establish school pride, announce reunions and sporting events, talk about group projects, interact with the community, and beyond.\textsuperscript{6}
In spite of the many applications of sites such as Facebook, educational institutions might be hesitant to adopt such practices because of a fear of privacy and security issues. Facebook has been under examination for the sale of users’ personal data to companies that sell this information to marketing firms. Most of the research in this area is based on testimonials or correlational evidence, and although the uses for a site like Facebook are seemingly endless, there is little proof that Facebook is an effective tool in an educational setting. Another area of concern is the issue of unintended feedback, harsh conversation, and negative or malicious comments by students or other Facebook users. Burns and Wolstencroft suggested closely monitoring Facebook pages to ensure that no inappropriate comments are made and no uninvited users have access.

Twitter

Twitter is an online platform for delivering short messages, similar to text messages, which educators can use to keep their students informed of class developments and schedules, as long as educators and students subscribe to be “followers” of the initiator of the Twitter feed. A study by Mistry examined the use of Twitter in critical care training of nursing students. Students were given a simulation scenario and asked to comment via Twitter on how they would react in certain situations. Comments were sent to either the course instructor or to other students in the scenario in either a synchronous format (students actively engaged in participation at the same time) or an asynchronous format (students participating at different times over a given time period). Students were then given information back from the instructor or their classmates, creating a dialogue based on response.

Many students expressed their satisfaction with the use of this method of education. Mistry found that, overall, the Twitter method was no different from any other online collaborative experience and that there was a “demonstrable articulation of ideas, assertions and diagnoses, sometimes conflicting with others’ ideas, which sometimes led to a co-construction of ideas, working closely with the tutor or peer.” There was widespread agreement that the materials developed for the scenarios were engaging and educational, and the discussion of the clinical information was useful. However, Mistry said that because of the time required for initial setup and constant involvement, effective use of this tool is a difficult, timely process and might not be applicable in all situations.

Some students had concerns about aspects of Twitter as an educational medium. Students who were not confident in the learning process, the instructional material, or both, tended to lose focus and motivation. Also, some of the unthreaded discussions in asynchronous mode were difficult to follow. Mistry suggested that instead of applying Twitter to all situations in an educational setting to try easing the technology into courses by replicating existing discussion forums and using it as a replacement tool for existing audience response systems.

Using social media could be important to today’s students as more than just the delivery method. Roland et al stated that students today are less skilled in written and oral communication and, because of this, are more hesitant to speak out or write independently for fear of ridicule by others. These students need to be supported in the development of communication skills using these same mechanisms, by virtue of their knowledge and familiarity with these technological advances. This comfort level will pave the way for increasing educational benefits, which recently have led to tremendous growth in online and hybrid education. When social media is properly implemented and integrated, the lines between social networking environments and teaching and learning tools are blurred.

Discussion

In an ever-changing world, radiologic technology educators continually modify their educational delivery methods. They must adapt to fluctuating learning styles and preferences, stay current with educational and radiologic science trends, and integrate new educational technologies into their teaching. Such technologies allow for better communication and delivery for educators and help provide education in a convenient, mobile, and effective mode with which most students are already familiar. Also, new educational technologies can give both educators and students the
luxury of setting their own schedule for communication and schoolwork. Modern technology has resulted in an age of instant gratification and information, the effects of which can be seen in health care and education. This requires imaging professionals and educators to be aware of the risks associated with new technologies identified throughout this review and how to properly implement new technologies despite these risks.

Conclusion
Radiologic technology educators have many tools available to them to assist with teaching in a fluctuating educational environment. Mobile electronic devices, podcasting, online education, and social media have been shown to be effective in helping educators deliver convenient, quality, and successful instruction. This innovative culture helps to foster the concept of continuing education in students’ lives and throughout their careers.

This review had some limitations. Many studies focused on the topics of mobile electronic devices, podcasting, online education, and social media; however, few actually performed qualitative or quantitative studies to prove or disprove their perspectives about these emerging technologies. Several reviews from non-peer-reviewed sources were based on opinions rather than facts, which is why they were not included in this review. It was difficult to find peer-reviewed articles reporting on studies with students as subjects, and only a small number of those covered the field of radiologic science education.

Although some studies have examined the use of new technologies in education, future studies should evaluate the effectiveness of evolving technologies and demonstrate their successful integration into the field of radiologic science education. Because individuals working in the field of radiologic technology continually work with new equipment and innovative technological advances, it is reasonable to expect that new educational technologies—if found to be effective—could play an important role in both educational delivery and learning. This integration of educational technologies could enable students to incorporate such methods into their daily practice.

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Care Considerations for Patients With Spinal Cord Injuries

John Colangelo, MSRS, RN, R.T.(R)

After completing this article, the reader should be able to:
- Summarize the incidence and prevalence of spinal cord injury in the United States.
- Explain the difference between tetraplegia and paraplegia.
- Explain the categories of complete and incomplete spinal cord injuries.
- Describe the pathophysiology of autonomic dysreflexia.
- Discuss how prompt intervention is vital to avoid a life-threatening situation with autonomic dysreflexia.
- Describe the various stages of pressure ulcers.
- Discuss future treatment options for people who have spinal cord injuries.
- Understand the physical and emotional needs of patients with spinal cord injuries.

A spinal cord injury has a tremendous effect on an individual’s physical and mental health. Besides causing paralysis, spinal cord injuries lead to chronic medical conditions, adjustments in employment or educational goals, changes to personal and sexual relationships, and more. As many as 327,000 people affected by spinal cord injury are living in the United States today, with an average age of injury of approximately 41 years.\(^1\) Costs to treat people with spinal cord injuries the first year after injury can be as high as $1 million, and subsequent care costs range as high as $178,000 per year.\(^1\)

Spinal cord injury patients undergoing medical diagnostic imaging warrant special care and consideration. Therefore, radiologic technologists must obtain a thorough understanding of the medical management of patients with spinal cord injuries so radiologic examinations involving this patient population can proceed safely and produce quality images. The radiologic technologist should demonstrate competence in caring for these patients’ unique needs.

Anatomy of the Spine

The vertebral column, also called the spinal column, is the central support of the body and bony protection for the spinal cord and nerves. The column has 5 regions: cervical, thoracic, lumbar, sacral, and the coccyx. The cervical region consists of 7 vertebrae that allow the head to rotate from a fixed point. The first 2 cervical vertebrae have unique morphology that allows the head to move forward and backward, rotate, tilt, and lift. The first cervical vertebra is the atlas, which articulates with the occipital bone at the base of the skull to make up the condylar joint, which allows backward and forward...
motion of the head. The inferior surface of the atlas articulates with the second cervical vertebra, the axis.

Twelve thoracic vertebrae descend through the thorax and attach to the rib cage. The lumbar region has 5 large vertebrae that support most of the body’s weight. The sacral region is inferior to the lumbar spine; it is composed of 5 fused vertebrae from which the bones of the pelvis articulate. The coccyx is the smallest and final segment of the bony spinal column, consisting of 4 to 5 extremely small, sealed vertebrae (see Figure 1).

The spinal column has an opening called a central foramen through which the spinal cord passes. The spinal cord is a sophisticated structure of nerves that relay information to and from the brain about sensations, movement, and autonomic functions. The spinal cord begins at the caudal end of the medulla oblongata in the brain at the base of the skull from the foramen magnum. The cord then descends through the cervical, thoracic, and lumbar vertebrae and ends between the L1 and L2 vertebrae. The end of the spinal cord forms a cone-shaped structure composed of a collection of nerves called the conus medullaris. The conus medullaris consists primarily of sacral spinal cord segments and provides critical sensory innervation to what is known as the “saddle area.” This includes motor innervation for the sphincters and parasympathetic innervation for the bladder and rectum. Inferior to the conus medullaris, the individual lumbar and sacral nerves extend beyond the spinal cord. These nerve bundles are called the cauda equina because they resemble a horse’s tail. A single fibrous strand called the filum terminale anchors the spinal cord at the coccyx (see Figure 2).

The spinal cord is made up of gray and white matter. Gray matter extends through the internal spinal cord and is composed of interneurons and motor neurons. Interneurons act as relay switches between the motor neurons. They also are found in between sensory neurons; however, an interneuron would not connect a sensory neuron with a motor neuron. Motor neurons conduct impulses from the central nervous system to the muscles or glands, and sensory neurons carry impulses from receptors in the skin, skeletal muscles, joints, and internal organs to the central nervous system. Motor nerves comprise only motor neurons, and sensory nerves comprise only sensory neurons.

Thirty-one pairs of spinal nerves emerge from the spinal cord. There are 8 cervical nerves, 12 thoracic nerves, 5 lumbar nerves, 5 sacral nerves, and 1 pair of coccygeal nerves. All of these nerves radiate out of the spinal canal through the intervertebral foramina, small openings between spinal vertebrae. For the first 7 cervical vertebrae the spinal nerves pass through the intervertebral foramina above the cervical vertebra that corresponds to that number. For example, the fifth cervical nerve passes through the foramina above the C5 vertebra. Because there are 8 cervical nerves and only 7 cervical vertebrae, the eighth cervical nerve passes above the T1 vertebra. From this point all subsequent spinal nerves running through the thoracic, lumbar, sacral, and coccygeal regions emerge from the intervertebral foramina below the vertebra with that same number (see Figure 3).
Each spinal nerve has a dorsal and ventral root. The dorsal root is made of sensory neurons that carry impulses into the spinal cord. The ventral root is the motor root, made of the axons of motor neurons that carry impulses from the spinal cord to muscles or glands (see Figure 4). Axons transmit electrical stimulation onto dendrites, branching projections that provide a larger surface area to pass a chemical signal to many target cells simultaneously. The white matter of the spinal cord envelops the gray matter and comprises myelin-covered axons and dendrites of interneurons. Myelin is a white fat and protein layer that insulates the axons. These axons and dendrites are grouped into 2 nerve tracts: ascending and descending. Sensations such as touch, pain, heat, cold, and position are transmitted via the ascending tracts. The nerve impulses move up from the body at the point of origin to the brain, where the signal is processed. The descending nerve tracts carry information from the brain to the rest of the body to create movement and control certain organ functions. Sensory innervation to the saddle area controls the sphincters and the parasympathetic impulses to control the bladder and the lower bowel.

Other specialized nerve cells called sensory ganglia are found in dense clumps just outside of the spinal cord. Their function is to relay information regarding pain, touch, temperature, vibration, pressure, and joint position back to centers in the brain.

The spinal cord is similar to the brain in that it is enclosed by 3 distinct membranes called meninges. The tough outer layer is the dura mater, the middle layer is the arachnoid mater, and the delicate inner layer is referred to as the pia mater.
Epidemiology of Spinal Cord Injuries

Estimates of the incidence and prevalence of spinal cord injury in the United States vary depending on the source. However, there are approximately 12,000 new cases of spinal cord injury in the United States every year, which is an incidence rate of 40 cases per 1 million people. The prevalence of spinal cord injury in the United States ranges from 238,000 to 332,000 people. Advances in acute medical care have made it possible for more than 65% of individuals who receive these injuries to survive their initial injury. Data about these spinal cord injuries as well as treatment outcomes after the injury are collected by the National Spinal Cord Injury Statistical Center. The most common causes of spinal cord injury in the United States are motor vehicle accidents, violence, sports injuries, and falls. The elderly population, those aged older than 65, are most likely to sustain a spinal cord injury from a fall. In the 1990s spinal cord injury due to violence peaked but has steadily declined since then. Sports-related injuries related to trampoline accidents, football, and diving also have declined because of increased training and proper safety equipment.

Pediatric populations have the lowest incidence rates for spinal cord injury. The highest rates of spinal cord injury are attributed to people in their late teens to early 20s. However, some studies suggest that as the percentage of elderly persons older than 65 years of age increases in the United States, there is a slight increase in incidence of spinal cord injury among this population. Gender is a significant risk factor, with 71% of all reported spinal cord injuries occurring in men. Data collected in the United States suggests that only 29% of spinal cord injury patients are women. According to data from the International Spinal Cord Society, the incidence and prevalence of trauma resulting in spinal cord injury is higher in the United States than in the rest of the world. Evidence also shows that the relative proportion of higher injury sites (ie, at the cervical spine) is increasing, along with injuries caused by falls.

Traumatic Spinal Cord Injury

Traumatic spinal cord injury is a serious and life-altering event. Most blunt trauma from falls, automobile accidents, and injuries from gunshot wounds, knives, and other penetrating trauma usually do not completely sever the
spinal cord. If the vertebrae are broken or dislocated, they can put harmful pressure on the spinal cord.\textsuperscript{11} Pressure from the vertebrae crushes and destroys the sensitive axons that carry signals. Minor injuries to the spinal cord seldom cause nerve cell death, but patients might experience pressure-induced blockage of nerve signals or demyelination without axonal damage. Patients who have minor injuries usually recover.

When a severe injury occurs to the vertebrae, however, the pressure from the injury can cause complete cell death across a horizontal level of the spinal cord, which can result in complete paralysis.\textsuperscript{11} Severe injuries usually occur from a sudden and powerful mechanical blow to the spine, and damage to the nerve cells commences at the moment of primary injury. Bleeding into or just outside of the spinal cord also can cause pressure-induced damage.

Spinal shock is a serious condition and is the loss of all neurological activity below the level of injury. During an episode of spinal shock, the spinal cord below the level of injury is rendered completely paralyzed and is temporarily disabled, resulting in complete paralysis and loss of all reflexes and sensation.\textsuperscript{11} Spinal shock can begin 30 to 60 minutes following a traumatic spinal injury and last up to 6 weeks.\textsuperscript{11} Secondary injury follows, resulting in additional damage from changes in blood flow, excessive release of neurotransmitters, invasion of immune system cells that cause inflammation through the breached blood-brain barrier, free radical attack on the nerve cells, self-destruction of nerve cells (apoptosis), and scarring. The scarring results in a physical and chemical barrier that limits or stops conduction of any remaining nerve signals.\textsuperscript{11}

**Classification of Spinal Cord Injuries**

The American Spinal Injury Association (ASIA) first published standards to classify spinal cord injury in 1982. The ASIA classifications include neurological level of injury and identification of corresponding muscles and sensation.\textsuperscript{13} In 1992, the International Medical Society of Paraplegia refined the ASIA classifications and established international standards. Finally, a standardized ASIA Impairment Scale was developed and instituted to classify spinal cord injury by neurologic level.\textsuperscript{13}

The impairment scale classifies a person’s limitation from spinal cord injury in grades of A, B, C, D, and E corresponding to the extent of injury. According to the scale, a complete injury represents the absence of sensory and motor function in the lowest sacral segments. An incomplete injury involves some sensory or motor function below the level of injury, including the sacral segments. The ASIA muscle grading scale ranges from 0 to 5* with 0 indicating total paralysis, and 5* indicating normal muscle exertion.\textsuperscript{14} The ASIA impairment scale is summarized in Table 1.

The concept of complete or incomplete injury, frequently referred to as severity of injury, is often not well understood.\textsuperscript{15} Complete injury does not refer to a spinal cord that has been completely severed or transected. A complete injury represents a total absence of sensory and motor functions below the site of the injury. An incomplete classification represents preservation of some sensory or motor functions below the level of injury, including the lowest sacral segments.\textsuperscript{15}

*Paraplegia* is a term that denotes paralysis of the lower half of the body, usually affecting both legs, and primarily as a result of disease or injury to the spinal cord.\textsuperscript{15} The injury usually occurs in the thoracic, lumbar, or sacral segments and may occur in the cauda spinal cord.
equina or the conus medullaris. Tetraplegia (formerly known as quadriplegia), is paralysis of the arms, trunk, pelvic organs, and legs below the level of an injury to the spinal cord in the cervical region. Impairment or loss of motor and sensory functions in the cervical spine is usually caused by injury to the cervical vertebrae in the area of C5 through C7 (see Figure 6).

Injuries that occur above C5 can result in immediate, life-threatening cardiovascular complications as a result of a blocked sympathetic nervous system. Respiratory failure is the major cause of death after such an injury. Low body temperature, impaired peristalsis, bradycardia, and autonomic dysreflexia are other symptoms of these types of spinal cord injuries. Autonomic dysreflexia is an acute medical emergency resulting in life-threatening hypertension.

**Autonomic Dysreflexia**

Autonomic dysreflexia is a potentially life-threatening medical emergency that affects 50% to 90% of people with spinal cord injuries from T6 and above, and sometimes from T10 and above. Autonomic dysreflexia does not occur in people with healthy spinal cords. The condition seems to be most common in adult patients with new traumatic injuries, with a level of injury at or above T6. Many of these patients are admitted to an intensive care unit immediately after injury because of their risk for autonomic dysreflexia.

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**Table 1**

<table>
<thead>
<tr>
<th>Category</th>
<th>Extent of Injury</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Complete</td>
<td>Complete impairment with no sensory or motor function in sacral segments S4 through S5</td>
</tr>
<tr>
<td>B</td>
<td>Incomplete</td>
<td>Some sensory but no motor functions below the injury site</td>
</tr>
<tr>
<td>C</td>
<td>Incomplete</td>
<td>Motor function preservation below the neurologic injury level; most key muscles below the injury level have a muscle grade &lt; 3</td>
</tr>
<tr>
<td>D</td>
<td>Incomplete</td>
<td>Motor function preservation below the injury site; key muscle grade of ≈ 3</td>
</tr>
<tr>
<td>E</td>
<td>Normal</td>
<td>Normal sensory and motor functions</td>
</tr>
</tbody>
</table>

*Muscle grade indicates the severity of muscle weakness.*

---

**Figure 6.** Spinal cord injury locations resulting in tetraplegia and paraplegia. Used with permission from apparelyzed.com.
The general signs and symptoms of autonomic dysreflexia include a sudden increase in blood pressure, reflex bradycardia, anxiety, blurred vision, headache, sweating, blotching of the skin, flushing above the area of injury, and restlessness. In regard to pediatric patients with spinal cord injuries, a significant gap occurs in the literature relative to understanding the symptoms of autonomic dysreflexia. In contrast to adults with spinal cord injuries, autonomic dysreflexia manifests in children as a result of developmental variations in blood pressure, their ability to communicate, and varying dependencies upon parents or caregivers.

Signs and symptoms of the condition in children are facial flushing, headache, sweating, and piloerection. Autonomic dysreflexia has been linked to myocardial ischemia and fatal cerebral hemorrhage.

Sympathetic output from the spinal cord normally is modulated by input from the higher brain centers. After a spinal cord injury, this input is no longer available, so there is no way for the body to return to homeostasis. Autonomic dysreflexia involves the interruption of descending inhibition and the development of an exaggerated hyper-responsiveness of the peripheral receptors. Activation of baroreceptors combined with a vagal-mediated response from an area of the spinal cord above the lesion causes bradycardia from the hypertensive crisis.

There are a number of causes of autonomic dysreflexia and sometimes the condition is asymptomatic. Stimulation of presacral or pelvic nerves could be one of the trigger mechanisms in patients with suprasacral spinal cord injury. Noxious stimuli—unpleasant sensations—travel upward to the spinal cord through the lateral spinal thalamic tracts and the dorsal columns. This impulse sparks a massive uninhibited sympathetic response through the intermediolateral cell column. Under normal conditions (in people with neurologically intact systems), the response is moderated by central inhibition, but for those with spinal cord injuries, the unopposed and pulsing sympathetic response induces severe hypertension.

In a cascading effect, the carotid sinus and aortic body baroreceptors stimulate the vasomotor center in the brain stem, which results in a vagal response precipitating autonomic dysreflexia symptoms. This leads to vasodilation above the spinal cord injury and vasoconstriction below the level of the injury. Patients with spinal cord injuries might have an increased responsiveness to vasopressors which could be due, in part, to increased reactivity of resistance vessels or decreased neuronal reuptake from the synaptic cleft.

The most common cause of autonomic dysreflexia is distension of the bladder, which can be caused by a kink in the urinary catheter, kidney stones, or infection of the urinary tract. Autonomic dysreflexia also can be caused by fecal impaction, pressure sores, fractures, menstruation, hemorrhoids, ingrown toenails, invasive testing, and sexual intercourse. Sometimes even seemingly harmless stimuli such as a crease in the bed sheet, sunburn, or a shoelace tied too tightly may invoke an episode of autonomic dysreflexia in patients with spinal cord injuries. In most cases, the condition will not resolve on its own after the stimulus is removed.

The key to prevention of autonomic dysreflexia in patients with spinal cord injuries is awareness of the triggers. Autonomic dysreflexia always should be anticipated, and caregivers should take appropriate precautions so they can respond immediately. This is particularly important in patients with high-level cord injuries. Radiologic technologists should speak with nurses certified in spinal cord injury care, nurse practitioners, physician assistants, or physician specialists before performing diagnostic examinations or interventional procedures to take steps to prevent iatrogenically (inadvertently) induced autonomic dysreflexia.

Special attention should be placed on Foley/suprapubic catheters when transferring patients to and from examination tables so the tubing doesn’t become kinked or twisted. Catheter disruptions can lead to urinary retention, impaired outflow, and possible autonomic dysreflexia, according to Juan Asanza, MD (written communication, October 2013). Seventy-five percent of autonomic dysreflexia cases in pediatric patients are caused by urological issues (bladder distension being the most common trigger). Bowel impaction is another common cause.

A lack of awareness about the symptoms of autonomic dysreflexia could lead to fatal complications in patients. Table 2 shows guidelines for identification and treatment of symptoms. Prompt identification
of this condition and rapid intervention are critically important to avoid death from autonomic dysreflexia in patients with spinal cord injury. If a radiologic technologist or radiologist suspects a patient is showing signs of autonomic dysreflexia, he or she should monitor vital signs, with a focus on blood pressure. The spinal cord injury unit, nurse, or provider should be contacted immediately for assistance.

**Considerations for Continuing Care Bladder**

Patients with spinal cord injuries should be monitored continuously for proper bladder management. Many of these patients do not have control over bladder functions because muscles in the lower urinary tract are often affected by spinal cord injury. These muscles include the detrusor muscle of the bladder and the valve muscles that open and close the sphincters in the bladder. The physiology of normal bladder function involves the brain stem and the spinal cord working in concert to keep the bladder relaxed and the sphincter muscles contracted so urine can fill the urinary bladder and not enter the urethra. During normal urination, the bladder contracts and the sphincter opens to allow urine to exit the bladder and enter the urethra. After a spinal cord injury a number of problems can occur in this normal bladder function, depending on the severity and level of the injury. Nerve-related lack of bladder control is known as neurogenic bladder.26 Each individual might prefer a different method of bladder management because of convenience, safety, and risk factors. The goal is to select the management system with the least morbidity and the highest ease of use for each particular patient.27 Suprapubic catheterization involves placing a catheter through the skin, subcutaneous tissue, and the rectal sheath into the retropubic space until it enters the bladder.28 To avoid complications during the procedure, ultrasonography

**Table 2**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Rationale</th>
</tr>
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<tbody>
<tr>
<td>Sit the patient upright.</td>
<td>This induces orthostatic hypotension to counter the hypertension.</td>
</tr>
<tr>
<td>Check in with the patient; ask if he or she suspects a cause of the symptoms.</td>
<td>Patients with spinal cord injuries often recognize the onset of autonomic dysreflexia and usually can assist health professionals. However, this might not be true for patients with a new injury.</td>
</tr>
<tr>
<td>Loosen or remove any restrictive clothing, including shoes.</td>
<td>Removing restrictive items relieves noxious stimuli.</td>
</tr>
<tr>
<td>Perform a survey of other possible causes of autonomic dysreflexia, beginning with bladder distention.</td>
<td>Urinary tract noxious stimuli is the usual cause of most cases of autonomic dysreflexia. Check for a kinked urinary drainage tube and ask the patient when his or her bladder was last emptied.</td>
</tr>
<tr>
<td>Check for fecal impaction.</td>
<td>Noxious stimuli resulting from fecal impaction can trigger autonomic dysreflexia. Ask the patient when bowel care was performed last and whether it was successful.</td>
</tr>
<tr>
<td>Perform a quick survey and assess the patient for bruising or recent injury. Check for fractures and hip dislocation.</td>
<td>Patients with spinal cord injuries might not feel the pain from a new fracture or dislocation and might not be aware it occurred.</td>
</tr>
<tr>
<td>Check for skin problems, pressure ulcers, infections, or burns.</td>
<td>These problems may be related to noxious stimulus below the level of injury.</td>
</tr>
<tr>
<td>If the patient’s systolic blood pressure remains above 150 mm Hg, administer a short- and fast-acting antihypertensive agent such as sublingual nifedipine or an intravenous agent of hydralazine or diazoxide.</td>
<td>Antihypertensive agents will relieve the dangerous blood pressure.</td>
</tr>
</tbody>
</table>
is used to ensure proper location and placement of the catheter. Complications of this procedure include bowel perforation and intra-abdominal visceral injuries. Other complications from suprapubic catheterization include leakage from the site or urethra, revision of the tube, and general surgical complications. A 2010 study by Katsumi et al suggested that morbidity from suprapubic catheter placement procedures might outweigh the benefits.

An alternative to the suprapubic catheter is a procedure known as clean intermittent catheterization. Clean intermittent catheterization alone or in combination with other methods of emptying the bladder is the most common method of bladder management among people with spinal cord injuries. The introduction of clean intermittent catheterization has led to remarkable improvements in problems associated with bladder incontinence. Clean intermittent catheterization involves inserting a urinary catheter, using sterile technique, via the urethra and into the bladder. A Swedish study found that patients using hydrophilic, low-friction techniques and catheters do as well as or better than patients with conventional catheters, and the authors demonstrated that use of the low-friction catheter seems to prevent urethral trauma and strictures.

Another option for bladder management is using conventional indwelling urethral catheters. Urologists avoid use of indwelling urinary catheters because of high infection and morbidity rates. Complications of the indwelling urinary catheter include urinary tract infection, ventral urethral erosion, and urethral fistula formation. Before 1940, patients with spinal cord injuries often died from complications of urinary tract infections a few months after the injury. After the advent of antibiotics later in that decade, deaths from urinary tract infections were replaced by kidney failure as the leading cause of death in patients with spinal cord injuries. Advances in clinical management and technology have reduced these deaths to 3% of patients with spinal cord injuries.

A study conducted at the Long Beach Veterans Administration Medical Center followed more than 600 men with spinal cord injuries who had sustained injuries between 1945 and 2007. The authors compared complications from indwelling urinary catheters vs indwelling suprapubic catheters. Morbidity associated with suprapubic catheterization offset any benefit from the slightly reduced complication rate related to using an indwelling urinary catheter. In addition, the authors found a similar rate of complications such as urinary tract infection, recurrent bladder and renal calculi, and development of cancer with both types of catheterization. Bladder cancer was listed as one of the most severe complications of the indwelling urinary catheter because of the development of squamous cell carcinoma. In the study, 2% to 10% of the patients developed cancer, and 80% of the participants in the sample had squamous changes in the bladder mucosa. The authors concluded that people with spinal cord injuries requiring chronic indwelling catheters for neurogenic bladders (regardless of type) should collaborate with their physician to select the catheter type based on long-term comfort and flexibility.

To minimize the occurrence of autonomic dysreflexia, radiologic technologists should help maintain proper urinary drainage for patients with spinal cord injuries who are undergoing imaging examinations. A simple assessment of the urinary drainage tubing and device is essential. If a patient has a urinary drainage bag, technologists should ensure that the tubing has not kinked in transport and that urine is flowing with gravity. A bent or occluded drainage tube can cause urine to build up in the bladder, potentially leading to a life-threatening episode of autonomic dysreflexia.

Radiologic technologists also should be aware that from a psychosocial point of view, loss of bladder control might diminish a patient’s subjective well-being. Nevertheless, patients with spinal cord injuries are accustomed to inquiries about bladder and bowel management, so imaging professionals need not feel apprehensive about asking these patients questions regarding bladder management. Because bladder and bowel issues are the 2 most common causes of autonomic dysreflexia in patients with spinal cord injuries, technologists must remain vigilant when these patients are in their care.

**Bowel Considerations**

Dysfunction of the bowel (eg, fecal incontinence, severe constipation, flatulence, and hemorrhoids)
in patients with spinal cord injuries is an important concern because of its role in quality-of-life issues and reintegration into the community. In a study of patients with spinal cord injuries published by Coggrave et al in 2009, respondents in the United Kingdom listed bowel dysfunction as the number one contributor to injury-related impairments. One of the first items that new patients face during rehabilitation is how to manage their bowel program. A patient-centered approach must be used to create a unique program that works for these individuals and their caregivers. The interdiscipli-
ary team must educate patients regarding their altered physiology after a spinal cord injury to implement an effective bowel care program.

Compilation of a baseline medical history for neurogenic bowel should be completed before implementing a bowel care program. This baseline assessment should include a premorbid history for daily fluid intake, diet (to include how much fiber the patient consumes, frequency of meals, and timing of meals), bowel movement frequency, the duration of the bowel movement, and a survey of the stool consistency (to include color, mucus, blood, and form). The baseline medical history for neurogenic bowel should include lifestyle goals, such as returning to the community, work and school sched-
ules, and the amount of time needed to complete the bowel care regime. Once an effective bowel care pro-
gram is established, the patient should strictly adhere to the program.

The time of day and frequency of bowel care can be adjusted to coincide with convenience for the patient and caregiver. Clinical guidelines for spinal cord injury medicine recommend that bowel care be completed no less than 3 times a week. Patients who neglect bowel care risk excessive buildup of stool in the bowel, which can become dry, less plastic, and difficult to eliminate. This accumulation of fecal matter stretches the colon, which adversely affects peristalsis, and renders the normal bowel care program ineffective. Bowel movements significantly affect health, well-being, self-esteem, modesty, and integration into the community. Because individuals with spinal cord injuries are unable to detect the sensation to defecate, control the anal sphincter, or sometimes position themselves for defecation, clean-up, and odor control, it is imperative that a preemptive strategy for regular and effective bowel management be fully implemented.

A correlation might exist between advancing age, length of time since injury, and changes in bowel function as a result of greater laxative use, use of strong rectal stimulants over time, and increased use of digital stimulation. Therefore, bowel function most likely deteriorates with time in people with spinal cord injuries. A recent study conducted in Korea by Kim et al reiterated that factors related to bowel care such as fecal incontinence, time in one defecation greater than 60 minutes, perianal skin irritations, and hemorrhoids are the factors that most greatly diminish the self-reported quality-of-life score.

Management of a neurogenic bowel includes stimu-
lation by chemical or physical methods. The patient also must be placed into a suitable position for defecation (usually a lateral recumbent position) and must be prepared to defecate. Some of the stimulation methods include digital rectal stimulation, manual evacuation, use of suppositories, and enemas. The most common form of defecation stimulation used in early rehabilitation is digital rectal stimulation, a procedure in which a gloved and lubricated finger is inserted into the rectum of the patient and rotated in a clockwise or counterclockwise motion to dilate and relax the distal rectum and anal canal. The continued rectal mucosal contact provides the stimulation for peristalsis and allows the fecal material, mucus, and gas to descend. Digital rotation continues until the bowel wall relaxes, flatus passes, stool is expelled, or the internal sphincter tightens. Digital rectal stimulation activates the recto-anal inhibitory reflex, which relaxes the internal sphincter, and the rectocolic reflex, which stimulates the pelvic nerve to commence peristalsis. The digital stimulation continues, and as stool descends, it is removed. This continues over a period of time until nothing but mucus is returned. At this point, the bowel care program is complete, and the patient can be cleaned.

In the Korean study, surveys were sent to 370 peo-
ple with spinal cord injuries with questions regarding defecation stimulation methods. Twenty-four percent of the respondents indicated they could defecate without stimulation, almost 60% responded that they used only one method, and approximately 12% indicated they used 2 or more bowel-care methods.
Directed Reading - Directed Reading

Patients with spinal cord injuries undergoing radiologic examinations or interventional procedures may or may not have had their scheduled bowel care before arriving in the radiology department. These patients are accustomed to managed bowel care programs, so technologists need not be apprehensive about asking patients if they have had bowel care. In addition, patients who have spinal cord injuries may be unaware that they have had an episode of incontinence or flatus because they might have absent or diminished sensation. Technologists should be prepared for this occurrence and should be ready to assist the patient. If the patient indicates a need for bowel care, radiology personnel should immediately contact the caregiver for assistance.

Pressure Ulcers

Pressure ulcers pose one of the greatest risks to the overall health and well-being of people who have spinal cord injuries, and many questions remain regarding how best to prevent and manage skin breakdown and subsequent pressure ulcer development. A pressure ulcer is localized injury to the skin or underlying tissue, usually over a bony prominence, as a result of pressure or pressure and shear. Epidemiological data show that pressure ulcers represent a lifelong threat to people who have spinal cord injuries, with 15% to 30% of spinal cord injury patients having had pressure ulcers during their lifetime. Acute care rehabilitation data suggest that individuals with spinal cord injuries who have complete tetraplegia are at the highest risk of developing a pressure ulcer (53%), followed by those with complete paraplegia (39%), incomplete tetraplegia (29%), and incomplete paraplegia (18%).

Pressure ulcers account for 24% of morbidity during the rehabilitation period, and the likelihood that patients will experience pressure ulcers increases over time. In 2007 it was estimated that the cost of treating pressure ulcers in the United States was $9 billion to $11 billion a year, with approximately $70,000 worth of expenses per hospitalization. In addition to the economic effect, chronic pressure ulcers represent a significant source of morbidity and mortality in people who have spinal cord injuries.

Risk factors for developing pressure ulcers fall into 2 groups: intrinsic and extrinsic. Intrinsic factors include age, limited mobility, inability to reposition independently, and loss of sensation. The loss of sensation contributes to tissue injury and subsequent ischemia. Extrinsic factors include pressure, humidity, friction, and shear force. The normal capillary filling pressure is 32 mm Hg, and patients who change positions infrequently or who are bedridden for extended periods greatly exceed the normal capillary filling pressure, thereby promoting skin ulcer formation. Lack of bowel and bladder control also contributes to risk because the addition of moisture and bacteria can promote skin breakdown. Transferring a patient from bed to stretcher can cause friction and shearing damage to the outer layers of the skin. Patients at particular risk are those who keep the head of the bed elevated at 30° or more. Capillary loops in the skin are vertically oriented, so when lateral forces are applied (shear), capillary loops are easily kinked, which results in dermal ischemia and necrosis.

The predominant location of pressure sores is the lower portion of the body, particularly the sacral region and the heels. Other common locations for pressure sores are bony structures that bear weight, such as the elbows, ankles, ischia, knees, scapulas, shoulders, and occiput.

As the number of people who have spinal cord injuries increases in this country, more caregivers will need the skills to assess and treat pressure ulcers. Measuring pressure ulcers can be time consuming and requires descriptions of the wound depth, circumference, length, undermining, and tunneling. Undermining can occur around the edges of the wound and is a space between the intact skin and the wound bed. It can appear as a “roof” over part of the wound. Undermining can occur from shear forces combined with sustained pressure on the wound. Tunneling occurs when a channel is formed through subcutaneous tissue or muscle to another part of the wound. Clinicians measure tunneling and undermining in centimeters by gently probing the wound with a graduated device as far as it will go without exerting undue force. The position and orientation of a tunnel is documented using a clock face, with 12 o’clock representing the patient’s head and 6 o’clock representing the patient’s feet. A variety of scales to measure and monitor...
pressure wounds are available. The goal of these tools is to provide objective and quantifying data that can be used to optimize the treatment and care of the wounds, but currently no international standard exists for measuring and classifying pressure ulcers.

A 2010 study in the Netherlands evaluated 3 different scales for efficiency: the Pressure Sore Status Tool, the Pressure Ulcer Scale for Healing, and the Sessing scale. According to the study’s authors, the most comprehensive is the Pressure Sore Status Tool scale, which consists of 13 domains in 5 categories. The Pressure Ulcer Scale for Healing scale assesses 3 domains and categorizes the surface of the wound by multiplying the longest length by the longest width while considering other wound attributes such as the amount of exudate and tissue type. The Sessing scale consists of 7 categories but does not include measurements. The authors reported advantages and disadvantages to each method. Specialists at the Long Beach Veterans Administration Medical Center in Long Beach, California, developed and implemented the Pressure Ulcer Monitoring Tool to collect data about wounds to design optimal clinical care, according to Asanza (written communication, October 2012).

The National Pressure Ulcer Advisory Panel is a recognized leader in the United States for promoting awareness of pressure ulcers. The staging system this organization endorses is the Shea system developed in 1975 (see Table 3).

Management of pressure ulcers requires a multidisciplinary team taking a holistic approach to include the patient’s biologic, psychological, and social needs to optimize conditions for healing. Four components to pressure ulcer management include prevention, correction of causative factors, debridement, and moist wound healing.

One of the tools used to prevent formation of pressure ulcers is the Braden scale. Components of this assessment tool include:

- Sensory perception.
- Skin moisture.
- Physical activity.
- Nutritional intake.
- Friction and shear.
- The patient’s ability to reposition.

Numeric values are assigned to determine the risk factor. The Braden scale score determines the level of risk. Interventions can be applied to alleviate and minimize the risk conditions based on the scores. For example, if an assessor rates a patient as “unable to reposition,” the caregiver might implement an intervention to turn the patient every 2 hours. Treatment of the pressure ulcer might include use of moist dressings, application of vacuum wound devices, surgical debridement, intravenous antibiotic therapy, use of biologics, and more. One study suggested that the use of medical-grade honey in the treatment of pressure ulcers could show some promise and that its use warrants further research.

Despite the fact that many people with spinal cord injuries receive good care, pressure ulcers remain a fact of life for them. Causes and consequences are numerous, and the sequelae are complex. Personnel in the radiology department should be cognizant of patients’ inability to reposition and should monitor them frequently. Pressure relief interventions such as using cushions on the examination table and frequent repositioning should be implemented.

**Respiratory Considerations**

Immediately following spinal cord injury, respiratory failure can occur as a result of complete or partial respiratory muscle paralysis, fatigue of the remaining intact musculature, or because of other pleuropulmonary pathology. After patients are stabilized, respiratory complications including pneumonia continue to be one of the leading causes of death for individuals with spinal cord injuries. Loss of lung volume is related to loss of respiratory muscle innervation for individuals with complete tetraplegia.

The severity of respiratory impairment is directly related to the level of the injury. For example, injuries to the nerves high in the cervical cord, from C1 through C4, are associated with the greatest respiratory muscle dysfunction, and patients with injury at C1 and C2 cannot maintain effective spontaneous ventilation. Injuries to the nerves in the lower cervical cord from C5 through C8 affect the intercostal, parasternal, scalene,
Table 3
National Pressure Ulcer Advisory Panel Staging System

<table>
<thead>
<tr>
<th>Category</th>
<th>Extent of Injury</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I</td>
<td>Nonblanchable erythema</td>
<td>Intact skin with nonblanchable redness of a localized area usually over a bony prominence.</td>
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<td></td>
<td></td>
<td>Darkly pigmented skin might not have visible blanching; its color might differ from the</td>
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<td></td>
<td></td>
<td>surrounding area.</td>
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<td></td>
<td></td>
<td>The area might be painful, firm, soft, and warmer or cooler than the adjacent tissue.</td>
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<td></td>
<td>Category I might be difficult to detect in individuals with dark skin tones.</td>
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<tr>
<td></td>
<td></td>
<td>May indicate “at risk” persons.</td>
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<tr>
<td>Stage II</td>
<td>Partial thickness</td>
<td>Loss of dermis presenting as a shallow open ulcer with a red or pink wound bed, without</td>
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<td></td>
<td></td>
<td>slough.</td>
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<td></td>
<td></td>
<td>May present as an intact or ruptured serum-filled or sero-sanginous filled blister.</td>
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<tr>
<td></td>
<td></td>
<td>Presents as a shiny or dry shallow ulcer without slough or bruising.</td>
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<tr>
<td></td>
<td></td>
<td>This category should not be used to describe skin tears, tape burns, incontinence-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>associated dermatitis, maceration, or excoriation.</td>
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<tr>
<td>Stage III</td>
<td>Full thickness skin loss</td>
<td>Full thickness tissue loss.</td>
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<tr>
<td></td>
<td></td>
<td>Subcutaneous fat might be visible, but bone, tendon, or muscle is not exposed.</td>
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<td></td>
<td></td>
<td>Slough might be present but does not obscure the depth of tissue loss.</td>
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<tr>
<td></td>
<td></td>
<td>Might include undermining and tunneling.</td>
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<tr>
<td></td>
<td></td>
<td>The depth of a Stage III pressure ulcer varies by anatomical location.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The bridge of the nose, ear, occiput, and malleolus do not have subcutaneous (adipose)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tissue, and Stage III ulcers can be shallow.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In contrast, areas of significant adiposity can develop extremely deep Stage III pressure</td>
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<tr>
<td></td>
<td></td>
<td>ulcers.</td>
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<td></td>
<td></td>
<td>Bone or tendon is not visible or directly palpable.</td>
</tr>
<tr>
<td>Stage IV</td>
<td>Full thickness tissue loss</td>
<td>Full thickness tissue loss with exposed bone, tendon, or muscle.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slough or eschar might be present.</td>
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<tr>
<td></td>
<td></td>
<td>Often includes undermining and tunneling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The depth of a Stage IV pressure ulcer varies by anatomical location.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The bridge of the nose, ear, occiput, and malleolus do not have subcutaneous (adipose)</td>
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<tr>
<td></td>
<td></td>
<td>tissue, and these ulcers can be shallow.</td>
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<td></td>
<td></td>
<td>Stage IV ulcers can extend into muscle and/or supporting structures (eg, fascia, tendon, or</td>
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<td></td>
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<td>joint capsule), making osteomyelitis or osteitis likely to occur.</td>
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<td></td>
<td></td>
<td>Exposed bone or muscle is visible or directly palpable.</td>
</tr>
<tr>
<td>Unstageable/</td>
<td>Full thickness skin or tissue loss depth unknown</td>
<td>Full thickness tissue loss in which actual depth of the ulcer is completely obscured by</td>
</tr>
<tr>
<td>Unclassified</td>
<td></td>
<td>slough (yellow, tan, gray, green, or brown) and/or eschar (tan, brown, or black) in the</td>
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<td></td>
<td></td>
<td>wound bed.</td>
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<td></td>
<td>Until enough slough and/or eschar are removed to expose the base of the wound, the true</td>
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<td></td>
<td>depth cannot be determined; but it will be either a Stage III or IV.</td>
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<td></td>
<td></td>
<td>Stable (ie, dry, adherent, intact without erythema or fluctuance) eschar on the heels serves</td>
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<td></td>
<td>as “the body’s natural (biological) cover” and should not be removed.</td>
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<tr>
<td>Suspected Deep Tissue</td>
<td></td>
<td>Purple or maroon localized area of discolored intact skin or blood-filled blister due to</td>
</tr>
<tr>
<td>Injury</td>
<td></td>
<td>damage of underlying soft tissue from pressure and/or shear.</td>
</tr>
<tr>
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<td></td>
<td>The area might be preceded by tissue that is painful, firm, mushy, boggy, or warmer or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cooler than adjacent tissue.</td>
</tr>
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<td></td>
<td></td>
<td>Deep tissue injury might be difficult to detect in individuals with dark skin tones.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evolution might include a thin blister over a dark wound bed. The wound might further</td>
</tr>
<tr>
<td></td>
<td></td>
<td>evolve and become covered by thin eschar.</td>
</tr>
</tbody>
</table>


*Bruising indicates deep tissue injury.
and abdominal muscles but render the diaphragm, trapezi, sternocleidomastoid, and clavicular portion of the pectoralis major muscles intact, which can lead to diminished cough capacity. When these patients contract an upper respiratory infection, they have difficulty clearing airway secretions because of the inability to produce a strong cough.

Signs of respiratory distress could include coughing, poor chest wall expansion, rales or rhonchi, pallor, cyanosis, tachycardia, paradoxical movement of the chest wall, increased or labored accessory muscle use, agitation, and panic. Registered nurses or respiratory therapy personnel should be available to clear respiratory secretions for patients undergoing examinations or procedures when indicated.

**Additional Complications**

Additional complications of spinal cord injuries are precipitated by 3 subsequent phenomena that occur below the level of injury:

- A reduction in overall sympathetic activity.
- Morphological changes in sympathetic preganglionic neurons.
- Peripheral alpha-adrenoceptor hyper-responsiveness.

Moreover, cardiovascular disease is one of the top causes of morbidity and mortality in patients with spinal cord injuries. Lack of exercise, decreased muscle mass, and a host of metabolic syndrome type conditions contribute to this risk. Cases of silent myocardial ischemia have occurred during episodes of autonomic dysreflexia. Loss of sensory input from the myocardium to the supraspinal structures places patients with spinal cord injuries at risk for asymptomatic myocardial ischemia. During an episode of autonomic dysreflexia, there is an increase in the visceral sympathetic activity with associated coronary artery constriction, which can lead to myocardial ischemia, even if the patient does not have preexisting coronary artery disease.

Neurogenic shock is one way that autonomic nervous system dysfunction is manifested following a spinal cord injury. Neurogenic shock is a life-threatening decrease in blood pressure resulting from a sudden loss of signals from the sympathetic nervous system after a spinal cord or brain injury. Neurogenic shock most likely occurs because of an imbalance in autonomic control from intact parasympathetic stimuli via the vagal nerve and a loss of sympathetic tone because of disruption in the supraspinal control center.

Reversible cerebral vasoconstriction syndrome also has been associated with autonomic dysreflexia and is characterized by the sudden onset of severe headache, which might include neurological deficits, and reversible narrowing of the vasculature of the Circle of Willis and its associated branches. It occurs most commonly in women with spinal cord injuries from 20 to 50 years of age.

**Pediatric Patients**

Approximately 5% of spinal cord injuries in North America occur in children 15 years old or younger. Spinal cord injuries in boys are more common during adolescence, but incidence is equal between girls and boys younger than 5 years of age. Motor vehicle accidents cause most spinal cord injuries in children and adolescents, but violence accounts for large numbers of injuries in pediatric patients. Children have a higher risk of spinal cord injury from seatbelts and abuse. They also are more likely to have spinal cord injuries without radiologic abnormalities. Conventional radiographs, computed tomography (CT), and dynamic flexion and extension studies can appear normal in more than half of children who have spinal cord injuries that show no radiologic abnormalities. This increases to an incidence of 64% in children younger than 5 years of age who have spinal cord injuries.

Many of the events that cause spinal cord injury in pediatric patients are extremely traumatic and could put these patients and their families at risk for posttraumatic stress disorder (PTSD). Boyer et al stated 3 reasons children who have a spinal cord injury during childhood or adolescence are at an increased risk for PTSD:

- The injury usually is caused by a traumatic event.
- The acquisition of the injury might indicate a greater severity of that traumatic event.
- The injury represents a life-changing and, at times, life-threatening medical condition.

Adults with pediatric-onset spinal cord injury have unique medical complications and risk having other sequelae. Because pediatric patients have a longer life...
span than patients whose spinal cord injury occurred during adulthood, they might have a heightened risk of pressure ulcers. In addition, sudden onset of spinal cord injury in school-aged children compels them to return to their earlier dependence on their parents, thereby disrupting the typical trajectory of increasing autonomy that is part of the developmental process. Therefore, one of the primary objectives of the pediatric rehabilitative process is to facilitate a positive adjustment to adulthood. 

Studies have demonstrated a negative relationship among medical complications, life satisfaction, jobs and income, and independent living in adults with pediatric-onset spinal cord injuries.

**Psychosocial and Sexual Considerations**

A number of studies have measured subjective well-being and other quality-of-life issues in people who have spinal cord injuries. Researchers found it difficult to distinguish between a temporary depressed mood and a persistent adjustment disorder immediately after the patient’s initial injury. People with spinal cord injuries tend to report higher levels of distress and a lower overall life satisfaction than the general population. This is not to say that all of these people report unhappiness; many have adapted well.

Assistive technology such as advanced mobility devices and technology that allows people with spinal cord injuries to more effectively interact with the world around them contributes to better rehabilitative outcomes. Spinal cord medicine professionals have organized and are sharing data at a global level to promote awareness and add to the spinal cord injury body of knowledge. The State of the Science Conference in Spinal Cord Injury Rehabilitation 2011 represented an international multidisciplinary team that focused on establishing a long-term research agenda for spinal cord injury medicine.

A European study conducted by Kennedy et al in 2006 focused on unmet needs of individuals with spinal cord injuries in the United Kingdom, Germany, Austria, and Switzerland. The needs that participants rated as highly met were necessities relating to skin management, wheelchair use, and accommodations for mobility. The unmet needs the participants identified most were gainful occupation, sexual activity, and pain relief. Lack of mobility, social isolation, and diminished self-esteem, combined with bowel and bladder management issues, contribute to depression and a feeling of isolation in some people living with spinal cord injuries.

Spinal cord injuries have significant psychological and physical arousal issues on both men and women. Many people with spinal cord injuries report having difficulty becoming psychologically and physically aroused, which contributes to an altered sense of the individual’s sexual self. Erectile dysfunction has been reported as a serious determinant of psychological distress in men. Treatment of erectile dysfunction with sildenafil has been reported to significantly improve the quality of life for men with erectile dysfunction caused by spinal cord injury. Nevertheless, bowel and bladder incontinence and the risk of autonomic dysreflexia also have been reported to negatively affect sexual activity and intercourse. Researchers continue to work on developing methods and strategies for people with spinal cord injuries to develop forms of sexual pleasure and activity so they can return to the most optimal lifestyle possible.

**Pain Management**

People who have spinal cord injuries list pain among the top most disabling conditions secondary to their injury. Some patients experience relentless and unremitting levels of pain despite best efforts to alleviate it. One study suggested that individuals report neuropathic pain from spinal cord injury is worse at night than at other times of the day. Neuropathic pain occurs when nerve fibers are damaged and send incorrect signals to pain centers. These patients must learn to adapt to life with some degree of chronic pain.

The International Spinal Cord Injury Pain classification was established to create a method for classifying pain reported by people with spinal cord injuries. The classification system was established with the premise that pain must be classified properly before it can be treated effectively. The system is comprehensive enough to be used by both experienced and inexperienced clinicians as well as clinical researchers. Its design incorporates pain that is directly related to spinal cord injury, along with pain not mechanically related to the spinal cord injury.
Care Considerations for Patients With Spinal Cord Injuries

The system examines pain relative to 3 tiers: the pain type, subtype, and the primary source or pathology.\textsuperscript{71} The International Spinal Cord Injury Pain classification system comprises assessments for nociceptive pain, which includes musculoskeletal, visceral, and other nociceptive pain. The system also includes neuropathic pain with an assessment of the level of pain relative to the spinal cord injury location and a category for other pain including fibromyalgia, complex regional pain syndrome type I, interstitial cystitis, and irritable bowel syndrome. The system also includes a category for unknown pain. Studies were conducted with clinicians to validate the reliability of the International Spinal Cord Injury Pain classification tool. Results showed that with training, clinicians achieved satisfactory results but further testing is indicated, including applying the tool to individuals who have pain from spinal cord injury.\textsuperscript{72}

Chronic pain that impairs quality of life in spinal cord injury patients has led to a substantial increase in research directed at managing pain related to the condition.\textsuperscript{73} Several studies have examined how pain affects the overall quality of life for these patients, the use of a variety of treatments for people who have chronic pain following spinal cord injury, and patients’ ability to adjust to chronic pain.\textsuperscript{68,74-80}

Management of chronic pain is an important attribute of long-term quality-of-life indicators.\textsuperscript{73} Pain treatment therapies consist of the use of pain medications, complementary therapies such as acupuncture and massage, external Qigong therapy, physical therapy, and more. In 2010, authors Norrbrink and Lundeborg reported that neuropathic pain after spinal cord injury only narrowly responded to most interventions but that both acupuncture and massage might relieve some neuropathic pain in individuals with spinal cord injuries.\textsuperscript{81} Care plans should effectively address comorbid pain and depression after a spinal cord injury because the 2 conditions are linked in this patient population.\textsuperscript{76}

**Medical Imaging**

Obtaining an accurate assessment of initial damage to the spinal cord is imperative so physicians can implement the optimal neuroprotective intervention. Conventional radiography is an inexpensive and beneficial tool to demonstrate vertebral misalignment or fracture or foreign body fragments lodged in the spine, but it is not as specific as magnetic resonance (MR) imaging or CT for demonstrating detailed information about the spinal cord, disk spaces, and bleeding. Conventional MR imaging is currently considered the best modality for evaluating the extent of injury in patients with traumatic spinal cord injuries.\textsuperscript{82} Cord compression, edema, and hemorrhage can easily be identified using standard clinical MR sequences (see Figure 7). The presence of large intraparenchymal hemorrhages has been shown to be an indicator of poor outcome following traumatic spinal cord injury.\textsuperscript{82} Unfortunately, conventional MR does not sufficiently display the integrity of

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*Figure 7. Magnetic resonance image of a cervical spine injury in a 28-year-old man who, while intoxicated, fell 30 feet after climbing a tree to escape the police. Tetraplegia was immediate upon impact. Used with permission © SpineUniverse.com.*
the long white-matter tracts responsible for the majority of the deficits following a traumatic spinal cord injury. However, diffusion-weighted imaging is reported to be more effective and yield a higher diagnostic value than conventional MR.\(^2\)

T2-weighted and diffusion-weighted imaging were shown to have comparable detection rates for spinal cord damage in patients with spinal cord trauma within 24 hours of injury.\(^2\) Pouw et al stated that spinal cord white matter tracts are well organized in the craniocaudal direction, and diffusion is anisotropically oriented (ie, differing from the direction of the white matter tracts), with a higher apparent diffusion coefficient along the fibers than transversely. Therefore, diffusion-weighted imaging is useful to evaluate the integrity of the white matter tracts in the spinal cord and might be able to provide more information than conventional MR techniques.\(^2\)

CT is an excellent modality for detecting bone fractures, bleeding, and spinal stenosis, but it is not optimal for imaging of the spinal cord or for identifying ligament injury associated with an unstable spine.\(^1\)

**Patient Care Considerations in Radiology**

Patients who have spinal cord injuries have unique needs that require interventions designed to promote an optimal and safe environment during a diagnostic imaging examination. Radiologic technologists should recognize these needs so they can respond competently and compassionately. For example, the department should have transport stretchers that are height-adjustable to allow safe transfers of patients to and from the examination tables. Other concerns include the prevention of pressure ulcers, the patient’s bowel and bladder management, pain control, recognition of early signs and symptoms of autonomic dysreflexia, and, in some cases, pulmonary and respiratory support. Technologists should be equipped to intervene promptly if signs and symptoms of autonomic dysreflexia develop during a procedure. They should consult with nurses and clinicians to identify specific needs a patient might have before beginning an examination or procedure. Before performing a medical imaging procedure, the technologist should determine whether the patient:

- Requires bowel care before the examination.
- Has any existing wounds.
- Can tolerate the pressure from the examination table.
- Has a history of autonomic dysreflexia.
- Requires specific positioning aids.
- Requires manual ventilation.
- Has adaptive equipment for communication.
- Requires administration of an anxiolytic agent.

Patients who have sustained a spinal cord injury as a result of a traumatic battlefield injury might suffer from PTSD. These patients might need special assistance while undergoing procedures that involve CT or MR scanners.

Because pain is one of the most difficult chronic conditions that people with spinal cord injuries face, technologists should assess patients in their care periodically for pain. Prompt intervention to mediate the pain by repositioning, the use of pharmacological agents, or other comfort measures should occur if the patient reports a pain level higher than a 5 on a scale of 1 to 10. Radiologic technologists should not hesitate to contact trained spinal cord injury caregivers before receiving the patient in the department. Patients with spinal cord injuries typically understand that they have unique care needs, and many patients appreciate the willingness of other health care providers to participate in an optimal care plan.

**Advances in Treatment**

Despite recent advances in spinal cord injury medicine, research and development needs to continue. Advances in adaptive technology are promising, but they do not address the biological need to regenerate the central nervous system.

In January 2013, doctors at the Miami Project to Cure Paralysis, part of the University of Miami Miller School of Medicine, announced the first phase of the first clinical trial to transplant a patient’s own Schwann cells, the cells that myelinate axons.\(^3\) According to neurosurgeon Barth Green, MD:

> This historic clinical trial represents a giant step forward in a field of medicine where each tangible step has tremendous value. This trial, and these first patients in this trial specifically, are extremely important to our mission of curing paralysis.\(^3\)
A study in India examined the use of autologous mesenchymal stem cells to treat patients with chronic spinal cord injury. The two patients in that study reported limited improvement in pinprick sensation below the level of injury.

Some anti-inflammatory medications such as rolipram show promise in regenerating axonal growth by stimulating central nervous system axons through inhibition of amino acid toxicity and resultant cell death after initial injury. Monoclonal antibodies such as Nogo-A are being studied because of their ability to block proteins that inhibit the regeneration of axons after an injury. Cethrin is a protein that stops activation of Rho, another protein that blocks axonal regeneration and has been tested in clinical trials. Histone deacetylases are a class of compounds that regulate gene expression and can limit cell regeneration after traumatic spinal cord injury. Preclinical studies are underway that could inhibit histone deacetylase activity and thereby allow axons to regenerate in spinal cord injury regions.

Other promising advances include chondroitinase ABC to clear away tangled and damaged proteins and sugars around the injury site, implanted matrices that allow the axons to bridge over the lesion, cell replacement using stem cells and glial cells, use of human oligodendrocyte progenitor cells to promote myelination, transplantation of bone marrow stromal cells, and use of nasal olfactory ensheathing cells to replace and encourage remyelination of the lesion site. More futuristic approaches include brain-computer interfaces, which use technology implanted into the damaged nerve system to reestablish a link from the brain to the muscles, and neural implanted impulse technology that coordinates movements to prosthetic limbs.

In a recent Chinese study, rodents with spinal cord injuries were vaccinated with dendritic cells pulsed with spinal cord homogenates. Researchers reported that the implanted dendritic cells pulsed with homogenate protein from the spinal cord showed promise relative to functional recovery and neural preservation in mice. They found that this procedure improved functional recovery and decreased the area of cysts and the density of glial scarring.

Research methods and clinical trials are varied, and many show promise. However, more research in neuroprotection, cell regeneration, cell replacement, and retraining central nervous system circuits will help advance spinal cord medicine toward a cure for paralysis. Until there is a cure, radiologic technologists and other health care professionals should be equipped to provide the best care possible for these patients.

**Conclusion**

Patients with spinal cord injuries arrive at the radiology department with a variety of unique medical and psychological needs. Awareness of the patients’ specific care considerations should be part of the core competency set for department personnel. For example, prompt recognition of autonomic dysreflexia leads to rapid intervention and can avoid a life-threatening episode. Radiology personnel should collaborate with the interdisciplinary care team before conducting any diagnostic examination or interventional procedure on a patient who has a new or chronic spinal cord injury. Knowledge of these patients’ special needs and compassionate application of care considerations will help create a safe and comfortable environment for the individual who has a spinal cord injury.

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Reprint requests may be mailed to the American Society of Radiologic Technologists, Communications Department,
References


Care Considerations for Patients With Spinal Cord Injuries

1. The average age of patients at the time of a spinal cord injury is _______ years.
   a. 15
   b. 24
   c. 36
   d. 41

2. The collection of nerves located at the end of the spinal cord is called the conus ________.
   a. equinas
   b. medullaris
   c. terminale
   d. foramina

3. Motor neurons conduct impulses:
   a. from the central nervous system to the muscles or glands.
   b. from receptors in the skin.
   c. from skeletal muscles and joints.
   d. from internal organs.

4. _______ are branching projections that provide a larger surface area to pass a chemical signal to many target cells simultaneously.
   a. Axons
   b. Dendrites
   c. Interneurons
   d. Sensory ganglia

5. Sensory innervation to which of the following controls the sphincters and the parasympathetic impulses to control the bladder and the lower bowel?
   a. thoracic region
   b. pelvic articulate
   c. coccygeal region
   d. saddle area
6. According to the article, the number of spinal cord injuries from which of the following have increased?
   a. football
   b. skiing
   c. motor vehicle accidents
   d. violence

7. Which of the following populations has the lowest incident rates for spinal cord injury?
   a. people aged 16 to 30 years.
   b. men
   c. children
   d. women

8. Spinal shock results in:
   1. complete paralysis.
   2. loss of reflexes.
   3. loss of sensation.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

9. According to the American Spinal Injury Association Impairment Scale, a complete injury represents the absence of sensory and motor function in the lowest sacral segments.
   a. true
   b. false

10. Paraplegia usually results from an injury in which of the following spine segments?
   1. cervical
   2. thoracic
   3. lumbar
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

11. Injuries that occur above the level of ______ can result in immediate, life-threatening cardiovascular complications.
   a. S5
   b. L5
   c. T5
   d. C5

12. Autonomic dysreflexia is a potentially life-threatening medical emergency that seems to be most common in patients:
   a. who are young and have lived with the injury for years.
   b. who are older with new traumatic injuries.
   c. with injuries below the level of T10.
   d. with bradycardia.

13. Which of the following are signs and symptoms of autonomic dysreflexia?
   1. sudden increase in blood pressure
   2. reflex bradycardia
   3. sweating
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

continued on next page
14. The **most** common cause of autonomic dysreflexia is:
   a. distension of the bladder.
   b. fecal impaction.
   c. pressure sores.
   d. hemorrhoids.

15. According to the article, the first procedure in treating a patient with autonomic dysreflexia is to:
   a. loosen or remove any restrictive clothing to relieve noxious stimuli.
   b. sit the patient upright to induce orthostatic hypotension to counter the hypertension.
   c. check for fecal impaction.
   d. administer an antihypertensive agent.

16. If a radiologic technologist suspects a patient is showing signs of autonomic dysreflexia, he or she should monitor vital signs with a focus on:
   a. heart rate.
   b. respiration.
   c. blood pressure.
   d. temperature.

17. According to the article, which type of catheter has led to remarkable improvements in problems associated with bladder incontinence?
   a. an indwelling catheter
   b. suprapubic catheterization
   c. clean intermittent catheterization
   d. filiform catheterization

18. Prior to 1940, people with spinal cord injuries typically died from:
   a. respiratory issues.
   b. urinary tract infections.
   c. kidney failure.
   d. pressure ulcers and resultant osteomyelitis.

19. According to a study at the Long Beach Veterans Administration Medical Center, bladder cancer was listed as one of the most severe complications of:
   a. an indwelling catheter.
   b. suprapubic catheterization.
   c. clean intermittent catheterization.
   d. filiform catheterization.

20. According to a 2009 study by Coggrave et al, which of the following did respondents list as the number-one contributor to injury-related impairments?
   a. bladder dysfunction
   b. bowel dysfunction
   c. pressure ulcers
   d. risk of autonomic dysreflexia

21. Patients with spinal cord injuries of which level are at the **highest** risk of developing pressure ulcers?
   a. complete tetraplegia
   b. complete paraplegia
   c. incomplete tetraplegia
   d. incomplete paraplegia

22. Intrinsic risk factors related to pressure ulcers include:
   1. friction.
   2. age.
   3. limited mobility.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3
23. According to the National Pressure Ulcer Advisory Panel staging system, a stage II pressure ulcer is described as:
   a. a nonblanchable redness with intact skin.
   b. a partial thickness wound with a loss of the dermis presenting as a shallow open ulcer.
   c. a full thickness wound with tissue loss and possible visible fat but no visible bone, muscle, or tendon.
   d. full thickness tissue loss.

24. Radiologic technologists can help prevent and manage pressure ulcers by using cushions on the examination table and frequently repositioning patients.
   a. true
   b. false

25. Patients with nerve injury at ______ cannot maintain effective spontaneous ventilation.
   a. C1 through C2
   b. C3 through C4
   c. C5 through C6
   d. C7 through C8

26. According to the article, cardiovascular disease is one of the leading causes of morbidity and mortality in individuals with spinal cord injuries because of:
   1. lack of exercise.
   2. decreased muscle mass.
   3. diet.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

27. Kennedy et al found that the main unmet needs of people with spinal cord injuries are gainful occupation, sexual activity, and:
   a. skin management.
   b. wheelchair accommodations.
   c. pain relief.
   d. treatment for posttraumatic stress disorder.

28. According to the article, which of the following is considered the best modality for evaluating the extent of injury in patients with traumatic spinal cord injuries?
   a. computed tomography
   b. conventional magnetic resonance imaging
   c. plain radiographs
   d. diffusion-weighted magnetic resonance imaging

29. Before performing a medical imaging procedure, the radiologic technologist should determine whether the patient:
   1. requires bowel care.
   2. can tolerate pressure from the examination table.
   3. has a history of autonomic dysreflexia.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

30. The clinical trial by the Miami Project to Cure Paralysis is the first trial of transplanting which type of a patient’s own cells?
   a. Schwann
   b. mesenchymal
   c. Dexter
   d. filiform
Directed Reading Evaluation
Spinal Cord Injuries

Thank you for taking the time to complete this evaluation. Your opinion helps us serve you better. Your comments will remain confidential and will not affect the scoring of your Directed Reading (DR) test. Choose only ONE response for each question. Use a blue or black ink pen. Do not use felt tip markers. Completely fill in the circles.

1. Why did you choose to complete this DR?
   ○ Interested in the topic
   ○ Needed CE credits immediately
   ○ Other

2. How relevant is this DR to your practice?
   ○ Very relevant
   ○ Relevant
   ○ Somewhat relevant
   ○ Not relevant

3. How beneficial is this DR to your professional or personal development?
   ○ Very beneficial
   ○ Beneficial
   ○ Somewhat beneficial
   ○ Not beneficial

4. How would you rate the level of difficulty of this DR?
   ○ Too difficult
   ○ Somewhat difficult
   ○ Just the right level
   ○ Somewhat easy
   ○ Too easy

5. How would you rate the length of this DR?
   ○ Too long
   ○ Somewhat long
   ○ Just the right length
   ○ Somewhat short
   ○ Too short

6. Did this DR meet your expectations?
   ○ Yes
   ○ Partially
   ○ No

7. Would you recommend this DR to a colleague?
   ○ Yes
   ○ No

8. Overall, how valuable are the DRs to you?
   ○ Very valuable
   ○ Valuable
   ○ Somewhat valuable
   ○ Not very valuable

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Care Considerations for Patients With Spinal Cord Injuries

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1 ○ ○ ○ ○ ○  11 ○ ○ ○ ○ ○  21 ○ ○ ○ ○ ○
2 ○ ○ ○ ○ ○  12 ○ ○ ○ ○ ○  22 ○ ○ ○ ○ ○
3 ○ ○ ○ ○ ○  13 ○ ○ ○ ○ ○  23 ○ ○ ○ ○ ○
4 ○ ○ ○ ○ ○  14 ○ ○ ○ ○ ○  24 ○ ○ ○ ○ ○
5 ○ ○ ○ ○ ○  15 ○ ○ ○ ○ ○  25 ○ ○ ○ ○ ○
6 ○ ○ ○ ○ ○  16 ○ ○ ○ ○ ○  26 ○ ○ ○ ○ ○
7 ○ ○ ○ ○ ○  17 ○ ○ ○ ○ ○  27 ○ ○ ○ ○ ○
8 ○ ○ ○ ○ ○  18 ○ ○ ○ ○ ○  28 ○ ○ ○ ○ ○
9 ○ ○ ○ ○ ○  19 ○ ○ ○ ○ ○  29 ○ ○ ○ ○ ○
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Reducing Errors in Radiology

Joyce Helena Brusin, MFA

Medical errors, even those that are relatively minor, can have serious consequences, such as misdiagnosis and longer and costlier hospital stays. Reducing errors requires all members of the health care clinical and administrative team to commit to the effort, and effective risk management addresses system-wide causes of errors. Errors often result from poor communication, inadequate training, chronic fatigue, and entrenched workplace hierarchies. Error reduction strategies support high-quality patient care, even in the most stressful and complex situations.

After completing this article, the reader should be able to:
- Define terms such as medical error, adverse event, and sentinel event in medical care.
- Explain how patient transfers provide opportunities for preventing errors.
- Describe how good communication practices can help avert medical errors.
- Discuss how specific approaches to medical imaging can help avoid errors in assessing and diagnosing patients in the emergency department and patients with multiple trauma.

Serious medical errors can threaten patient safety and lead to increased health care costs. Even minor medical errors can erode patient confidence and increase anxiety for medical professionals, patients, and families. Reducing errors as much as possible is best practice for radiologic technologists and makes sense financially for health care providers. Error reduction measures require effort but once instituted prove to be effective and time saving. Other industries in which errors can compromise safety, such as aviation and construction, can provide models for improved risk management and patient safety in medicine.

Medical errors that potentially can harm patients generally can be traced to one of several factors:
- Human fallibility.
- Deficiencies in the system used to accomplish health care–related tasks.
- Inadequate quality-control measures.
- The inherent complexity of modern medical technology.
- The potential complications of the disease or injury in question.

Managing risk and reducing errors requires identifying and reporting errors when they occur, examining and improving system-wide practices, moving from a workplace culture of blame to one of shared responsibility, and improving communication among physicians, other medical personnel, and patients.

Defining Medical Errors

To reduce medical errors, health care workers should understand precisely what is meant by the term medical error and how the concept relates to other concerns regarding quality patient care. The definition of a medical error historically has relied on whether an error resulted in an adverse event. Adverse events are not caused by a patient’s underlying injury or condition but are rather the unintended consequences of medical mismanagement.
Adverse events generally result in measurable disability, prolonged hospitalization, or both.²

Risk management also addresses sentinel events. A sentinel event is an unexpected occurrence that results or is at risk of resulting in death or serious physical or psychological injury. The Joint Commission, which evaluates the quality and safety of patient care in medical facilities and accredits facilities accordingly, promotes national patient safety goals and encourages institutions to report and investigate sentinel events. According to The Joint Commission, sentinel events “signal the need for immediate investigation and response.”³ The Joint Commission further asserts that “the terms ‘sentinel event’ and ‘medical error’ are not synonymous.” According to the organization, not all sentinel events originate from medical errors and “not all errors result in sentinel events.”³

Medical errors also differ from medical complications. Medical complications typically are adverse developments caused not by medical errors but by pre-existing factors such as overall patient health, lifestyle, or individual healing capacity.

Medical errors can be errors of omission—that is, something that should have been done and was not, or they can be errors of commission, which means a task or responsibility was actively mismanaged or performed incorrectly. Authors Pinto and Romano organize potential medical errors and the circumstances under which they might occur into the following categories⁴:

- Errors of execution (ie, failing to complete a planned action as intended).
- Errors of planning (eg, insufficient planning to achieve a particular treatment goal).
- Deviations from the standard of care.

The nature of medical imaging—the use of radiation in several modalities and imaging’s significant role in diagnosis and treatment—requires that radiologic technologists adhere to strictly defined protocols and carefully planned procedures. In such circumstances, an error can be defined as any deviation from these expected norms, regardless of whether the error results in harm to the patient or technologist.⁵ The potential for error is present in both diagnostic and interventional radiology.⁵ Diagnostic radiology, unlike histological or microbiological diagnosis, relies on visual perception and identification of specific physical characteristics found during visual evaluation of an imaging study. Radiologists who interpret examinations rely on radiologic technologists to provide quality images so the radiologists can carefully combine a patient’s clinical history and pathology revealed in the radiological image.⁶,⁷

Errors must be identified before they can be eliminated. Author and surgeon Atul Gawande, in his book The Checklist Manifesto: How to Get Things Right, points out that few professions outside of aviation practice the sort of self-examination mandated by the National Transportation Safety Board (NTSB). NTSB examiners carefully analyze the aftermath of serious transportation-related accidents to determine cause and recommend ways to prevent similar accidents in the future.⁷

In 2007, the World Health Organization (WHO) launched a campaign to improve the safety of surgical procedures around the world. The campaign included a Surgical Safety Checklist. Based largely on the lists used by pilots in the aviation industry, the purpose of the list is to improve staff teamwork in the operating suite and make the use of safety processes a habit. The checklist included in the WHO campaign takes an estimated 2 minutes to implement. A 2010 report from Semel et al estimated a 10% relative reduction in complications with use of the checklist.⁸

The Joint Commission recommends a similar approach to accredited organizations’ self-examination of sentinel events. The Joint Commission’s standards specifically call for identifying, reporting, and evaluating sentinel events. Further, the standards require that sentinel events be investigated by using root cause analysis. Root causes are described as causes related to existing systems, which can then be redesigned to reduce risk. The Joint Commission template for root cause analysis suggests that each root cause be examined for possible corrective action. That corrective action should then be included in the health care facility’s plans for future changes or redesign.⁹

Health care organizations interested in reducing error rates in medical imaging and interventional radiology procedures can begin by conducting formal surveys of radiologists, medical physicists, radiologic technologists, sonographers, and others. Despite the best intentions and training, radiologic technologists might inadvertently
overlook or mishandle some activities. Instead of dismissing them as solitary missteps, radiology departments should conduct a thorough examination of when and how errors occur. Doing so can help avoid future errors, which improves patient care and the organization’s management. If a pattern of specific recurring errors is identified, managers should develop a system of education and implement changes to avoid these errors in the future.\(^7\)

**Causes of Errors**

**Patient Hand-Overs**

Patient hand-overs, also called *hand-offs*, *transfers*, or *sign-outs*, are acknowledged as pivotal moments in the continuity of patient care. When handled inadequately, hand-overs can result in confusion, frustration, narrowly missed errors, and adverse events.\(^9\) A 2009 Institute of Medicine report on improving patient and medical resident safety suggested that patient hand-overs be approached as opportunities for learning, better communication, and enhanced teamwork.\(^9\) In the context of radiologic technology, the arrival of patients for examinations or interventional procedures and their subsequent departure from the department can be viewed as a type of patient hand-over. Each such occurrence presents radiologic technologists with opportunities to reduce or prevent errors in patient care. These opportunities include:\(^11\):

- Recognizing early warning signs of possible medical complications or problems in a patient, either in the aftermath of recent treatment or in preparation for imaging procedures.
- Anticipating problems that might arise when a patient is transferred from the imaging department to the next area of clinical care.
- Recognizing and acting on opportunities to improve communication with patients and exercise teamwork skills with colleagues.

To facilitate the accurate exchange of all clinically significant information during patient hand-overs, the Institute of Medicine report recommends that all individuals involved in the clinical care of patients take the following actions:\(^11\):

- Increase face-to-face interactions that combine oral and written hand-over instructions. Face-to-face interaction supplements and improves comprehension of the written order. It facilitates emphasis of certain aspects of hand-over instructions, allows for questions and answers, and provides the opportunity to clarify information as needed.
- Use uniform terminology and language when conveying information.
- Whenever possible, convey hand-over instructions without interruption or distraction.
- Attempt to structure shift changes with slight overlap to allow for easier and more structured exchange of information.

Written and electronic sign-out systems, similar to checklists, have been developed to increase the completeness and accuracy of information conveyed during patient hand-overs. Electronic systems in particular can enhance the use of uniform terminology because multiple departments or entire facilities access the same electronic program.\(^11\) The incorporation of standardized fields in electronic documents helps ensure that important information is not omitted.\(^10\) Some programs provide greater flexibility for manually added treatment plans or for staff to anticipate tasks needed for individual patients.

Regardless of the written or electronic system used, standardizing the information conveyed during patient hand-overs improves efficiency, reduces content omission, and makes up-to-date and consistent information about patients uniformly available. Electronic sign-out systems can seem cumbersome or time consuming when first introduced. Adequate training during implementation can reduce errors that occur when the systems are used improperly.\(^11\)

Including Patients in the Hand-Over Process

Encouraging patients to participate verbally in the hand-over process is a component of patient-centered care. Patients who feel empowered to participate in their own care will more readily ask questions, identify problems, or express concerns, thus reducing the likelihood of error.\(^7\) Integrating patients into their own care team begins with properly introducing the other members of the team by name and identifying their titles and roles. This is particularly important for hospital inpatients who experience many shift changes in personnel and for
patients new to an imaging facility. Staff members should remember to use a spoken vocabulary that is culturally appropriate and age appropriate for a particular patient.\textsuperscript{11}

Avoiding Errors at Discharge

Although radiologic technologists do not participate directly in discharging a patient from the hospital, patients are discharged from the department, particularly following interventional procedures. Examining the discharge process as a specific type of hand-over in care affords an opportunity to identify potential intervals at which errors are more likely to occur. During hand-overs involving patient transfers to other levels of care within the same organization, or in situations in which patients are cared for by large integrated teams of medical professionals, it is particularly helpful for staff members in a variety of professional roles to receive training in the discharge process.\textsuperscript{11}

Patients can perceive hand-overs in care, and particularly discharges, as confusing interruptions in the care they have been receiving. Adhering to a formally structured protocol for departmental and facility discharges is particularly important. Discharge protocols differ according to the limits and capacities of the setting where they occur, but any discharge protocol can reduce potential errors by incorporating the following suggestions\textsuperscript{11}:

- Determine what information is most pertinent for maintaining quality care in the new setting.
- Determine what information is most pertinent for patient safety in the new setting.
- Use a consistent and structured protocol to transmit this information thoroughly and accurately to other health care professionals, family members, and patients.
- Use a vocabulary that is appropriate to the audience and readily understood in face-to-face discussions and written instructions.

Reliance on Technology

Although automation and computerized procedures have helped minimize the effects of human fallibility, there is a limit to technology’s ability to prevent or reduce errors. In radiology specifically, technological advances can handle tasks that once took far more time and occupied greater physical space, including mathematical calculation, information processing, image storage, and image transmission.\textsuperscript{7} These innovations have helped protect against errors in radiation dose, patient identification, subsequent surgery or hospitalization, and even billing.

Technology alone cannot manage the day-to-day realities of medical practice, however. Automated processes cannot address uncertainty or the individual complexity of each patient’s clinical situation. Only a human being with appropriate education and experience can handle potential crises and unexpected developments. In many ways, according to Gawande, technology further complicates clinical situations by adding “another element of complexity to the systems we depend on and [has] given us entirely new kinds of failure to contend with.”\textsuperscript{7}

Worker Fatigue

Working more and sleeping less has traditionally been accepted as a mark of highly motivated individuals who possess professional dedication. Sleep research, however, has demonstrated that no one can compensate for or adapt to inadequate sleep.\textsuperscript{12} Chronic fatigue is inevitably the result. The connection between employee fatigue and workplace errors has prompted numerous industries, including nuclear power, transportation, mining, and aviation, to address the effects of fatigue on work performance and safety.\textsuperscript{13} For example, commercial airline pilots are limited to an 8-hour shift; flights of a longer duration must carry relief personnel.\textsuperscript{13}

Awareness of the effects of fatigue in the health care environment increased dramatically in 2003 when the Accreditation Council for Graduate Medical Education issued new duty-hour regulations. Intended to address concerns regarding the length of time medical residents were required to be on duty in training hospitals and the subsequent errors directly attributable to fatigue, the new regulations limited residents to working no more than 80 hours per week.\textsuperscript{13} Fatigue and its consequences are perhaps more of a concern at hospitals and after-hours clinics, where the characteristics of shift work in a 24-hour world are more marked. However, concerns regarding workplace fatigue in the health care sector are not limited to these organizations.
Shift Work

Professionals who staff health care facilities after hours, at night, on rotating shifts, or who remain on call for emergencies are particularly susceptible to the effects of sleep deprivation and fatigue. Night workers in particular must remain awake and alert at a time when the body typically expects to sleep. This schedule disrupts circadian rhythms, which are affected by light and help regulate important physical functions, such as release of the hormones cortisol and melatonin. Disruption of circadian rhythms potentially affects the ability to remain awake and alert during the night, and, conversely, to sleep during the day.\textsuperscript{12,13} The chronic fatigue that often results can be exacerbated if employees have chosen to work more lucrative alternative shifts to supplement income from another job. Such a schedule means that their time off is not used for required rest, and chronic fatigue subsequently can worsen.\textsuperscript{13}

In the workplace, effects of fatigue caused by chronic sleep deprivation can take the form of reduced cognitive ability, short-term memory lapses, moodiness, clumsiness, lack of motivation, and lapses in attention and vigilance.\textsuperscript{13,14} Reductions in cognitive ability in particular have been the subject of numerous studies. Among the cognitive skills and functions negatively affected by fatigue are the ability to multitask and the ability to integrate new information,\textsuperscript{12} both of which can have significant effects in the health care arena. Unusually long shifts and staffing shortages also contribute to fatigue in many health care settings.

Chronic staffing shortages in the nursing field have had a dramatic effect on fatigue in the workplace. Registered nurses often are required to work more than a standard shift length (exceeding 12 hours), forego work breaks, work extra shifts, and regularly be on call during their time off. For nurses, the likelihood of making an error increases with hours worked per week, overtime hours, and increased shift duration. Medication errors account for many documented errors, but mistakes in performing procedures, maintaining patient records or medical charts, and conducting medical transcription also have been noted.\textsuperscript{13,15} Because staffing shortages also can affect the work schedules and hours demanded of radiologic technologists, recognizing and addressing potential errors attributable to fatigue is similarly important.

In addition to limiting medical resident work hours per week, the Accreditation Council for Graduate Medical Education made several general recommendations for mitigating the effects of fatigue. Several of these recommendations are relevant to error reduction in the entire health care environment, including radiology departments\textsuperscript{15}:

- The educational experience intended for medical residents demands their full participation in quality improvement efforts at their respective institutions. Radiologic technologists similarly would benefit from an error reporting and investigation system that allows them to participate fully in identifying errors, as well as in planning and instituting actions to prevent them.
- In cases where fatigue is unavoidable, measures should be taken to mitigate its effects. Subsequent work schedules should allow predictable, protected, and sufficient opportunity for recovery sleep.
- Institutions should provide safe alternative transportation options for staff members who are too tired to drive home safely.

Additional suggestions to mitigate or prevent workplace fatigue are offered by the editors of the book \textit{Principles of Risk Management and Patient Safety}.\textsuperscript{15} More general in nature, these recommendations are intended for adoption by a variety of health care facilities and allied health professionals\textsuperscript{15,16,17}:

- Educate employees on the importance of sleep to overall health and job performance. Present evidence on good sleep hygiene, the physical stages of sleep, symptoms of fatigue and sleep deprivation, and the effects of drugs and other substances on sleep.
- Discuss how environmental factors, such as lighting, ventilation, and taking regularly scheduled work breaks can increase alertness on the job.
- Examine work schedules to take into account shift length, number of consecutive working days, and start and end times for shifts. On-call or overtime expectations can be effective in reducing fatigue and work burnout. Supervisory and management personnel can place value on and actively support efforts to prevent worker fatigue.
For employees who work rotating shifts, assign work shifts that rotate forward to facilitate circadian rhythms.

Use scheduling software to determine whether work schedules for employees allow for adequate rest. Fatigue Avoidance Scheduling Tool software is an example; it was originally developed for the U.S. Air Force (Fatigue Science).

Safety Culture

The 2009 Institute of Medicine report on medical resident safety stressed the importance of implementing a safety culture that extends across hospital settings. The report noted that “[b]usinesses in particularly risky industries that could have a catastrophic impact on the public, such as military operations, commercial airlines, and nuclear power generation, were among the first to adopt the continual processes needed to achieve high-reliability operations while producing minimal errors.”11 The report’s authors also stressed the importance of implementing organizational and system strategies that use adverse event and error reporting systems as opportunities to further medical education and training.11

Radiologic technologists practice radiation safety on a daily basis to protect their patients and themselves from the potential radiation exposure risk associated with some medical imaging examinations. Maintaining a culture of safety throughout the patient care continuum and all settings requires a broadening of what the Institute of Medicine report called “continual processes.”11

Individuals and workplaces might define a culture of safety differently, but the following foundational qualities generally are found in organizations that successfully reduce errors while maintaining and improving workplace and patient safety11,17:

- Organizational values and behavioral norms place a high priority on safety.
- Sufficient resources and incentives are in place to implement the commitment to safety.
- Staff members communicate openly, regardless of job hierarchy, particularly in safety-related scenarios.
- Employees acknowledge and openly report errors that occur.

Management responds to errors as opportunities for organizational learning.

Any tendencies to blame individuals for errors are discouraged.

The Institute of Medicine report further stressed that organizations interested in reducing medical errors should replace a system focused on blaming for errors with a system focused on sharing responsibility for reducing and preventing errors.11

Checklists

Once medical errors have been reported, their root causes identified, and changes put in place, the next challenge is to disseminate information and educate staff members. Publications, bulletins, e-mail messages, and similar efforts can be lost in the mass of information typically encountered by health care professionals. Peer-reviewed articles and error reduction studies also risk being lost among the many articles and pieces of information that radiologic technologists and other health care professionals receive.

Gawande offered a lesson from the safety-conscious airline industry. Aviation safety experts take the results of intensive studies produced by the NTSB and create checklists to address and prevent the problems uncovered. Pilots are not required to read massive, densely worded manuscripts issued in response to every new finding. Instead, they receive and test a simple list of steps to prevent the error.7 The intensity of work and demands on employees’ time in most health care settings make similar simplification and distillation essential to error reduction efforts, and a properly developed and implemented checklist can provide similar results.

Although the idea of a preventive checklist to address potential medical errors might seem new, such a list has existed for decades and consistently is used in clinical encounters. According to Gawande, vital signs such as pulse, body temperature, respiratory rate, and blood pressure that hospital staff members record for patients provide a perfect example of a safety checklist. Recording vital signs has taught clinicians that missing one of these signs can harm a patient and that reliable and consistent recording of vital signs helps monitor patients’ overall health.2
All safety checklists should be kept short, and the exact length depends on the context. In aviation, for example, emergency checklists might take only 20 seconds to complete simply because that is all the time available. In medicine, checklists short enough to be truly useful might take from 30 to 90 seconds to complete, depending on their purpose. Completing a checklist any longer than 90 seconds introduces opportunity for distractions and can lead to taking shortcuts or missing steps, which defeats its purpose.

In addition to length recommendations, suggestions for developing a checklist include:

- Focusing on the most urgent items or steps that might be simple but easily forgotten and can cause the most harm if skipped.
- Incorporating steps that address frequent errors uncovered through research such as an employee survey.
- Intentionally omitting items that staff and supervisors know are never forgotten. This helps shorten the list and increases its potential for truly reducing error.
- Keeping the wording simple but exact.
- Maintaining the language and terminology used in the medical profession.
- Ensuring that the checklist is no longer than one page.
- Keeping the checklist appearance simple, without colorful illustrations or other distractions.
- Ensuring that the text is large enough and clear enough to read easily.

Implementing Checklists

The surgical checklist first developed by Gawande and his team was introduced slowly and systematically into the pilot hospitals that adopted it. A similar systematic approach might ease the implementation of error reduction methods in other organizations and in medical imaging departments or outpatient imaging centers:

- Introduce new checklists or other risk management strategies in a series of presentations. Include all imaging professionals concerned with the quality and reliability of imaging equipment, procedures, and outcomes. Avoid using impersonal channels such as e-mail or memos to communicate error reduction protocols.
- Acknowledge errors that have been identified in staff surveys and describe how the measures being implemented will help prevent or reduce those specific errors.
- Limit the introduction of checklists to a single department, section, clinic, or shift. Introducing checklists incrementally facilitates problemsolving and revision before organization-wide or facility-wide implementation.
- Secure a commitment from senior staff members and management. Gawande emphasized the importance of involving people who can implement new efforts to reduce errors, especially those that originate from systemic problems.

An example of how checklists can be introduced and supported by senior staff members took place at a hospital in which the director of surgery created a one-of-a-kind visual reminder and trigger for checklist completion. He designed a metal tent stenciled with the words “Cleared for Takeoff” for the nurses to place over the scalpel as they were laying out the surgical instruments. Only when the items on the operating room checklist had been completed would the nurse lift the metal tent and provide the scalpel to the surgeon. In the ensuing months, the director of surgery measured how surgeries had changed since the introduction of the metal tent. After 3 months, 89% of appendicitis patients received the correct preoperative antibiotic at the appropriate time. Ten months after the introduction of the metal tent, the percentage had improved to 100%. The habitual use of the list was credited for the improvement, as was the fact that team members other than the surgeon, namely the nurses, could delay an operation until the necessary steps and checks had been completed.

Instituting error reduction measures, including checklists, can be met with resistance. One type of criticism is the time, effort, and risks required when implementing checklists. Some members of the staff might fear that checklists increase rigidity and discourage innovation and independent thinking and response. Although there are costs associated with implementing safety checklists, Semel et al compared these costs to the relative reduction in costs of complications from errors and concluded that...
Reducing Errors in Radiology

the WHO Surgical Safety Checklist was effective and ultimately could save hospitals money. Another way to counter resistance is to explore how error reduction measures can save time. Anticipating a potential problem and proactively working to prevent it can prevent future errors, saving time in the long run. Another factor to consider is the fact that the implementation and use of checklists requires collaboration within and between departments.

When Gawande and his colleagues published the results of their pilot program in 2009, they included results from an anonymous survey conducted at the close of the trial period. The results revealed that although many individuals on surgical teams, including surgeons, nurses, and anesthesiologists, had been skeptical about the usefulness of the pilot checklist at the beginning of the study period, by the end of the 3-month trial period, 80% of them reported the list was easy to use, did not take long to complete, and improved the safety of care.

Types of Checklists

Checklists serve as assurance that staff members will forget no step in a particular process, but they do not work well unless implemented within a culture of safety. Error reduction checklists fall into 2 categories: a read-do list or a do-confirm list. A read-do list requires that a staff member or team reads the list and checks each item off as it is completed. A do-confirm list allows greater flexibility in how and in what order tasks are completed; users of this type of list complete tasks and then pause at key points in the procedure to confirm that everything necessary has been done and nothing has been overlooked.

An advantage of a do-confirm checklist is that it provides for brief pauses during a procedure. The increased complexity of medical care, increased demand for medical services, shortage of medical personnel, and other limitations can inadvertently discourage even brief pauses to assess the progress of a particular procedure. Establishing set pause points, as they are known in aviation safety, can provide a useful structure and establish a protocol to discourage errors and mishandling.

Pauses should occur at intervals at which a significant part of the procedure has just finished or is about to begin. For example, Gawande’s surgical team instituted specific pauses at 3 key intervals in their surgical checklist:

- Before the patient received anesthesia.
- After the anesthesia had taken effect but before the surgeon made an incision.
- After surgery, just before the patient was moved to recovery.

The pauses were used to check for recommended antibiotics, patient allergies, and equipment readiness, among other important concerns.

Pause points in medical imaging examinations or interventional procedures would depend on the specific examination or procedure. Although many procedures, such as commonly performed interventional procedures in cardiology, might already have established pause points, an increased awareness among both management and patient care personnel of the importance of these in reducing and preventing errors can encourage their use. Pause points are an excellent example of an error reduction effort that might appear to consume time but that actually helps save time and improves efficiency and safety.

Radiologic technologists might set up a checklist system to ensure they first ask a patient about recent injuries or chronic discomfort that might be exacerbated by positioning during an imaging procedure. It is imperative that technologists do not hesitate to pause and clarify any part of an imaging order that seems inconsistent with or contrary to the patient’s medical condition (eg, a badly swollen right ankle with an order for a left ankle radiograph). Despite the increasing complexity of diagnostic procedures and medical technology, errors continue to originate from simple and often easily overlooked factors. In some cases, the items listed on checklists might seem routine or rudimentary, but surgical teams who have used checklists confirm that the double checks afforded by lists removed the possibility of easily avoidable errors.

Communication

Poor communication has been found to be a contributing factor in approximately 30% of adverse medical outcomes studied. Even in cases where a medical error does not result in an adverse outcome, failures in communication contribute to frustration and confusion.
for both patients and those caring for them. Patients can lose trust in the health care system and in their provider if they note errors in simple tasks or are given contradictory information regarding their condition and care. These concerns make good communication a key component of effective risk management. Communication from referring physicians can lead to errors or repeat examinations. Radiologic technologists and radiologists need complete and accurate clinical information about patients to complete timely and accurate examinations, and radiologists need detailed clinical history to complete their image interpretations.

Improved communication should not, however, be understood as mere collegiality. In fact, health care professionals’ practice of ensuring they know one another’s name and precise role in any clinical encounter introduces a structure and discipline into communication with both colleagues and patients. Paying consistent attention to communication improves the quality of attention dedicated to the task at hand, whether a radiologic technologist is confirming instructions from a radiologist or attending in a systematic manner to technique factors.

In medical imaging, improving communication to reduce errors also accomplishes improved communication with patients and their families. Taking time to confirm the name of the patient, along with the identity and role of others accompanying a patient, improves efficiency and can prevent errors caused by mistaken assumptions or misunderstandings. Asking patients whether they understand what is about to happen or have any questions or concerns regarding an examination or procedure can help to uncover mistakes in patient identity or the anticipated imaging examination.

Technology has increased the complexity of some medical imaging modalities and techniques. Likewise, increasing specialization in medicine has inadvertently encouraged some individuals to confine themselves to narrow domains of highly specialized skill, often to the detriment of a team’s efforts and patient-centered care. In addition to discouraging effective teamwork, such narrow specialization can create what Gawande called silent disengagement, a situation where team members observe problems or potential errors but choose not to reveal or correct the errors because the problem falls outside their area of specialization.

Imaging technology historically has required attention to detail. New imaging technologies ease some burdens and heighten expectations. The increased number of choices necessary and options available simply leaves more room for error. In addition, technologists can choose to specialize, as in mammography or through assignment to the emergency department of a large urban hospital. The most pressing concerns in either setting might differ widely, but good communication regarding patient status, immediate needs, and potential complications or consequences of errors is essential in both.

Making professional introductions routine can be more crucial in a large metropolitan hospital than in a small outpatient clinic, where staff members are more likely to know one another well, yet the principle behind the practice remains the same. When nurses on a surgical team, for example, were given an opportunity to introduce themselves by name and discuss any potential concerns they might have regarding the upcoming surgery, they were more likely to offer comments and observations than if a short time for introductions and comments had not been set aside.

Talking to radiology team members and the patient about examination or procedure expectations, including the expected length of time and any risk factors the patient might have for potential complications, can increase the quality of patient care and prevent errors due to mistaken assumptions. In addition, knowing that one’s participation and opinion are valued can increase the sense of responsibility a team member has for the success of an examination or procedure. In effect, encouraging participation produces the opposite result of that produced by Gawande’s concept of silent disengagement. Reports have shown that using checklists helps surgical staff communicate and work together better as a team.

**Failures in Communication**

Failures in communication might occur between individuals, but poor communication across an entire workplace offers an example of how medical errors can originate from system-wide deficiencies. Besides its significance in affecting patient and technologist safety, poor communication influences workplace efficiency,
relationships among coworkers, and use of valuable resources.® Practicing effective communication begins with understanding how communication can be undermined.

To be effective, communication must be thorough, detailed, and clear. Just as medical errors originate in a variety of contexts and take various forms, communication failures can be categorized in the following ways®:®:

- Failure of content – critical information is omitted from the content of either written or verbal communications or is conveyed inaccurately.
- Failure of occasion – information is provided too late to be useful.
- Failure of audience – key individuals are left out of discussions or not provided with information.
- Failure of purpose – issues to be decided are left unresolved; that is, the communication has not fulfilled its purpose.
- Failure of process – communication is handled improperly or inadequately. For example, in-person consultations do not occur, handwritten notes are illegible, terminology used is confusing, or personnel in charge are unprepared.

Anyone who has worked a number of years in radiology or another health care field can probably recall examples of each of these types of communication failures. However, despite definitions of good communication in health care, medical errors continue to result from a lack of communication. Although communication takes place between or among individuals, good communication depends on systemic practices within the workplace to foster an environment in which it can reliably occur.

In a 2011 book on risk management and safety, DeVito examined 7 system-level factors that contribute to communication failure in the health care environment®:

- The presence of workplace hierarchies.
- A culture that discourages communication.
- Differences in or lack of education and training.
- Insufficient staffing.
- Lack of team integration and stability.
- Lack of standardized training in communication.
- Limits on duty hours and the subsequent increase in transfers of patient care.

Hierarchies might be one of the biggest contributors to poor communication in the medical workplace. In many industries, a clear chain of command allows those working on the lower links of the chain to approach superiors with problems or concerns. In contrast, in some medical settings superiors might prefer not to be approached with the concerns or questions of coworkers or colleagues with less authority.® This tendency might appear more pronounced within particular work pairings, especially in teaching hospitals.

In academic settings, medical residents and other personnel might be reluctant to approach attending physicians with questions or concerns that could reveal an error or lack of knowledge. The staff member might be hesitant to approach the physician, even in cases in which he or she has too little initial information about a particular patient.®

Timely and efficient exchange of information can be compromised during transfers of patients from the emergency department to inpatient units, especially in academic settings. Residents, nurses, and other staff members often hesitate to question physicians. Hierarchical structures might also encourage communication through written materials or electronic health records, which delays the exchange of important information that could reverse an error.

The exclusive use of written orders and the absence of face-to-face communication might allow for better documentation but is a form of impersonal communication that does not offer a context for discussing the specific concerns of a patient’s case in any detail.®

Use of electronic health records and an increasing reliance on electronic communication decreases personal communication between radiologic technologists and radiologists. Communication that used to take place when technologists and radiologists interacted during delivery or hanging of radiographs now occurs through electronic notes that accompany digital images.® Written orders and communication do not allow radiologic technologists, nurses, and other staff members to ask questions or clarify issues that occur to them as they begin caring for the patient.®

In addition, personal communication incorporates nonverbal communication, a significant factor in effective communication. For example, nonverbal communication can signal to an observer how receptive a superior might be to hearing unexpected information.
Regardless of an individual’s official status, his or her body language also can influence how coworkers respond to his or her concerns. Among the most important nonverbal communicators are:

- The presence or absence of eye contact.
- The length of a gaze.
- Tone of voice.
- Body posture.
- Facial expression.

Face-to-face communication allows opportunities for questions and answers, clarification of written instructions, and emphasizing certain instructions. The effect of hierarchies on communication is not limited to communication between coworkers and superiors. There also could be implied hierarchies between health care providers and their patients. The risk of medical error can increase when patients feel powerless or uninvolved in the decision-making process. Without active involvement, they might hesitate to offer information that could prevent complications or errors. The use of medical terminology instead of commonly understood terms exacerbates the hierarchical relationship.

A major principle of patient-centered care is to improve communication among health care providers and between providers and their patients and patients’ family members. The improved communication is designed to involve patients and family members in their care and to improve patient outcomes and safety. For example, patients who are involved in care might be more likely to adhere to recommendations for preventive care or medication regimens. Improved communication and collaboration between providers reduces errors and can improve care, such as in the patient-centered medical home concept. Minimizing hierarchical effects on communication and improving collaboration begins with cultivating a work culture that encourages a sense of shared responsibility.

Health care practitioners often believe that they should be able to handle a situation on their own, without requesting assistance or advice. In such a cultural context, errors inevitably are viewed as personal failures and potentially occur unreported and unaddressed. Personal accountability examines the individual who is to blame for an error, as opposed to a process or systemic issue that might have led to the error. Looking for fault for an error can lead to a culture of blame in the workplace, rather than a sense of shared responsibility and open communication.

Examining and improving the performance of groups, as opposed to individuals, helps to implement changes system-wide and ensures compliance from everyone in the organization. A culture of shared responsibility and system-wide change also ensures that improvements do not diminish or disappear when individual personnel leave a workplace.

Organizations also can benefit from encouraging the growth and expression of strong leadership skills among all levels of employees. A positive workplace culture encourages individuals to come forward with and discuss concerns, seek solutions to problems, and publicly support constructive change.

Recognizing how educational preparation of health care practitioners affects workplace interactions also is important in decreasing medical errors. The educational preparation of physicians such as radiologists, for example, stresses accuracy but also conciseness. Radiologic technologists learn about the technical aspects of conducting examinations but rely on radiologist and manager feedback for ongoing education about image quality and how to minimize radiation exposure to patients. Technology can interfere with many of the traditional feedback mechanisms.

Although complex and sophisticated technology is a defining feature of diagnostic medical imaging in particular, the educational preparation of radiologic technologists also emphasizes patient-centered care. Patients’ immediate and pressing physiological needs, their safety and comfort, and their personal concerns take precedence over the requirements of the imaging procedure. Radiologic technologists who habitually observe and inquire about a patient’s needs and concerns before and during imaging procedures are more likely to earn a patient’s trust. Patients who trust the technologist performing their procedure are, in turn, more likely to communicate effectively regarding their care and to alert the technologist to any potential problem or complication.

Staffing shortages can lead to disruptive employee fatigue and consequent medical errors, along with decreasing levels of communication. Staffing shortages...
can adversely affect the quality and length or number of patient care team meetings, which can result in the goals for a particular patient’s care being communicated inadequately. Staffing procedures also can lead to communication difficulties, particularly to a lack of clinical team integration. Integrating work teams improves communication among workers and informal education as health care professionals observe how peers perform equivalent duties.

**Standardized Communication Training**

Patient transfers are daily occurrences in hospitals and other health care facilities, yet little formal training is available in how to consistently and effectively communicate patient needs during transfers and handovers. In addition, staff fatigue at the end of a long shift can compromise the quality and extent of discussion regarding a patient’s care. Standardized instructions in how to communicate effectively—regardless of staffing, shift changes, coworker or supervisor hostility, or other personnel concerns—can help reduce errors that originate during patient transfer.

Standardized instructions in communication also can address differences in interpersonal dynamics. Assertiveness training might prove especially helpful for employees.

Standardized protocols for briefing coworkers or supervisors usually are structured to include examining the situation, summarizing its history, and anticipating what might happen next. An example is the situational debriefing model, originally developed by the U.S. Navy and abbreviated SBAR, which stands for situation, background, assessment, and recommendation. Standardized communication or briefing protocols developed by government agencies in other industries, such as aviation, can be used in health care to structure discussions that are least likely to omit important details or, conversely, to include so much information that pertinent details are lost.

DeVito suggested that even in situations in which workplace hierarchies and staffing shortages make open communication difficult, an agreed-upon phrase representing what DeVito called **critical language** can help avoid a crisis. If employees are trained to use a phrase such as “we have a serious problem; stop and listen to me,” whenever they observe a critical error or situation developing, any staff member within a strict hierarchical environment can help avert a potentially serious error. Critical language offers a straightforward tool for immediate use, even as leaders implement system-wide changes.

Gawande described a situation he witnessed during a surgical procedure at a Jordanian hospital in which a female nurse overcame cultural and hierarchical norms to point out a breech in protocol to a male surgeon. The surgeon had contaminated his surgical gloves when adjusting the operating lights. The nurse pointed out the problem and, despite the surgeon’s initial dismissal of her concerns, persisted in her demands that he change his gloves. He eventually did so, and only then did the procedure continue.

**Reducing Errors in Emergency Departments**

Emergency department imaging is especially complex for radiologic technologists. The nature of many patients’ conditions and the urgency associated with turnaround times for examinations and physician interpretation requires that technologists be prepared and technically accurate. In addition, technologists might be working independently during evening hours, with radiologists performing after-hours interpretation via teleradiology coverage. Technologists might need to make rapid decisions autonomously and acquire the best images possible to facilitate a timely emergency diagnosis.

Professionals in the aviation industry are known for facing rapid decisions regarding unexpected events. The emergency checklists used by airline pilots begin with a simple and straightforward admonition: “Fly the airplane.” Before and while completing checklists and other emergency measures, pilots must ensure that they continue flying the plane. This admonition echoes medicine’s traditional instruction to “first, do no harm.” It also is reminiscent of the “ABCDE” approach (airway, breathing, circulation, disability, exposure) used by emergency responders and personnel to assess, treat, and stabilize patients. Ideally, from such basics can evolve a firm foundation from which to avoid and reduce error in a rapidly evolving emergency situation.
Radiologic science instructors offer the following tips for adopting routine radiographic procedures for use in emergency situations. Readying equipment and preparing for procedures in advance can free valuable time for addressing emergency situations once patients arrive. The following suggestions can provide a framework for developing an emergency department checklist. 24

Before a patient arrives:
- Obtain as much information as possible about the incoming patient and his or her injuries.
- Based on this information, prepare equipment for expected imaging examinations (eg, cassettes and markers).
- Prepare required protective equipment (ie, lead aprons, gloves, gowns).

Once a patient arrives:
- Assist the trauma team in assessing the patient.
- Introduce yourself to the patient before beginning the examination.
- If possible, explain what images you plan to acquire.
- Ask the patient about his or her mobility, and, if possible, obtain the patient’s assistance in positioning.
- To prevent worsening the patient’s injury, seek assistance from nurses or physicians when moving and positioning the patient.
- Provide radiation protection to any individuals required to stay in the room during imaging.
- Use appropriate shielding on the patient.

Multiple Trauma

Personnel in emergency departments must frequently work with patients who have sustained multiple traumatic injuries. Handling multiple trauma presents specific challenges and more potential for medical errors than most other clinical situations. Errors can occur even in specially designated trauma centers. 24 Medical imaging is essential to correctly diagnose patients who have multiple trauma. Emergency department physicians preliminarily assess trauma patients for the possibility of vertebral fracture immediately after assessing their cardiac and respiratory status because the danger of paralysis is so pronounced in patients with multiple trauma. 24

Today most trauma, especially multiple trauma, is evaluated with computed tomography (CT). 24

Conventional radiography and ultrasonography provide less resolution than other modalities and are inherently limited in their field of view. This can lead to errors in diagnosis and the downgrading of injuries in emergency department patients. For example, ultrasonography’s sensitivity and specificity might be adequate for initial assessment of blunt abdominal trauma but inadequate for injuries involving some internal organs and skeletal injury. CT is considered superior to focused assessment with sonography for trauma in definitive diagnosis. 29,30

Radiography of Extremity Trauma

Radiographic images of the extremities often are acquired after initial CT imaging has been completed. Conventional radiography remains the first-line imaging modality for suspected osseous injuries. Protocols for trauma radiography specify that 2 radiographs at 90° angles be obtained of all extremities and that these include both joint spaces on one or more images of all long bones. 24,31

Conventional radiography can fail to show skeletal injuries, however, especially those of the appendicular skeleton, such as fractures of the small bones of the wrist. The wrist is susceptible to both subtle and complex effects of trauma, 32 and misdiagnosis of wrist fractures can ultimately result in disability or local neurological complications. Of the variety of wrist fractures typically encountered in an emergency department, fractures of the scaphoid are among those most commonly missed (see Figure 1). Occurring most frequently among young healthy individuals, scaphoid fractures are the most common fractures of the carpal bones. Missed diagnoses can be partially explained by the fact that scaphoid fractures can take up to 6 weeks to become conclusive on radiographs. 29

Today most trauma, especially multiple trauma, is evaluated with computed tomography (CT). 24

Two other common fractures encountered in emergency departments, elbow and forearm fractures, represent up to 10% of all adult fractures. 32,33 Although a patient with a fractured elbow might complain of significant pain and loss of function, a patient with a smaller nondisplaced fracture might initially experience only minimal pain and loss of motion. For the radiologist to fully see the injured site, the radiologic technologist must acquire a minimum of 2 perpendicular
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Fractures of the calcaneus sometimes occur as work-related injuries among middle-aged and younger men. Missed diagnosis of a fractured calcaneus can lead to prolonged pain and disability, along with associated soft tissue injury. Where a calcaneal injury is suspected, an axial projection should be acquired along with antero-posterior and lateral projections of the foot. Lateral projections usually are best for displaying the calcaneus because they allow assessment of the posterior facet position and the loss of calcaneal height.\(^\text{32}\)

Most diagnoses missed on radiography are fractures. Avoiding misdiagnoses in the emergency department requires proper examination of the patient. This suggests that physicians must take great care in requesting the specific radiographic projections they require to aid in diagnosis. For example, when assessing finger injuries, physicians should request radiographs of the fingers rather than of the hands. Specific requests ensure that radiographers obtain the most useful images possible. Misdiagnoses that result from no radiographs being obtained usually are because of poorly localized injuries or the presence of other significant or painful injuries that draw attention away from the fractured extremity.\(^\text{32}\)

**Torso and Spine Injuries**

Possible injuries to the vertebral column are of immediate concern in assessing patients with multiple trauma. Although spinal injuries from trauma are more common at the craniocervical junction, an identified injury in any segment of the spine should prompt suspicion of similar injuries in other vertebral locations.\(^\text{29}\)

Standard radiographic evaluation of the traumatic cervical spine usually comprises at least 3 projections: anteroposterior, cross-table lateral, and open-mouth odontoid. However, studies found these standard projections to be inadequate in identifying half of the fractures ultimately detected.\(^\text{29,35,36}\)

In 2009, the American College of Radiology recommended that multidetector computed tomography (MDCT) with multiplanar reconstruction be the method of choice for imaging suspected spinal trauma, especially in patients who show clinical indicators of risk for cervical fracture.\(^\text{37}\)

These clinical indications include:\(^\text{32}\)

- A confused or altered mental state.
- Tenderness at the posterior midline cervical spine.
- Focal neurologic deficit.
- Neck pain on range of motion.
- Any other painful injury that might distract the patient from cervical spine pain.

Incorrect classification of lumbar spine fractures is more likely in patients who are overweight or obese or in patients who have multiple trauma with coexisting abdominal injuries. This is especially true if patients have injuries to the hollow viscera, the mesentery, solid organs, and large blood vessels. Lumbar spine injuries also are more likely to be missed when injury has resulted in abdominal bleeding, which can increase diagnostic errors by as much as 45%.\(^\text{29}\)

In thoracic trauma patients, a traditional chest radiograph results in underestimation of pneumothorax 50% of the time. Injuries to the sternum also are frequently underestimated, but accompanying pain usually prompts additional diagnostic examinations to determine the cause. When a patient has multiple trauma, costal fractures might remain undetected for several days.
Pediatric patients with multiple trauma cause special concern. Among those with already identified skeletal and solid visceral organ injury, coexisting injury to the area of the ureteropelvic junction is missed in some 50% of cases initially evaluated with radiography and ultrasonography.29,38

Use of Multidetector Computed Tomography

MDCT offers emergency departments detailed imaging studies that can uncover subtle signs of injury, often before other clinical signs are evident or patients experience symptoms. Speed of acquisition is an additional advantage of MDCT; new equipment allowing rapid whole-body scans expands the diagnostic advantages of MDCT to more emergency department and multiple trauma patients. Newer multidetector equipment can display the exact location of vascular injury, along with the nature and characteristics of the injury. Characterizing vascular injury contributes to decisions regarding whether patients are managed with an endovascular approach or with traditional surgery (see Figure 2). In addition to hemodynamically stable patients, patients who are slightly unstable clinically and patients with borderline status now can benefit from the advantages of MDCT imaging.

MDCT is an example of increasingly complex medical technology that, despite its benefits and advantages, can lead to heightened expectations. Although contrast-enhanced MDCT is highly sensitive and specific for evaluating injury in patients with multiple trauma, the technology requires attention to protocols and acquired skills specific to MDCT; error reduction and prevention remain concerns.29 Most errors in the use of

Figure 2. A.–B. Blunt cerebrovascular occlusion in a 51-year-old man who was involved in a motorcycle accident. The axial multiplanar reconstruction image (A) in 3-mm-thick slices shows the absence of contrast material within the right vertebral artery (arrow) and the coexistence of a C4 lateral mass fracture (arrowhead) involving the right vertebral channel. The same findings (arrows and arrowhead) are clearly detectable on the sagittal multiplanar reconstruction image (B), on which the presence of contrast material is detectable within the right vertebral artery upstream and downstream from the occlusion. C.–D. Multidetector computed tomography images of a 28-year-old man who was involved in a bicycle accident. The axial multiplanar reconstruction image (C) in 3-mm slices shows multiple skull base fractures (arrows) involving the clivus and no contrast material within the basilar artery (arrowhead). Midfacial fractures also were present. The sagittal maximum intensity projection reconstruction (D) (4-mm thickness) confirms a focal absence of contrast material within the lumen of the basilar artery (arrow). Reprinted with permission from Bonatti M, Vezzali N, Ferro F, Manfredi R, Oberhofer N, Bonatti G. Blunt cerebrovascular injury: diagnosis at whole-body MDCT for multi-trauma. Insights Imaging. 2013;4(3):347-355.
MDCT can be traced to lack of experience on the part of the radiologist and incorrect patient management.\textsuperscript{29} For example, massive pneumothorax is a frequent cause of death after deceleration trauma, and the interpreting physician should search for monolateral or bilateral pneumothorax in the scout projection at the start of the MDCT trauma examination.\textsuperscript{29,39}

Patients must be prepared and managed appropriately following established protocols for body scans of patients with multiple trauma.\textsuperscript{29,40} According to radiologists familiar with patient management during contrast-enhanced MDCT, reducing or preventing common errors begins with strict collaboration among the trauma team.\textsuperscript{29}

Important considerations for MDCT teams in successful patient management and error reduction include\textsuperscript{29,39}:

\begin{itemize}
  \item Ensuring correct venous access for contrast administration and sufficient flow rate for the detection and correct identification of vascular injuries.
  \item Delaying use of an oral contrast medium until the absence of enteromesenteric lesions is confirmed.
  \item Using sedation only as needed for patients who cannot cooperate.
  \item Positioning patients correctly to image anatomy with as few artifacts as possible.
  \item Characterizing vascular injury to assist in deciding whether patients will be managed with an endovascular approach or with traditional surgery.
  \item Using the precontrast phase of contrast-enhanced MDCT to detect a small blood clot or enteromesenteric injury, which can help characterize underlying injuries that can be difficult to see in the contrast-enhanced phase.
  \item Recognizing that respiration artifacts can be a source of interpretation error.
\end{itemize}

The craniocervical region is a frequent site of spinal injury and the region associated with 2 frequent errors in imaging that can result in increased morbidity and mortality in multiple trauma patients\textsuperscript{29}:

\begin{itemize}
  \item The first common error is understaging of injury in the supraaortic trunks. This can be prevented by extending the arterial chest-abdominal phase to the neck. The frequency of traumatic vascular injury in this region, along with the threat of associated morbidity and mortality, is significant enough to warrant this extension.
  \item The second is missing underlying vascular damage due to intraparenchymal hematomas of the brain. Intraparenchymal hematomas in a patient with multiple trauma can indicate either an arteriovenous malformation or the spontaneous bleeding of an intracranial aneurysm. In such cases, integrating the precontrast study of the skull with CT angiography or magnetic resonance angiography can offer the best possibilities for evaluation.
\end{itemize}

Many trauma patients with multiple injuries undergo urinary catheterization, which can disguise even large bladder lacerations. If bladder lacerations are suspected, the first or subsequent contrast-enhanced MDCT examinations should involve using the catheter to fill the bladder with iodinated contrast medium. This helps to identify even the smallest trauma-caused lacerations, which might otherwise remain undetected.\textsuperscript{29}

Multiple trauma is an evolving condition that requires highly coordinated monitoring and care. Although radiology professionals play a critical role in initial examination, reducing the occurrence of errors in trauma care is the responsibility of the entire trauma team. Awareness of fundamental concerns, knowledge gained by experience, and adherence to imaging protocols are essential to a successful diagnosis of trauma patients.\textsuperscript{29}

\textbf{Conclusion}

Awareness of the potential harm to patients from errors and the need to remain vigilant in following institutional policies and procedures improves patient safety, outcomes, and trust. As technology continues to improve medical imaging capabilities and work flow, radiologic technologists must continually improve their skills to ensure quality diagnostic imaging for their patients. Improved communication, concise checklists, structured protocols, and increased attention to the effects of fatigue can help reduce errors in the medical imaging workplace.

Joyce Helena Brusin, MFA, works as an essayist and freelance medical writer and editor in Missoula, Montana.
She previously has written Radiologic Technology Directed Readings about radiation protection, digital mammography, osteogenesis imperfecta, bone densitometry, ergonomics, and the role of cultural competence in addressing health disparities.

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References


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Reducing Errors in Radiology

1. Which of the following is **not** a contributing factor to medical errors?
   a. human fallibility
   b. system-wide deficiencies
   c. the complex nature of modern medical technology
   d. the size of the hospital or outpatient center

2. Which of the following statements is **true** regarding adverse events?
   a. Adverse events are caused by unintended consequences of medical mismanagement.
   b. Adverse events are the consequences of a patient’s underlying condition.
   c. Patients seldom have measurable disability from adverse events.
   d. Adverse events seldom result in hospitalization.

3. According to The Joint Commission, a sentinel event signals the need for:
   a. formation of a team to address potential long-term solutions.
   b. firing of the responsible employee or employees.
   c. immediate investigation and response.
   d. legal action.

4. Medical complications are caused solely by medical errors.
   a. true
   b. false

5. An error of commission occurs:
   a. when a necessary task is not done.
   b. when a task or responsibility is mismanaged or done incorrectly.
   c. most often in emergency medicine.
   d. when a staff member forgets to transfer a patient.

*continued on next page*
6. Which of the following is an example of root cause analysis examination?
   a. how systems can be redesigned to prevent or reduce risk
   b. determining which individual is to blame for an error
   c. what causes staffing shortages
   d. how to eliminate workplace hierarchies

7. As patients arrive for and depart from radiologic imaging procedures, radiologic technologists can help prevent medical errors by:
   1. anticipating problems that might arise.
   2. recognizing early signs of developing medical complications.
   3. acting on opportunities to improve communication with patients.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

8. Patient hand-over instructions are best conveyed:
   a. through written instructions only.
   b. through oral instructions only.
   c. through a combination of written and face-to-face communication.
   d. in the presence of family members.

9. Electronic sign-out systems offer all of the following advantages except:
   a. they enhance the use of uniform terminology.
   b. multiple departments or entire facilities can access them.
   c. patients can individualize their own care plan.
   d. they contain standardized fields that make it harder to omit important information.

10. Which of the following statements is true about chronic sleep deprivation?
    a. Sleep deprivation is not a problem for individuals who are accustomed to it.
    b. The problem can be addressed with caffeine or other stimulants.
    c. It increases the ability to multitask.
    d. Sleep deprivation causes lapses in short-term memory and attention span.

11. In situations where fatigue is unavoidable, managers should:
    a. allow for sufficient and protected opportunities for recovery sleep.
    b. allow for recovery sleep on the job.
    c. schedule overlapping shifts.
    d. provide compensatory time in the next week’s schedule.

12. How do managers respond to medical errors in a workplace culture of safety?
    a. by identifying and firing the employee responsible
    b. as opportunities for organizational learning
    c. by discouraging employees from reporting errors
    d. by taking individual responsibility for correcting all errors

13. Which of the following statements are true regarding an ideal checklist for preventing medical errors?
    1. the list should take 30 to 90 seconds to complete.
    2. the list should include all urgent items.
    3. the list should include at least 2 illustrations.
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

continued on next page
14. A study of the World Health Organization Surgical Safety Checklist revealed that the safety checklists:
   a. can be too time-consuming and costly to use widely.
   b. are inexpensive and quick to implement.
   c. involve costs to implement but are effective in saving money by reducing complications from errors.
   d. are completely ineffective.

15. A read-do checklist requires users to:
   a. read each item and check it off as it is completed.
   b. complete tasks and then pause to confirm that everything necessary has been done.
   c. complete longer items with more detailed instructions.
   d. complete shorter items with less detailed instructions.

16. Established pause points during an examination or procedure usually occur when:
   a. staff members are retrieving necessary supplies.
   b. a staff member takes a phone call.
   c. it is noted that previous errors have occurred.
   d. a significant part of the examination or procedure has just finished or is about to begin.

17. Poor communication has been found to be a contributing factor in approximately ______% of adverse medical outcomes.
   a. 5
   b. 10
   c. 30
   d. 50

18. Reports have shown that use of ______ helps surgical staff communicate and work together better as a team.
   a. regular staff meetings
   b. 360° evaluations
   c. error reporting software programs
   d. checklists

19. In poor communication, failure of content means that:
   a. the communication takes place too late to be useful.
   b. key people are left out of the discussion.
   c. key issues are not resolved.
   d. essential information is omitted from the communication.

20. Radiologic technologists and radiologists communicate in person less often today because of:
   a. increasing emphasis on hierarchies in all health systems.
   b. increasing use of electronic communication accompanying digital images.
   c. intervention of supervisors.
   d. poor communication and safety cultures.

21. A major principle of patient-centered care is to improve communication among health care providers and between providers and their patients and patients’ family members.
   a. true
   b. false

22. Which of the following statements is not true regarding standardized instructions in communication?
   a. Standardized instructions help reduce errors.
   b. Standardized protocols should not summarize history of the situation.
   c. Interpersonal dynamics can be addressed by standardized instructions.
   d. Protocols developed in other industries can be transferred to health care.

continued on next page
23. Emergency department imaging is made more complex for radiologic technologists by the:
   1. urgency associated with turnaround times.
   2. nature of patients’ conditions.
   3. potential to work independently and without a radiologist present.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

24. Which imaging modality is used to image most emergency department multiple trauma?
   a. digital radiography
   b. ultrasonography
   c. computed tomography
   d. magnetic resonance imaging

25. ______ is a frequent cause of death after deceleration trauma.
   a. Stroke
   b. Pneumothorax
   c. Myocardial infarction
   d. Spleen rupture
Directed Reading Evaluation
Reducing Errors in Radiology

Thank you for taking the time to complete this evaluation. Your opinion helps us serve you better. Your comments will remain confidential and will not affect the scoring of your Directed Reading (DR) test. Choose only ONE response for each question. Use a blue or black ink pen. Do not use felt tip markers. Completely fill in the circles.

1. Why did you choose to complete this DR?
   ○ Interested in the topic  ○ Topic pertained to my area of practice
   ○ Needed CE credits immediately  ○ Other

2. How relevant is this DR to your practice?
   ○ Very relevant  ○ Relevant  ○ Somewhat relevant  ○ Not relevant

3. How beneficial is this DR to your professional or personal development?
   ○ Very beneficial  ○ Beneficial  ○ Somewhat beneficial  ○ Not beneficial

4. How would you rate the level of difficulty of this DR?
   ○ Too difficult  ○ Somewhat difficult  ○ Just the right level  ○ Somewhat easy  ○ Too easy

5. How would you rate the length of this DR?
   ○ Too long  ○ Somewhat long  ○ Just the right length  ○ Somewhat short  ○ Too short

6. Did this DR meet your expectations?
   ○ Yes  ○ Partially  ○ No

7. Would you recommend this DR to a colleague?
   ○ Yes  ○ No

8. Overall, how valuable are the DRs to you?
   ○ Very valuable  ○ Valuable  ○ Somewhat valuable  ○ Not very valuable

If you have comments or questions about this Directed Reading, please write them below or send them separately to Ellen Lipman, Director of Professional Development, ASRT, 15000 Central Ave SE, Albuquerque, NM 87123-3909 or elipman@asrt.org.
Reducing Errors in Radiology

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Accreditation Resources: Help Is Available

Debra J Poelhuis, MS, R.T.(R)(M)

A n e-mail from the Joint Review Committee on Education in Radiologic Technology (JRCERT) has just arrived. Your interim report or self-study is due, and whether this is your first or your fifth time, you are probably asking yourself where to find help. The JRCERT’s systematic review of programs is designed to focus on excellence in education, quality of patient care, and safety of patients and students. This assessment is verified through programs’ compliance with the JRCERT Standards. Documenting your program’s quality and compliance is the goal, and the JRCERT has many resources to assist you.

Defining Accreditation

Accreditation is intended to strengthen and sustain higher education and make it worthy of public confidence. Continuous self-study and improvement are integral to a quality educational program. A program should proactively engage in an ongoing process of discovery and analysis to successfully identify program strengths, weaknesses, and gaps and, most importantly, demonstrate program improvement.

A successful programmatic review:

- Is planned and includes set objectives and a schedule for completion.
- Measures compliance with the JRCERT Standards, achievement of program goals, and level of success in meeting community needs.
- Uses multiple measures and methods to determine whether the Standards are achieved.
- Involves all program faculty, clinical educators, and administrators in the planning process.
- Engages program and community resources.
- Involves input from all communities of interest and areas of expertise (ie, students, advisory committees, clinical department directors).
- Uses results to help improve the program.
- Evaluates the success of self-study measures and methods.
- Is ongoing and builds on previous self-study or interim report results.

Resources

Many resources are available for assistance in writing an interim report or self-study. The JRCERT provides interim report modules on the JRCERT Web site for programs in radiography, radiation therapy, medical dosimetry, and magnetic resonance. These video modules explain what an interim report is and the particular objectives that need to be addressed when composing this report. An interim report checklist also is provided on the Web site to allow programs to confirm the inclusion of all required documentation. This checklist also discusses the difference between an interim report and a continuing accreditation self-study in both the required responses to certain objectives and in the accreditation awards that can be granted following review by the
JRCERT Board of Directors. These resources are available online at http://jrcert.org/programs-faculty.

A chart explaining the accreditation process and accreditation cycle also is available on the JRCERT Web site, along with numerous resources regarding assessment. Video modules are available on the topics of outcomes assessment, student-centered goals, student learning outcomes, and developing and evaluating a mission statement. These modules, which were produced in collaboration with the American Society of Radiologic Technologists, can answer many questions that might arise while preparing your accreditation documents.

An extensive list of assessment resources compiled by the JRCERT—including Web sites, books, videos, and podcasts—is available online at http://jrcert.org/sites/jrcert/uploads/documents/Assessment_Resources.pdf. A recent Radiologic Technology JRCERT Update column also offered information available outside of the JRCERT for learning about best practices in assessment.

Workshops

The JRCERT offers many learning opportunities in the form of workshops. Outcomes assessment workshops and accreditation seminars both are offered throughout the year, usually preceding a state or national conference such as the annual conferences held by the American Society of Radiologic Technologists or the Association of Educators in Imaging and Radiologic Sciences. These workshops and seminars also are offered in Chicago at the JRCERT office.

The outcomes assessment workshop covers “the general theoretical background relative to outcomes assessment” and includes “activities to facilitate the design of an outcomes assessment plan.” Participants have the opportunity to work directly with JRCERT staff in developing or updating their outcomes assessment plan, and they are encouraged to bring their current assessment plan and tools or rubrics referenced in that plan.

The accreditation seminar is appropriate for program officials and others who participate in the accreditation process and is particularly helpful for those who are preparing a self-study report. Participation in the seminar facilitates an understanding of the JRCERT accreditation process, the JRCERT accreditation Standards, and methods for preparing and submitting a self-study or interim report. Upcoming seminar and workshop registration information can be found on the JRCERT Web site at http://jrcert.org/calendar.

Conclusion

Through a process of continuous self-evaluation, your program can benefit by achieving the following objectives:

- Well-articulated educational goals that communicate your program’s vision for the future.
- A documented process that helps maintain continuity through times of transition, such as changes in program officials or budget.
- A process that engages faculty, administration, students, and community members in improving program quality.
- An increased ability to provide answers to questions about program quality and value that are asked by institutional administrators and prospective students and their parents, as well as accreditors and the community at large.

The resources discussed in this article should assist you in this evaluation process. And remember, the focus is on excellence in education.

Debra J Poelhuis, MS, R.T. (R)(M), has served as program director for Montgomery County Community College in Pennsylvania since the radiography program’s inception in 2003. She has worked in radiography education for 34 years, 24 of those as a program director. She has clinical experience in computed tomography, mammography, forensic radiography, trauma radiography, and interventional radiography. She has presented professionally at the local, state, and national levels and has coauthored a textbook in radiography and another in nursing. The Indiana Society of Radiologic Technologists granted her the Distinguished Service Award when she was president in 1992, Technologist of the Year in 1986, and Life Membership in 1997.

Poelhuis has served 5 years on the JRCERT Board of Directors and is currently chair of the Board. She can be contacted at dpoelhui@mc3.edu.
References
Behind the Curtain: A Look Inside the Publication Process

Rebecca L Ludwig, PhD, R.T.(R)(QM), FAEIRS, FASRT
Alicia Kellogg, MA, ELS

If you have ever submitted an article for publication in *Radiologic Technology*—or if you are considering taking this step for the first time—you might wonder what goes on after you turn in your manuscript for consideration. Although what happens next might be unfamiliar, the process is not a secret, and learning what takes place behind the scenes might demystify some aspects of the publication process.

**How to Submit a Manuscript**

*Radiologic Technology* uses an online manuscript submission system that allows authors to upload their manuscript and track the status of their submission throughout the review process. Manuscripts submitted for peer review are evaluated by *Radiologic Technology*’s Editorial Review Board (ERB), and journal columns are evaluated by American Society of Radiologic Technologists staff editors. Three types of research are evaluated for peer review in *Radiologic Technology*:

- Original research (quantitative and qualitative).
- Case reports.
- Literature reviews.

An author can submit a manuscript by visiting http://asrt.msubmit.net, creating an account, and following the author instructions.

**How the Peer-Review Process Works**

Once an author has completed the submission process for an original research article, a case report, or a literature review, the ERB chairman matches the type of research and the topic of the paper to the areas of expertise of at least 2 ERB members. For example, if the article is based on a survey of radiologic technologists regarding the radiation protection strategies they use most often, the reviewers need to have expertise in radiation protection and survey-based research. In an effort to maintain confidentiality, all information that might identify the author and location of the study is removed before the selected ERB members receive an invitation to review the article.

The invitation to review is declined more often than you might anticipate. Sometimes ERB members believe a potential conflict of interest exists because they think they recognize the work of a colleague or the place where the study was conducted, even though this information is withheld. Sometimes reviewers believe that they lack the appropriate expertise to evaluate the merits of the study, or they might not have time to complete the review within 30 days. The work of the ERB begins in earnest when at least 2 ERB members have agreed to serve as reviewers.

**What Reviewers Look For**

Most reviewers begin the review process by simply reading the manuscript. After getting a sense of the scope of the project and the style of writing, the reviewers go through the manuscript carefully while considering specific criteria related to the particular type of research to guide the review process. The reviewer takes into account broad, high-level assessments, such as whether the subject is appropriate for the journal and...
whether the manuscript validates or adds to the body of knowledge, as well as more specific considerations regarding the manuscript’s content.

Regardless of the specific article type or the details of a particular paper, a manuscript should incorporate the following features:

- A topic of interest for the journal’s readers.
- A concisely summarized literature review or background information.
- A title that clearly reflects the theme of the project.

Manuscripts submitted for peer review should demonstrate use of the correct research design, provide meaningful data analysis, identify the study’s weaknesses, and relate the study’s findings to clinical practice.

All research projects have limitations and weaknesses, and the outcomes of the research might or might not support the author’s hypothesis. It is important for authors to remember that a project does not have to be perfect to be published. As long as these issues are recognized and addressed, the manuscript remains worthy of consideration for publication.

Reviewers routinely check for congruency between the article or study’s goals and its conclusions. Interestingly, authors sometimes state objectives for the project that remain unaddressed in the manuscript’s conclusions. Reviewers also use key words from the manuscript to search the literature to validate the scope and depth of the literature review.

**Reviewer Decisions**

When the review process is complete, the reviewer makes a recommendation to accept the manuscript, reject the manuscript, or request revisions. The reviewer writes comments for the author to explain the rationale for the decision and to guide the author’s efforts when making revisions, if revision is recommended. Revisions are a common recommendation designed to strengthen a manuscript, and this decision should not be viewed as a rejection of the work. The revisions that take place at this stage play a key role in preparing the article for publication in the journal. For peer-reviewed articles, if the 2 ERB reviewers make significantly different comments and different recommendations, a third reviewer evaluates the manuscript. Throughout this process, every effort is made to provide a balanced and fair evaluation of each manuscript.

After the reviewers’ decisions have been made, the manuscript’s lead author is notified of the recommendation and the reviewers’ comments. If the reviewers recommend revisions, the same reviewers are asked to evaluate the revised manuscript. After the reviewers recommend acceptance and plagiarism detection software confirms that the author’s work is original, the article is officially accepted for publication. A member of the journal staff assigns the manuscript to an issue, and the article usually is published within 12 months of acceptance.

**From Acceptance to Publication**

Accepted manuscripts are ready to begin the final steps toward publication in *Radiologic Technology*. Members of the journal staff edit the article according to the journal’s editorial style requirements, recommend revisions to enhance the clarity of the writing, and correct any grammatical errors. The author then has the opportunity to review the edited article. After the journal’s editorial staff receive this author feedback, the article is formatted for publication. From there, an editor e-mails the author a PDF of the article as it will appear in the journal, and the author has a final opportunity to review the article and provide feedback. Once this step is complete, the next time the author sees his or her article, it will be in the pages of *Radiologic Technology*.

**Conclusion**

With each manuscript that is reviewed and published, the *Radiologic Technology* ERB and journal staff work to provide high-quality, interesting, innovative, and thought-provoking information that will enhance the expertise of radiologic technologists, advance the discipline, and ultimately improve patient care. These objectives would not be possible without the radiologic technology professionals who write for the journal. The knowledge these authors share through publication makes a vital contribution to the field.

Rebecca Ludwig, PhD, R.T.(R)(QM), FAEIRS, FASRT, is the dean of the College of Health Sciences at St Petersburg College in St Petersburg, Florida. She is active in the radiologic technology profession, presenting nationally and internationally and serving on many national and...
Behind the Curtain: A Look Inside the Publication Process

international boards, councils, and committees. She currently serves on the Radiologic Technology Editorial Review Board for the American Society of Radiologic Technologists and is a manuscript reviewer for the Canadian Association of Medical Radiation Technologists.

Alicia Kellogg, MA, ELS, has 10 years of publication editing experience and serves as managing editor of Radiologic Technology.

If you are interested in submitting an article for publication but have questions about the process, please contact the Radiologic Technology editorial staff at communications@asrt.org.

Click here in the online version of this issue or visit http://asrt.msubmit.net to submit a manuscript for publication in Radiologic Technology.
Service Quality in Mammography

Constance Noble, BSRSA, R.T.(R)(M)

The quality of service patients receive is important—it is what they remember and talk about. Ensuring patient satisfaction can be challenging for radiologic technologists who need to keep up with new care interventions, devices, and drugs to deliver safe patient care effectively and efficiently. The growing complexity of science and technology in health care along with new methods of organizing and delivering care that meets the expectations of patients and their families can make providing quality patient care daunting.

Learn what patients value in medical services by listening to their concerns. Some health care organizations have invested in patient surveys that record, define, assess, and help improve the quality of service to their patients. One survey reported that 28% of patients believed that staff members should explain a service being provided, and 17% of patients assumed that staff members would respond to their concerns. However, the authors also noted that a “small number of patients . . . do not complain or they complain only to the front-line employee” (eg, the mammographer). A mammographer can explain the importance of compression before the examination and give the patient some control by encouraging her to express how much compression she can withstand. The mammographer’s role is to make sure the amount of compression is beneficial while not causing bruising, splitting of the skin, or severe pain or redness during the examination.

Occasionally redness and pain occur during a mammogram, but other complaints arise too, such as a long wait, inability to find convenient parking, or inability to find the facility because of poor signage. Some patients might feel they were not greeted cordially at the front desk, or they might question why another patient was called before them.

Of those patients who are willing to voice a concern to a mammographer, a small percentage will file a written complaint if the mammographer cannot address their concern. Therefore, some patients’ concerns could remain unknown to those in management. Regardless of whether they file a formal complaint, patients might tell other patients about their dissatisfaction with the mammography experience. These word-of-mouth comments can have a significant effect on a mammography facility. Unsatisfied patients are unlikely to return to a facility for services, and they could influence others not to use a particular facility. Conversely, it is more likely that patients will return to a facility if staff members implement the principles of service recovery.

**Service Recovery**

Service recovery in the health care field “is all about making it right after something goes wrong,” according to Clark and Malone, and “it can be as simple as apologizing” or making a follow-up call days later. Sometimes offering a gift card will mollify a dissatisfied customer. Because of company policies, some mammography centers’ only option for service recovery is to verbally apologize for a patient’s disappointments. Methods for fixing service problems such as long wait
times, poor parking conditions, or scheduling mishaps will depend on the circumstances involved.

Service recovery policies should include the flexibility to adjust responses to patient concerns and differing expectations. For example, some patients expect first-row parking while others do not. Some patients expect quick service, and others view a long wait as normal and similar to their experiences at their doctor’s office. Regardless of patients’ expectations and experiences, service recovery policies should be in place to respond to patient concerns.

Clark and Malone suggested 3 steps in service recovery:

1. Recognizing that something went wrong.
2. Apologizing for the dissatisfaction.
3. Making amends for the dissatisfaction.

It is estimated that health care departments that do not use service recovery will lose 20% of their patients as a result of poor service. Dissatisfied patients will complain only 4% of the time, and the rest will go away angry. For every complaint received, there are an average of 24 more complaints out there, and 6 of those are severe. Of patients who complain, 56% to 70% will return for future services if the complaint is resolved. This figure increases to 96% if the complaint is resolved quickly.

Recognizing

The first step in service recovery is to recognize when something goes wrong. The mammographer should observe the patient’s facial gestures, listen for any tone of disappointment, and notice body language. For example, if a patient stands up quickly, sighs, and does not make eye contact with the technologist, then bolts ahead of the technologist into the examination room and throws her purse down while speaking only in short phrases, she is likely disappointed. The mammographer should recognize that something has gone wrong and should carefully find out why the patient is upset. When acknowledgement of a concern is addressed soon, it is less likely to become a formal complaint.

Most times patients do not voice concerns, so the only way to determine whether they are uncomfortable is to watch for signs. A patient’s expectations can be formed by initial communication, previous experience, and comments from others who have used the facility. Patients might pass on comments that a particular mammography center has a “rough technologist,” an “inefficient, unfriendly front desk staff,” or a “serious parking problem.” The mammographer should be aware of these factors and how quickly such comments circulate through the community. Patient satisfaction surveys and an attentive staff prepare a facility to mitigate and make the patient’s current experience rewarding.

Responding

The second crucial step in service recovery is responding appropriately to patient concerns. Some hospitals have established “minute rules” in which staff members discover concerns and complaints and dedicate 5 to 10 minutes to addressing them. If all efforts fail, then they seek help from management. Nevertheless, how technologists handle complaints is essential. Gitomer stated that word choices and tone can make or break the interaction. The technologist should be sincere and show understanding and concern, empathizing with the patient. A list of phrases that a radiologic technologist should not say to a patient who is upset—and positive alternatives—is shown in the Box.

Body language also is an important part of responding to patients who are upset about the service they received. It is difficult for people to think one thing and make their body show something else convincingly. What goes on in our minds comes out nonverbally through body language, and patients can tell. If technologists do not introduce themselves, do not make eye contact, do not smile, or if they cross their arms in front of them when speaking, patients can interpret this body language as showing an indifferent or uncaring attitude. Conversely, using positive phrases along with eye contact, attentive listening, and showing awareness of the patient’s feelings will express a positive message through one’s body language.

Making an effort to understand patients’ dissatisfaction might mean technologists have to put themselves in the patients’ place. An immediate response to those concerns with a positive attitude and accepting responsibility for one’s actions are elements of quality patient care. The mammographer should make it clear to patients that he or she understands their concerns and will do what is possible to make amends.

Making Amends

Making amends is the third step in service recovery. Taking action is a more sincere gesture than
simply responding to the patient’s unmet expectations. Options for making amends with patients can be limited in some organizations because of policies prohibiting gifts to patients. However, there are certain methods that mammographers might consider using.

When an apology is not enough to satisfy a patient, exhibiting extra effort with services might help. For example, if a patient complains about a long walk from the parking area and has an injury that makes it difficult to walk, the technologist might offer to take the patient to her car via a wheelchair. Another gesture would be a follow-up call in a day or two to check on a patient who experienced pain during an examination. Long wait times sometimes cannot be helped, but having some kind of refreshment on hand might be enough to calm patients and let them know staff cares about their comfort.

Patients always will have certain expectations of how issues should be resolved. Health care research has found that 55% of patients believe that their complaints will be ignored. Only 8% expect an apology, and 5% believe that the health care provider will empathize with them. Research shows that “in the event of service failure patients want education, information and a sense that the person listening to the complaint will actually do something about it.” Making amends helps the technologist to regain the patient’s trust.

In any event, patient concerns should be reported to a supervisor. The Mammography Quality Standards Act provides guidelines for consumer complaints. The guidelines require that each facility:

- Establish a written and documented system for collecting and resolving consumer complaints.
- Maintain a record of each serious complaint received by the facility for at least 3 years from the date the complaint was received.
- Provide the consumer with adequate directions for filing serious complaints with the facility’s accreditation body if the facility is unable to resolve a serious complaint to the consumer’s satisfaction.
- Report unresolved serious complaints to the accreditation body in a manner and timeframe specified by the accreditation body.

Patients’ comments and concerns should be welcomed because this feedback provides opportunities for health care workers to improve service quality. Technologists should always ask patients whether their expectations have been met, encourage them to make suggestions for improvement, and thank them for their input. If a method for making amends in response to a patient’s dissatisfaction is outlined by the facility, this step should be taken as soon as possible.

Creating Loyal Patients

Sometimes it takes more than courtesy and empathy to please patients; patients want a facility that displays professionalism. Once rapport is established between a patient and an imaging center, trust and loyalty usually follow. Nevertheless, communication, a good attitude, reliability, assurance, empathy, and exceptional service
also are important. In terms of the mammography facility, patients need exceptional service from caring mammographers and a facility they can rely on and return to.

Some ways all radiologic technologists can provide exceptional service quality include:

- Making an effort to understand the patient.
- Being prepared to serve the patient and his or her family.
- Addressing a patient’s concerns immediately.
- Asking the patient for information.
- Listening to the patient.
- Taking responsibility for one’s actions.

“Satisfied” patients are those who believe that their health care services were completed as expected. In other words, everyone involved did the job the way he or she was supposed to. When patients are satisfied, they will come back to a facility and tell others about it.

Satisfaction is one thing, but loyalty means the patients trust the staff and are more likely to return to the facility.

Conclusion

Quality patient service is important for an organization because without patients, there would be no organization. The American Registry of Radiologic Technologists Standards of Ethics state that technologists are to act in a professional manner, provide services with “full respect for the dignity” of their patients, and deliver patient care without discrimination based on a patient’s “personal attributes, nature of his or her disease or illness, sex, race, creed, religion, or socioeconomic status.” In addition, health care delivery systems need to include a “strong emphasis upon continually improving 3 specific types of quality indicators”: Efficacy of care – knowing what works. Appropriateness of care – doing what works. Execution of care – doing well what works.

Mammographers should take the time to provide quality care for each patient, adding personal, special touches to their performance and demonstrating clinical skills to increase patient satisfaction and loyalty. One personal touch is to check a patient’s previous history and follow up with comments. For example, one technologist read a note in a patient’s chart indicating that this patient was difficult to image. Because the patient used a wheelchair, 2 technologists performed her previous study.

When the patient came in for an examination the following year, she was walking with a cane. The attentive technologist commented on the patient’s improved health, which made this patient very happy. She felt noticed and personally recognized and probably told others about her positive experience. Personal touches like this create satisfied patients and loyalty to your facility.

Constance Noble, BSRSA, R.T.(R)(M), is a mammographer at Akron General Partners in Akron, Ohio. She graduated cum laude from Saint Joseph’s College of Maine. She has many years of experience as a radiologic technologist, a radiology clinical instructor, and a mammographer. Noble is interested in health care quality and is pursuing a health care leadership career. She can be reached at cnoble58@hotmail.com.

References

The third edition of *Diagnostic Breast Imaging* is a comprehensive book dedicated to the entire spectrum of breast health. It encompasses every aspect of the breast, from anatomy to diseases and disorders both benign and malignant. The material is presented in a highly organized, systematic manner. Breast pathologies are clearly identified and explained, detailing specific examination procedures, imaging requirements, technical considerations, diagnostic strategies, and clinical findings.

The book is an impressive instructional text that is beneficial for all breast health practitioners, including radiologists, surgeons, oncologists, and technologists, as well as registered nurses and patient navigators dedicated to improving the outcomes of breast diseases. *Diagnostic Breast Imaging* can serve as a resource for practitioners across the spectrum of breast health, with an added benefit of functioning as a review manual for professionals preparing for licensing examinations.

The subject matter is well organized, practical, and presented in a manner that flows well. An extensive section of references and recommended reading follows each chapter, and a list of the medical terminology abbreviations used is presented at the beginning of the book. More than 1000 illustrations and medical images emphasize and complement the wide range of breast pathologies covered, and tables and charts are easy to follow and clearly explained.

An entire chapter is dedicated to the male breast and the unique challenges presented in the male population as it relates to breast pathologies. The chapter is comprehensive, covering all of the imaging modalities used in the diagnosis of male breast pathology, and supported by a variety of corresponding medical images.

Another chapter in the book is dedicated to emerging technologies in breast imaging, including up-to-date information about digital breast tomosynthesis, spectral mammography, contrast-enhanced digital mammography, and sonoelastography. Advances in breast magnetic resonance imaging as well as the role that nuclear medicine plays in oncology imaging are clearly explained.

At more than 700 pages, the book is large; however, it holds a wealth of accurate information that captured my attention. The quality of the medical images presented throughout was outstanding. The images were clear, and each was supported by a clear explanation. Because the book provides comprehensive coverage of a full range of breast pathologies, it easily can be used...
as a reference book by practitioners in the field of breast health. The book does not contain a glossary, which might have been helpful considering the vast amount of sometimes complicated medical terminology used throughout.

It was a privilege to review such an outstanding book on breast imaging and pathologies, and I would recommend it without reservation to practitioners at every level.

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The goal of The Physics of Clinical MR Taught Through Images was, as stated by the authors, to help radiologists, nonradiologists, residents, and medical students increase their knowledge and understanding of the complexities of magnetic resonance (MR) imaging physics. They definitely hit the mark. This book is an excellent resource for practicing MR technologists in need of a refresher on MR physics or who have a desire to increase their expertise in their daily practice. While most MR physics–related materials are lengthy and highly technical, this book was easy to read and understand, with short and concise chapters that made it a quick, accessible reference.

The 124 chapters cover 7 distinct sections ranging from hardware and basic principles to pulse sequences and advanced principles for both 1.5T and 3T MR imaging. Each chapter ranges from 2 to 4 pages, which made it easy to identify, comprehend, and apply fundamental concepts. In short, this book provides an economy of words without loss of detail or accuracy.

Concise, practical wording is a staple throughout, along with excellent illustrative quality that enhances the reader’s understanding of the results obtained when using various MR principles. The concepts in this text are current, and the figures and images associated with them have been taken from both 1.5T and 3T magnets, demonstrating current and advanced technologies. Generally, it is difficult for any text to provide an overview of material that can fulfill the expectations of both the student and physician alike, but the authors have succeeded by covering an array of topics in comprehensible terms.

In summary, The Physics of Clinical MR Taught Through Images was a pleasure to read, both as a refresher of my current practice in MR physics as well as a resource to add to my knowledge and understanding of the many advances and improvements in MR. This book would be of great value to the intended audience as well as to MR technologists who want to update their knowledge of procedures and techniques and to MR students who are preparing to sit for their registry examination.

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Breast Imaging is one book in a series of books called RadCases published by Thieme Medical Publishers. A quick-reference guide intended to help radiologists and radiology residents hone their skills and study for mammography certification, Breast Imaging includes the hard-copy book and 12 months of online access to all of the cases listed in the book as well as additional online-only content.

This case study reference book contains 250 mammography cases to study, compare, contrast, and review; tips to help radiologists with image interpretation; and facts and pitfalls about managing mammography patients. The book does not have a table of contents, nor is it split into categories or disease classes, so searching
for a specific case can be difficult; however, online readers can search for cases by case number, type, modality, or patient factor. The book presents cases related to both female and male patients.

The images are of diagnostic quality—some are magnified to better demonstrate pathology or characteristics—and mimic the imaging techniques that imaging departments follow. Multiple mammographic projections are included, which gives the reader an opportunity to see the subtle differences between projections. Images from other modalities are included in some of the cases to demonstrate different aspects of the disease process. Images of foreign bodies and artifacts also are included, along with tips to prevent these artifacts. It would have been beneficial to have all the views on facing pages in the book, but the online version shows the views in the traditional format.

Using the code provided in the book, readers can register on the Thieme Web site to access all the content contained in the book as well as extra online-only information, including an additional 150 cases. Readers have 12 months from the time of registration to access this content, and access can be renewed annually for a fee.

As an imaging professional, I enjoyed this text for the help it provided regarding proper positioning and for the additional perspectives related to radiographic abnormalities or history presentation in these case studies. The information presented was written in a way that any imaging professional working with breast health can understand.

Many good books about mammography are available, but finding good reference case books can be difficult. *Breast Imaging* is a valuable resource both for the intended audience and for imaging professionals, especially those who are just starting to gain experience in mammography.

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RAD-AID International is a nonprofit organization founded by radiologists in 2009. The organization leads an extensive multidisciplinary volunteer team that includes physicians, technologists, sonographers, and nurses. RAD-AID’s mission is to improve and optimize radiology services and radiology access in developing countries through assistance, training, and collaboration. The organization builds international relationships through its chapters established by individual radiologists or technologists. Members can then reach out to countries to determine individual needs based on RAD-AID’s evaluation process. RAD-AID expands its reach by collaborating with international organizations such as the World Health Organization and the International Society of Radiographers & Radiological Technologists.

The Asha Jyoti Program

In 2010, RAD-AID partnered with the Postgraduate Institute of Medical Education & Research (PGIMER) hospital in Chandigarh, India, to create a women’s mobile health program designed to offer screening and referral for breast cancer, cervical cancer, and osteoporosis (see Figure 1). Philips Healthcare donated a specially designed van to provide screening mammography, colposcopy, and bone densitometry testing, as well as educational programming, bringing vital health services to underserved populations in northern India in the Punjab province and the city of Chandigarh (see Figure 2). The van is the first of its kind, and the private–government–nonprofit partnership created among Philips Healthcare, PGIMER, and RAD-AID has become a model for creating and deploying innovative health care technology and programs.

On September 30, 2011, the American Society of Radiologic Technologists (ASRT) partnered with
RAD-AID to recruit radiologic technologists for volunteer opportunities in developing countries. One such project is the Asha Jyoti: Women’s Healthcare Mobile Outreach Programme. *Asha jyoti*, which means “light of hope” in Hindi, signifies the use of advanced medical technology to bring hope and vital health services to underserved women.

The program has screened more than 4000 women during the first 2 years of a 5-year pilot program. RAD-AID provides on-site and online educational and program planning support to health workers and staff to optimize quality and safety. An initial 6-month testing phase took place from April 22 to October 22, 2012. Based on staff and community feedback, educating technologists was a critical need because there is no formal mammography training in India.

In the next 4.5-year phase, which is only just beginning, imaging and clinical data will be reviewed to improve diagnostic quality and match best-practice procedures. Biannual reviews evaluate personnel and communications, and RAD-AID provides training workshops for the technologists in India as well as public health support to increase outreach and dialogue among all participating staff. The program involves continuous review of outcome data collection and follow-up procedures such as biopsies. The services have expanded to more villages and sites in India, and information gathered from this endeavor will be shared with public institutions in India and abroad to help others implement similar preventive care programs.

### Mammography Education in India

For the Asha Jyoti project, one goal was to provide the mammography technologists in India with an advanced-level of education in mammography comparable to that which is offered in the United States. It was a 4-week project that involved 2 teams. The first team consisted of RAD-AID ASRT volunteers Jackie Kobeski, BS, R.T.(R)(M); Olive Peart, MS, R.T.(R)(M); and Monica Vazquez, R.T.(R)(M).

The first team offered clinical instructions each day at PGIMER, followed by didactic education (see Figure 3). Kobeski and Vazquez rotated the technologists through individualized hands-on positioning skills from 9 AM to 1 PM. Peart then presented the didactic course from 2 to 5 PM. The course included breast anatomy and physiology and associated terminology, breast pathology, breast imaging modalities, patient preparation and education, mammographic imaging equipment and exposure factors, quality assurance and control standards, interventional options, breast cancer treatment options, and routine and supplementary mammographic imaging, critique, and evaluation. The technologists were given a comprehensive final exam at the end of the 2 weeks that certified them in mammography.

The second team followed up with 2 weeks of intensive clinical hands-on training with a focus on positioning, image critique, and image quality.

### Conclusion

The technologists in India were enthusiastic and eager to learn, and it was an honor for us to have the opportunity to present them with the educational tools necessary to perform imaging with expertise. It is with
great gratitude and joy that we shared our passion for improving women’s health with our colleagues in India. We hope our actions inspire continued support of women serving women internationally.

Olive Peart, MS, R.T.(R)(M), is the clinical coordinator for Stamford Hospital’s radiography program in Stamford, Connecticut. Her Technical Query columns appear regularly in Radiologic Technology, and she is the radiologic technology editor with Gannett Education. Peart has authored several textbooks including Spanish for Radiology Professionals, an English-to-Spanish translation of often-used technical terms and radiological instructions; Mammography and Breast Imaging: Just the Facts; Lange Q&A Mammography Examination; Mammography and Breast Imaging Prep; and Radiographic Positioning Flashcards, a quick procedure reference.

Kathryn Everton, MD, is a diagnostic radiologist with fellowship training in breast imaging. She has been a volunteer with RAD-AID International since 2011 and serves in 2 positions within the organization. She is RAD-AID’s director of women’s imaging and codirector of RAD-AID India.

Jackie Kobeski, BS, R.T.(R)(M), is a radiologic technologist who has specialized in mammography for more than 30 years. She has a bachelor of science degree in radiologic science. She has been a volunteer with RAD-AID International for the past year serving the Asha Jyoti program in India as its lead consulting technologist.


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Millions of people travel by plane every day. Before they are allowed to board, they are required to go through a security check-point where their luggage and their bodies are scanned using an x-ray machine and possibly a whole-body imaging machine. These safety measures have been implemented to help prevent terrorist attacks such as 9/11 and the attempted bombing of a U.S. aircraft on Christmas Day 2009.

According to Brian Rey, a transportation security officer at Raleigh-Durham International Airport in North Carolina, the majority of passengers who pass through security—approximately 99%—are cooperative and often thankful for the Transportation Security Administration (TSA) officers and procedures that are helping to ensure their safety (oral communication, February 2012). However, the remaining 1% of passengers are upset about having to be scanned or resistive to it (eg, pregnant women traveling with breast milk or people who take homeopathic medicines).

This article focuses on consumer concerns regarding privacy rights violations and radiation exposure. The operation of the 2 most common types of whole-body imaging scanners, backscatter x-ray scanners and millimeter wave scanners, is examined as well as the different privacy-promoting software and settings used. This article also compares the radiation dose from a backscatter x-ray scan used for security purposes to more common occurrences that people may encounter.

The significance of educating those operating these machines and the public, in addition to the continuing need for research and technological advances, is discussed. Travelers who understand how the scanners work and the risks vs benefits are less likely to fear them. They also should understand their right to question how the scanners work and to refuse scanning in favor of alternative screening methods.

**Information Sources**

Research for this review began with an investigation of public opinion and concerns about airport scanners on February 2, 2012. Broad search terms such as airport scanners, airport security dose, and airport scanners public concern were used to search 3 databases containing peer-reviewed literature, and, ultimately, 15 articles were selected. The search strategy is depicted in the Figure.

In addition, information was gathered during a February 17, 2012, interview with Transportation Security Officer Brian Rey. The interview included the following questions:

- What is a typical day like for you, and what does your job entail?
- Tell me about the types of scanners you use to screen people at security.
- How do they work, and how much radiation do they give off?
- How have scanners been improved over the years?
- Do the operators of these machines understand how the scanners work and the risks involved?
Do you find the public voices opinions about being scanned? If so, what are the concerns?

How do you alleviate these concerns, and how do you advise your employees to deal with these concerns?

From your experience, what does the future of airport security look like?

Rey, who had been in his position for 9 years at the time of the interview, is responsible for resolving customer concerns and equipment problems and for supervising officers who inspect x-ray baggage scans. None of the scanners at this airport that are used to screen travelers use backscatter technology.

Travelers are scanned using whole-body radio wave scanners, and property and luggage are scanned using x-ray or low-dose computed tomography (CT) machines. These whole-body radio wave scanners create 2-D images of passengers at the security checkpoint. Operators can choose which slices from x-ray or CT scans of luggage they want to look at more closely and rotate images, if desired.

Security employees are educated about how the equipment works, which allows them to explain to passengers that the machines are safe. This in turn promotes an environment where passengers feel comfortable around the radio wave scanners. Most people are cooperative, but some are angry about the scanning requirement. In addition, people are cautious about the new scans that use radio waves. Although there are signs in place with information about the machines, often people do not read them.

Rey says that TSA officers emphasize customer service and treating all passengers and belongings with respect. Other screening methods such as physical pat-downs, metal detectors, and equipment that tests liquids can be used if the passenger does not feel comfortable being scanned by the new machines. Rey’s job is to ensure procedures are followed according to practice standards. Technology is always improving, and the future promises safer and easier means of scanning that might combine different types of equipment into one machine.

How Scanners Work

The 2 types of advanced imaging used for security scanning at airports are backscatter x-ray scanners and millimeter wave scanners. The most common type of scanner is the backscatter x-ray scanner that uses very low-dose x-rays to detect the radiation that reflects off the person imaged. Unlike the radiation received during medical examinations, all the energy sent out from the backscatter x-ray scanners is absorbed by the most superficial tissue of the body. The 3 backscatter models currently manufactured for use in airports are SmartCheck (American Science and Engineering Inc), the Ait84 (Tek84 Engineering Group), and the Secure 1000 (Rapiscan Systems).

These machines create extremely detailed images that generate outlines revealing genitalia, breasts, buttocks, and fat creases, as well as prosthetics, catheters, and piercings. Individuals scanned are pictured with photolike quality. As a result, Congress has mandated that all U.S. TSA body scanners be equipped with automated target recognition, which turns these graphic images into generic outlines of a human body while still allowing the scanner to detect liquids, plastics, gels, powders, metals, ceramics, explosives, and drugs.
Millimeter wave scanners can be classified as active or passive. Active millimeter wave scanners construct 3-D images using reflected energy from dual antennas that deliver extremely low energy in the form of radio-frequency waves (similar to those emitted by mobile phones) as they rotate around the target. Passive millimeter wave scanners detect naturally emitting energy from the body or objects concealed on the body to provide an image similar to a negative photograph, and they are as safe as a digital camera.

The use of whole-body imaging provides superior ability to detect both metallic and nonmetallic threat objects, and airport authorities believe that it is the preferred choice compared to physical pat-downs or strip searches.

**Dose Delivered by Scanners**

In part because the federal government requires advanced imaging scanners, some passengers worry about the dose of radiation received from being scanned. The international unit used to measure radiation dose is the sievert (Sv). The dose delivered by backscatter x-ray scanners is measured according to well-established guidelines using calibrated ionization chambers. Although some quality assurance is performed every morning by the security checkpoint operators, some TSA members are assigned solely to monitor and maintain the equipment and test the doses to be sure they are within the appropriate range.

The estimated dose received by a backscatter scan is between 0.01 μSv and 0.88 μSv. The dose to children up to 5 years of age is estimated to be 0.037 μSv per scan, 0.050 μSv for infants, and a negligible dose to a fetus. In comparison, an airport backscatter x-ray scan delivers less than 1% of the dose received during a 6-hour flight.

Air travel is associated with approximately 0.04 μSv per minute of cosmic radiation, or 0.005 mSv per hour, meaning a 6-hour flight would expose a passenger to 20 μSv, which is 200 to 400 times greater than the amount of radiation received during a backscatter x-ray scan. According to the NYU Langone Medical Center in New York, a passenger would have to be scanned with a backscatter x-ray scanner 200,000 times to be exposed to the same amount of radiation as a CT scan, while having a backscatter x-ray scan every day would expose a person to one-tenth of the radiation dose used for CT.

The average person receives 2100 μSv to 2400 μSv per year from natural background radiation exposure depending on his or her region, housing materials, workplace, number of medical imaging examinations, and proximity to nuclear power plants, as well as foods consumed and other lifestyle habits such as smoking.

Fifty whole-body security scans are equal to one dental x-ray, and 1000 security scans are equal to one chest x-ray. Putting the dose received from one backscatter x-ray scan at airport security into perspective alongside many other sources we encounter daily might help alleviate some of the public’s fears concerning radiation exposure.

**Safety**

Media reports play a large role in influencing the public’s apprehension about radiation exposure. For example, the damaged Fukushima nuclear power plant in Japan and reports about inappropriately high radiation doses delivered during medical imaging have caused heightened public concern. Although the amount of radiation received from a backscatter x-ray scan is estimated to be extremely small, there is a growing concern for the cumulative amount of radiation individuals are exposed to over their lifetime. The dose measurements from security backscatter x-ray machines are within safe dose limits according to the TSA and the U.S. Food and Drug Administration (FDA), but some argue the method of determining the measured dose can affect the results and thus influence the potential risk it poses. Dose measurements for security scans are measured in the same way medical exposure is measured—as an exposure over the entire body rather than a concentrated area. However, some say the dose should be based only on skin exposure because backscatter beams skim the body’s surface. Therefore, the measurements of dose would be higher if only skin exposure were considered. Another complication to dose calculation is that medical equipment manufacturers use different methods to quantify the dose delivered by their product.

One of the greatest debates is whether the small dose from a security scan has the potential to increase health risks to passengers later in life. At low doses, radiation
can cause biological damage, but cells repair this damage rapidly, and it is not known whether the exceedingly low dose from backscatter x-ray scans could cause harm. In addition, it is difficult to estimate the biological effects of radiation because not all tissues react the same way to the same level of exposure. The equivalent dose measurement takes into account the varying relative biological damage that results from different types of radiation affecting different types of tissues. The estimate of cancer risk from this small amount of radiation is based on the linear and nonthreshold model, meaning that as the radiation dose increases, so does the risk, and any exposure—no matter how small—increases risk.

The connection between exposure to small radiation doses and the risk of cancer is complicated because the general population has a high incidence of a lifetime risk of developing cancer. Therefore, extrapolations of cancer risk from miniscule exposures to radiation across large populations are difficult to statistically support. The lifetime risk of developing cancer is 38% for women overall and 44% for men. Among 100 million passengers, 6 cancers over the lifetime of these individuals might develop from backscatter x-ray scans, but 40 million cancers could develop over the course of their lifetimes when underlying cancer incidence is taken into account. Among 1 million frequent flyers who take 10 trips per week for a year, 4 additional cancers could occur from backscatter x-ray scans, which is slight when considered in the context of the 600 cancers that could occur from the radiation received from flying at high elevations and in the context of the 400,000 cancers that would occur in these individuals over the course of their lifetimes.

Because we cannot reliably quantify individual risk at low doses, we do not know for sure that population risk is negligible, and as more people are exposed to scanners, the probability that a population would see more malignancies increases. Risk is higher for frequent flyers, although long-term consequences are unknown. Pregnant women, children, cancer patients, and those with a compromised immune system are often extremely cautious about being scanned, but the TSA and the FDA have stated that potential health risks from whole-body screening are miniscule and present no significant risk to public health. Current calculations indicate backscatter x-ray systems are safe for all types of passengers, and the risks associated with the dose delivered by backscatter screening are trivial compared to daily exposures to natural sources and the improved security benefits to the traveling public.

Privacy

The other great cause of uneasiness among passengers as they come through airport security is the issue of privacy. Some news media reports negatively influence the public’s understanding of how whole-body scanners work with terms such as naked scanner. Only secondarily has the debate over these scanning technologies focused on detection of potential threats.

In the initial stages of implementation of whole-body imaging, many countries were wary of using these machines for security screening. In 2006 the Central Industrial Security Force in India rejected the use of whole-body scanners because the images they produced were too revealing. The European Parliament ruled in 2008 that the scanners “have a serious impact on the fundamental rights of citizens” and voted for further study on privacy and safety implications before using them as a screening tool. In 2009, the United States became the first to adopt whole-body imaging for primary screening of passengers.

To address public concerns about privacy, the TSA has implemented technology that blurs the image of the face of the person being scanned, and technical solutions have been developed that separate the display of weapons, drugs, and explosives from the visualization of the person’s body. The TSA has implemented procedures for remote viewing of the whole-body images so the screener viewing the images cannot see the individual being imaged and the images are viewed in a nonpublic, enclosed space. Security personnel in these separate viewing rooms do not have access to the passenger’s details, but they can communicate any potential threats to screening personnel through a separate graphic interface. This helps ease privacy concerns of passengers who are interacting with airport screening officials. The TSA also has made it impossible to save and export images; the images are immediately deleted after an individual has been scanned.

Automatic detection capabilities allow screeners to only look at certain portions of an image and respond to automatically detected threats. The TSA now uses
automated target recognition (ATR) software on millimeter wave imaging machines, which addresses passenger privacy considerations while highlighting potential threats. According to information regarding advanced imaging technology from the TSA:

ATR is designed to enhance privacy by eliminating passenger-specific images and instead auto-detecting potential threats and indicating their location on a generic outline of a person. Areas identified as containing potential threats will require additional screening.  

The Pacific Northwest National Laboratory in Washington state also developed a privacy algorithm for millimeter wave scanners based on technology known as speckle detection. Plastics, ceramics, and other non-conducting materials produce a speckled texture in the scanned image, while the skin remains smooth. This neural network–based algorithm that performs a series of postprocessing tasks was as effective at identifying threat objects as were trained human examiners who viewed the same image. They also developed a backscatter machine privacy algorithm designed to reduce human features to the level of a chalk outline, with threats outlined but facial features unrevealed. Continued research and development of improved systems and a better-informed public will help reduce resistance to backscatter x-ray scans on the basis of privacy violation.

**Conclusion**

The main focus of this article was to provide more information about the types of airport security scanners the public might encounter while traveling and an understanding of how the scanners work to alleviate concerns about invasion of privacy and radiation dose. The 2 types of whole-body imaging machines discussed were millimeter wave scanners, which use radiofrequency waves, and backscatter x-ray scanners, which use extremely low amounts of radiation to obtain an image. While both machines produce detailed images of the passenger being scanned, software adaptations have been added to reduce privacy exposure and identification of the person.

It is important for the public to know that they may opt out of whole-body scanning and go through a metal detector and a physical pat-down. However, some might feel this physical contact is an even greater invasion of privacy. Although backscatter machines pose no known threat to passengers as far as radiation dose is concerned, people still are cautious because they lack this knowledge.

Not only does the public need to be educated about the technologies in use, but the TSA and other security employees operating these machines also need to be well informed. They must know how both the millimeter wave and backscatter scanners function to operate these machines in accordance with policy. Additionally, they should undergo radiation safety training so they can explain the backscatter machine’s safety to passengers and point out that it poses no known threats or increased risk of cancer. However, further research involving large-scale clinical testing should be done to estimate risk to the entire population. TSA and security employees also must be well informed of the new advances being made and the future of security screening because as terrorists adopt alternate strategies designed to bypass both types of scanners, these strategies could render the scanners irrelevant and lead to more focus on the effectiveness of these devices.

For improvements in public perception of the TSA to occur, for more trust to be placed in the security process, or for the easing of people’s concerns about privacy to occur, airport security managers and policy makers must not only set quality standards but also require audits and other assurance methods to ensure compliance.

__Stephanie Renee Sutton, BSRT, R.T.(R)(MR)(T), was born and raised in Charlotte, North Carolina. She attended the University of North Carolina at Chapel Hill for her undergraduate education, earning a bachelor of science in radiologic science with a focus on radiography and magnetic resonance imaging. She then attended the year-long radiation therapy program at UNC Hospitals. Sutton is a radiation therapist for Wesley Long Hospital Cancer Center in Greensboro, North Carolina, and is a member of the American Society of Radiologic Technologists. She can be contacted at srsutton@live.unc.edu.  

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Adjustment Issues

This radiograph demonstrates a cervical dislocation. Cervical dislocation is the displacement of one cervical vertebra relative to another. The condition can be caused by a disruption in the supporting ligaments either from trauma or degenerative change. Damage to the spinal cord is possible. Image courtesy of Gonstead Family Chiropractic, Albuquerque, NM.

Archive

Keeping Track of Wastage.
The X-Ray Technician, October 1936.

If every technician were told that he would receive an increase in compensation of two dollars a day he would think that the millennium had come; yet this much, and often much more, is quietly slipping through the department in the form of unnoticed (or very often unmentioned) waste. One or two films a day out of a heavy schedule does not seem like a great deal, yet collectively they add up to an impressive total. . . .

In one institutional x-ray department a check sheet is posted in the x-ray room on which each unsatisfactory radiograph is listed, with the cause of failure indicated, no matter what it might be. When the mistakes of the month were first totaled and the causes discussed with the technicians involved there was a noticeable reduction in errors.

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* PPV for recall is a widely used measure of the proportion of women recalled from screening that are found to have breast cancer.

** PPV for biopsy is a widely used measure of the proportion of women having a breast biopsy that are found to have breast cancer.

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