DIRECTED READING ARTICLES
Radiation Protection Education in Fluoroscopy
PAGE 511

Meditation, Stress Relief, and Well-Being
PAGE 535

PEER-REVIEWED ARTICLES
Manipulation of Projection Approach in Pediatric Radiography
PAGE 481

Using Mobile Electronic Devices to Deliver Educational Resources in Developing Countries
PAGE 490

Preoperative Breast MR Imaging: Its Role in Surgical Planning
PAGE 499
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Erratum

An error occurred in the Setup Solutions column, “A Modified Danelius-Miller Method Solution,” which appeared in the March/April 2015 issue. The description of the method should read, “The Danelius-Miller method is performed with the detector/image receptor positioned parallel to the affected femoral neck,” rather than “parallel against the affected leg.”

Thank you to the reader who brought this error to our attention.
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MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.

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PEER-REVIEWED ARTICLES

Manipulation of Projection Approach in Pediatric Radiography
Quentin T Moore ................................................................. 481

Using Mobile Electronic Devices to Deliver Educational Resources in Developing Countries
Jonathan Robert Mazal, Rebecca Ludwig ................................. 490

Preoperative Breast MR Imaging: Its Role in Surgical Planning
Ashley Barrett ......................................................................... 499

DIRECTED READING ARTICLES

Radiation Protection Education in Fluoroscopy
Marlene M Johnson .................................................................. 511

Meditation, Stress Relief, and Well-Being
Julie Dunlop ................................................................................ 535

COLUMNS

Editor’s Note
New Opportunities ................................................................. 480

Research & Technology
New Software Application Assesses Lung Tissue Damage .......... 563

My Perspective
Brain Imaging Studies Can Help Educators ............................. 565

Case Summary
Left Ventricular True Aneurysm Following Myocardial Infarction .... 570

Focus on Safety
Addressing Magnetic Resonance Safety Using a Modified Preoperative Time-Out Approach ................................. 574

Teaching Techniques
Teaching Trauma Radiography ................................................ 580

Writing & Research
Guidelines for Conducting Responsible Research .................... 584

A Challenging Diagnosis .......................................................... 592

ON THE COVER

“Golden Chole Maple” is the fifth in a series of 6 paintings by Lizzy Rainey, R.T.(R), of Lafayette, Indiana. In a routine radiographic image of a surgical cholangiogram, Rainey saw the branches of an old maple tree tangled within the surrounding vessels. “While creating this scene on canvas, I was mixing the greenish tones inspired by the gallbladder itself with deep hue yellows and oranges. So a portrait of the unlovely gallbladder becomes sunlight pouring in through the leaves of a golden maple tree.”
Editor’s Note

New Opportunities

Lisa Ragsdale, MA, ELS

You might have noticed a few new columns in recent issues of Radiologic Technology. I’d like to formally introduce them and invite you to share your expertise through them.

- **Focus on Safety** – provides current information regarding quality and safety.
- **Setup Solutions** – discusses innovative solutions to patient setup.
- **Advances in Technology** – presents new technology and equipment.
- **Practice Fundamentals** – reviews basic practices and procedures to refresh technologists’ skills.
- **Patient Care** – provides tips on educating and caring for patients.

In this issue, we include a Focus on Safety column that explains how to perform a “time-out” before magnetic resonance imaging examinations to enhance patient safety. The authors use a modified preoperative time-out approach to ensure patients are safe before undergoing a procedure. The column includes a checklist that takes as little as 2 minutes to complete.

We’d like every issue of Radiologic Technology to be packed with as much practical information for our readers as this one, and we’d like you to contribute. Most of our authors are R.T.s, and just like them you have valuable information to share. Won’t you join our published authors by sharing your better practices, techniques, or interesting case summaries?

Our editorial staff are experts in preparing your manuscript for the journal, and our Editorial Review Board members are available as mentors. Remember— you’re welcome to e-mail any Editorial Review Board member with your research or column idea and ask for their insight or guidance. Learn about the reviewers on page 476. Find author guidelines and submit your manuscript at http://asrt.msubmit.net. Simply register for your free account and follow the instructions.

Radiologic Technology is written largely by ASRT members. It’s your right and duty to share ideas with your peers and add to the body of knowledge in the radiologic sciences. As your new managing editor for the journal, I look forward to hearing from you soon!

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Lisa Ragsdale, MA, ELS, is the managing editor of Radiologic Technology and serves as an advisory board member for Radiologic Science Administration online degree programs at St Joseph’s College Online in Standish, Maine. She can be reached at lragsdale@asrt.org.
Manipulation of Projection Approach in Pediatric Radiography

Quentin T Moore, MPH, R.T.(R)(T)(QM)

**Purpose** To determine whether manipulating routine projections from anteroposterior (AP) to posteroanterior (PA) during projection radiography studies will result in reduced pediatric radiation exposure.

**Method** A literature analysis was conducted on pediatric radiation exposure, radiation protection, and tissue weighting factors. Multiple quantitative datasets were used to support findings related to projection manipulation.

**Results** Dosimetric studies confirm that the PA projection significantly decreases radiation exposure to nearly all radiosensitive tissue, with the exception of the patient’s bone marrow.

**Discussion** Pediatric patients are inherently more sensitive to ionizing radiation, making this patient population a major focus of dose-reduction issues. Radiologic technologists are charged with keeping dose as low as reasonably achievable (following the ALARA principle), and performing PA projections rather than routine AP projections might decrease radiation to the pediatric population.

**Conclusion** The PA projection results in a definitive reduction in radiation exposure to the majority of radiosensitive organs and tissues and should be considered for implementation on a routine basis.

Projection radiography represents the bulk of diagnostic imaging in pediatric patients. Routine projections can be acquired quickly and at a relatively low radiation exposure compared with other ionizing imaging modalities. Yet, in this era of radiation dose uncertainty, every opportunity to lower pediatric radiation dose should be explored. Children are more susceptible to the potential effects of ionizing radiation, which requires radiographers to adjust their imaging approach for this patient population. The purpose of this literature review was to:

- Understand the need for limiting pediatric radiation exposure in projectional radiography.
- Discuss historic and current approaches used for pediatric radiation protection.
- Explain the relative location of radiosensitive structures.
- Evaluate the exposure differences between AP and PA projections to determine the need for a projectional paradigm shift.

**Methods**

The researcher performed a literature search using the MEDLINE research database, a subset of the PubMed database. Advanced search features, including Title/Abstract and Medical Subject Heading (MeSH) search terms, were used to restrict the results. The Title/Abstract terms *posteroanterior* or the abbreviation PA were combined with the following MeSH terms: *radiography, radiation dosage, radiation protection, child, and female*. The “Related searches” function was used on article discovery to locate additional articles providing technical information related to pediatric dose reduction in radiography, gonadal doses, and patient positioning manipulation. The Google Scholar search engine also was used to locate supplementary journal articles related to *projection radiography dose reduction, effective dose, and patient dosimetry*. Time frame restraints were excluded based on the limited availability of articles about the narrow topic and the high quality of information presented in previous decades. This literature review
relied on published evidence-based quantitative data from multiple datasets.

**Results and Discussion**

**Pediatric Sensitivity**

The 2006 National Council on Radiation Protection and Measurements Report No. 160 showed that radiography is the most common type of examination performed in diagnostic imaging.\(^1\) Seventy-four percent of all imaging examinations are projection radiographs, and radiography represented 85% of all ionizing radiation imaging examinations in children.\(^1,2\) Children most commonly underwent radiographic procedures of the chest, followed by the extremities, spine, and abdomen, with lumbar spine radiographs contributing the largest dose by examination.\(^3\) It is estimated that a child could undergo more than 7 ionizing radiation imaging studies by 18 years of age, which further conveys the importance of limiting radiation exposure to this patient population on a routine basis.\(^2,3\)

Although children undergo medical imaging in smaller total numbers than do adults, they are more susceptible to stochastic effects of ionizing radiation.\(^5,8\) Stochastic effects refer to the probability of a biologic response as a function of exposure to radiation; disease incidence increases proportionally with increases in radiation dose, and there is no minimum dose needed for a stochastic effect.\(^7\) This nonthreshold model for stochastic effects means that all doses, regardless of how low, carry risk (see Figure 1).\(^8\) In childhood, girls are reportedly more susceptible to these radiation effects than are boys, largely because of superficial and dormant breast tissue.\(^11,12\) However, all children have immature tissues with rapidly dividing and evolving cells, which places them at greater risk for the manifestation of possible radiation-induced injuries, some of which have long latency periods.\(^6,11,13\) Further, children with chronic conditions might receive a higher cumulative lifetime dose as a result of repeated procedures and exposure.\(^5,8\) This is especially true for premature infants receiving multiple examinations just after birth and patients with scoliosis who are diagnosed at a young age and receive annual whole-spine imaging evaluations.\(^14,15\) The combination of cell status, procedure type and number, imaging ordering practice, and total radiation exposure could yield greater potential for radiation-induced cancers for these patients later in life.\(^6,8,16\)

**Tissue Weighting Factors and Radiosensitive Structures**

Certain anatomical structures are more sensitive to ionizing radiation than are others.\(^7\) The International Commission on Radiological Protection (ICRP) established tissue weighting factors (\(W_T\)) to explain the relative radiosensitivity of tissues, organs, and structures to determine how tissues are affected by the stochastic nature of ionizing radiation.\(^4,13,14,18\) Low total exposure in projection radiography per examination means that any patient’s radiation risks generally relate to the probability of stochastic processes occurring, including carcinogenesis and genetic effects, rather than induction of deterministic effects, such as skin erythema, epilation, and desquamation.\(^8,19-21\)

A list of \(W_T\), as presented in the 2007 ICRP Report, is shown in Table 1.\(^22,23\) The table categorically lists tissues from the most to least sensitive to the stochastic effects of ionizing radiation, reflecting that breast tissue, lung, bowel, and bone marrow are among those most sensitive.\(^22\) According to the ICRP, the \(W_T\) for breast tissue represents an average for both sexes and is actually larger for women. In addition, the \(W_T\)
would be higher for girls of a younger age, meaning that it might be even more important to protect the breast tissue in this population.\textsuperscript{13,22} Note that many of the most radiosensitive tissues are commonly within or abutting projectional radiographic exposure fields (see Figures 2 and 3); therefore, safe exposure practices are essential to keeping dose as low as reasonably achievable (ALARA).\textsuperscript{4}

\textbf{Historic Perspective of Radiation Protection}

The radiation exposure problems that Bishop and O’Laughlin wrote about in 1959 are similar to the dose reduction issues of today. They noted that radiologic operators were responsible for the quantity of radiation they were using and the hazards associated with its use.\textsuperscript{24} The chief concerns involved protection of the gonads, proper immobilization, and reduction of exposed field size (see Table 2). However, the largest concern reportedly revolved around the reduction of unnecessary radiologic examinations.\textsuperscript{24}

\textbf{Today’s Radiation Protection Recommendations}

Image Gently, an international pediatric radiation dose campaign sponsored by the Alliance for Radiation Safety in Pediatric Imaging, announced its “Back to

<table>
<thead>
<tr>
<th>Tissue Weighting Factor</th>
<th>Tissue</th>
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<tbody>
<tr>
<td>0.12</td>
<td>Breast, Lung, Colon, Stomach, Red bone marrow</td>
</tr>
<tr>
<td>0.08</td>
<td>Gonads</td>
</tr>
<tr>
<td>0.04</td>
<td>Bladder, Esophagus, Liver, Thyroid</td>
</tr>
<tr>
<td>0.01</td>
<td>Bone surface, Brain, Salivary glands, Skin</td>
</tr>
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Abbreviation: ICRP, International Commission on Radiological Protection.
Basics’ digital radiography key awareness points in 2012 (see Box). The recommendations have similarities to those expressed by Bishop and O’Loughlin in 1959, including collimation, shielding, and avoidance of grid use if the body part is less than 10 cm thick. However, important updates in the modern recommendations include measurement of body-part thickness, the use of technique charts for proper technique selection, and the required review of exposure indicators to evaluate the appropriateness of exposure settings. Medical practitioners also are encouraged to use the alternative nonionizing modalities of ultrasonography and magnetic resonance imaging for diagnosis whenever possible, apply the ICRP’s recommendations for examination justification and dose optimization, and use the American College of Radiology’s Appropriateness Criteria for determining necessity of the imaging study.

Radiation dose reduction and examination tracking is of major importance today, and progress is being made in Digital Imaging and Communications in Medicine (DICOM) radiation dose structured reports, diagnostic reference levels, the American College of Radiology’s Dose Index Registry program, and the International Atomic Energy Commission’s SmartCard. In addition to following Image Gently’s recommendations, facilities possessing digital radiography equipment should follow the guidelines shown in Table 3 to reduce dose to pediatric patients. Many factors are involved in properly managing pediatric radiation exposure, most of which relate to safe operating procedures and proper use of dedicated equipment. However, a potential paradigm shift will be explored throughout the remainder of the discussion to determine whether positional adjustments can be made to further protect the radiosensitive tissues in developing pediatric patients.

### Radiation Dose Estimation and Comparison Methods

In projectional radiography, the difference between an anteroposterior (AP) and posteroanterior (PA) projection can greatly affect which aspect of the body receives the maximum dose ($D_{\text{max}}$) of radiation. Regardless of the kilovoltage peak (kVp) energy...
selected for the projectional radiography examination, the \( D_{\text{max}} \) will always be greatest at the entrance skin surface of the patient.\(^8\) Some studies on radiation dose in children reflect this through measurements of entrance surface dose and dose-area product via the use of thermoluminescent dosimeters and dose-area product meters (see Figures 4 and 5).\(^{7,11,14,30}\) Other studies have used air kerma-area product, incident air kerma, and entrance surface air kerma measurements for comparison.\(^{20,30,32}\) Regardless of the method chosen, these measured values allow for dosimetric comparison in terms of patient exposure.\(^7,32\) Specific testing phantoms, such as the Rando phantom (Phantom Laboratory), also have been used to provide accurate data measures of specific organs of interest.\(^{33}\) For example, thermoluminescent dosimeters can be inserted into the location of the ovaries, testes, breasts, thyroid gland, or lens of the eye in these phantoms.\(^{33}\) Data points from each of these methods have been used to determine whether AP or PA projections would be ideal for dose reduction to given radiosensitive structures.

**Why the PA Approach?**

As our understanding of radiation-induced cancers from projectional radiography evolves, evidence reflects that small alterations in projectional approach could have major effects on the patient’s long-term well-being.\(^{11,14,34}\) Transitioning to a PA approach instead of using the traditionally accepted AP projection might provide the best possible service with the least possible risk to the patient.\(^34\) For example, this could include manipulating abdominal, spinal, and pelvic projections from AP to PA. The literature indicates that this type of manipulation might reduce effective dose for both girls and boys.\(^{14}\) In fact, the British Institute of Radiology has advocated that the PA projection be used (over the AP projection) whenever the gonads are within the primary beam, especially for female patients.\(^{34}\)

Remembering the concepts of \( D_{\text{max}} \) and entrance surface dose is important. The majority of the ICRP Wr radiosensitive structures are anteriorly situated structures. When the AP projection is selected, such as in AP abdomen, AP pelvis, or AP spine studies, the technologist is essentially opting to deliver a greater surface dose to the anterior structures.\(^{34}\) Anterior tissues include the breasts, colon, liver, small bowel, stomach, and urinary bladder.\(^{14,34}\) Therefore, technologists can manipulate their approach from AP to PA to significantly reduce exposure to these anterior structures.

The literature indicates that a major dose reduction to radiosensitive tissues is possible.\(^{15,37,35}\) Ben-Shlomo
et al found that the PA approach reduced patient effective dose by 180% and absorbed breast dose by 550% to 879% compared with an AP approach for pediatric scoliosis examinations. In a comparison of the radiographic projections, Marshall et al found that effective dose for a PA abdomen examination can be lowered by at least a factor of 5 with the use of digital radiography systems compared with the AP method. Brennan and Madigan found that the PA lumbar projection would reduce small bowel absorbed dose by 39%. In the phantom study by Nic an Ghearr and Brennan, ovarian dose was shown to be reduced by 68% and uterine dose by 50% with a PA approach. In a PA clavicle study by McEntee and Kinsella, significant dose decreases of 28% to the eyes, 56% to the breast, and 78% to the thyroid gland were reported. Finally, Mekiš et al reported that the testicle radiation dose received by the patient was 93.1% lower in a PA projection than in a traditional AP projection for sacroiliac joints. These dose-reduction statistics are important as studies begin to link cancers to projection radiography procedures, such as breast cancer and scoliosis radiography.

Although the data sets convincingly reflect that the PA projection inherently limits exposure to anterior radiosensitive structures, they also are relevant for tissue displacement. The PA projection effectively functions to compress the soft tissue when the patient lies prone or tightly abuts the image receptor while erect. A thinner body part requires less exposure to produce an acceptable radiograph, and the compression created from the PA projection will function to lower patient exposure. To apply this, the exposure factor milliampere seconds (mAs) should be manipulated downward accordingly; a 25% reduction in mAs for every 1 cm change in measured body thickness is recommended. Brennan and Madigan reported that the body thickness of the patients they studied decreased by 9.6% (1.8 cm) when moving the patient from the supine (AP) to prone (PA) position. This change is significant because it allows for nearly a 50% reduction in mAs, resulting in major decreases in total pediatric radiation exposure during the examination.

**Why Not PA?**

The PA projection is already standard for chest radiography. Although this practice has a tremendous effect on dose reduction to the breast, thyroid gland, and eyes, the PA projection is used to reduce the magnification of the heart and is not a dose-driven choice. Commonly cited rationale for traditionally accepted AP projections largely revolves around reduction in size distortion to improve image quality. For example, the AP lumbar projection is standard because it places the part closer to the image receptor; the reduced object-to-image distance functions to minimize size distortion of the anatomy of interest. This principle is widely accepted, but some suggest that magnification does not hinder image quality and patient diagnosis.

Studies report minor decreases or increases in image quality when the PA projection is used instead of the standard AP projection, essentially conveying that clinical image quality is not significantly altered with the PA projection. Heriard et al reported that magnification was evident on comparison radiographs, but evaluating radiologists felt that it did not affect the quality of the radiographs. Ben-Shlomo et al reported that the best image quality is not always required for scoliosis radiography, especially given the potential for substantial dose reduction from the PA projection. Furthermore, there is some evidence that the PA projection for spine radiography might actually allow for improved visualization of vertebral bodies because of the natural divergence of the radiation beam through the vertebral joint spaces.

Although the image quality theory might be dismissed as insignificant, bone marrow exposure is a considerable factor. Recalling Table 1, bone marrow has been determined to be highly radiosensitive, comparable to breast tissue and bowel, and has been assigned the highest Wz. Distribution of bone marrow does, however, vary with age. For example, in a 5-year-old patient, the bone marrow distribution is as follows: skull, 20%; thorax, 48%; and extremities, 32%. In a 15-year-old patient, the bone marrow distribution is as follows: skull, 10%; extremities, 15%; pelvis, 19%; vertebrae, 28%; and ribs, 14%. Nonetheless, it is thought that there are larger percentages of the bone marrow posterior to the midcoronal plane, meaning that the PA projection will subject the patient to larger bone marrow doses, although the percentage of exposure...
increases will depend on the area being imaged and the patient’s level of development.\textsuperscript{13,44}

Although the PA chest is standard, studies reflect that a 24% to 49% increase in radiation exposure to bone marrow is delivered compared with the AP method.\textsuperscript{14} Heriard et al\textsuperscript{45} found a 28% increase in bone marrow for lumbar radiography, and Fearon et al\textsuperscript{15} found that the PA projection resulted in double the exposure to bone marrow. These figures are important, given that active bone marrow is believed to be the target site for radiation-induced leukemia.\textsuperscript{44} However, some researchers believe that the risk-benefit ratio still strongly favors the PA projection because of decreased exposure to breast tissue.\textsuperscript{17}

Confirmation of projectional manipulation benefits largely depends on the ongoing development of test phantoms that mimic a wide range of patient characteristics.\textsuperscript{32} These phantoms will better enable organ and tissue absorbed dose estimates to become patient-specific and ultimately will help to determine whether the PA or AP projection should be used. Studies showing that image quality is not greatly reduced between AP and PA projections mean that it might be less important to place the part of interest closer to the image receptor when considering radiation exposure issues. In terms of dose reduction, perhaps the most radiosensitive structures should now be placed closer to the image receptor to avoid inherently higher entrance surface dose to these parts.

**Conclusion**

Although projectional radiography exposure levels are generally considered low, long-term use of ionizing procedures, young ages of exposure, and involvement of radiosensitive structures in the exposure field emphasize the need to consider the dose reduction potential of projection manipulation where possible.\textsuperscript{44} Radiologic technologists are charged with effectively using the ALARA principle, and choosing PA projections instead of routine AP projections might decrease radiation exposure to pediatric patients. Dosimetric studies confirm that the PA projection functions to significantly decrease radiation exposure to nearly all radiosensitive tissues, with the exception of the patient’s bone marrow. Strong consideration is warranted for implementation of projection manipulations on a routine basis. However, even as epidemiologic evidence suggests a link between the increased incidence of cancers and AP radiography projections that include breast tissue, future studies should be conducted to determine the implications associated with increased dose to bone marrow and the potential for radiation-induced leukemia. Qualitative studies regarding patient comfort and feasibility of prone projections in pediatrics also would be helpful to evaluate the effects of projection manipulation.

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**References**


Manipulation of Projection Approach in Pediatric Radiography


Using Mobile Electronic Devices to Deliver Educational Resources in Developing Countries

Rebecca Ludwig, PhD, R.T(R)(QM), FAEIRS, FASRT

Background Developing countries have far fewer trained radiography professionals than developed countries, which exacerbates the limited access to imaging services. The lack of trained radiographers reflects, in part, limited availability of radiographer-specific educational resources. Historically, organizations that provided such resources in the developing world faced challenges related to the limited stock of current materials as well as expenses associated with shipping and delivery.

Methods Four mobile electronic devices (MEDs) were loaded with educational content (e-books, PDFs, and digital applications) spanning major radiography topics. The MEDs were distributed to 4 imaging departments in Ghana, India, Nepal, and Nigeria based on evidence of need for radiography-specific resources, as revealed by survey responses. A cost comparison of postal delivery vs digital delivery of educational content was performed. The effectiveness of delivering additional content via Wi-Fi transmission also was evaluated. Feedback was solicited on users’ experience with the MEDs as a delivery tool for educational content.

Results An initial average per e-book expense of $30.05, which included the cost of the device, was calculated for the MED delivery method compared with $15.56 for postal delivery of printed materials. The cost of the MED delivery method was reduced to an average of $10.05 for subsequent e-book deliveries. Additional content was successfully delivered via Wi-Fi transmission to all recipients during the 3-month follow-up period. Overall user feedback on the experience was positive, and ideas for enhancing the MED-based method were identified.

Conclusion Using MEDs to deliver radiography-specific educational content appears to be more cost effective than postal delivery of printed materials on a long-term basis. MEDs are more efficient for providing updates to educational materials. Customization of content to department needs, and using projector devices could enhance the usefulness of MEDs for radiographer training.
Nepal, India, and Bangladesh, some Central American countries, and some African nations still do not have formal recognition of the radiography profession and do not have an established national standard for radiography education. This situation results in a lack of radiologic technologist educational programs and inconsistent educational standards where educational programs do exist.

With the absence of comprehensive training programs for radiographers comes a lack of necessary radiography-specific educational resources. For example, a 2009 survey conducted by the WHO and the Japan Association of Radiologic Technologists on the state of the technologist profession in Guyana found that a single certificate-based program, run by the local Ministry of Health, was the only available program for the entire country. Furthermore, the report specifically noted a need for access to books and manuals on selected medical imaging subjects for program support, as well as for continuing education of the technologists currently practicing in Guyana.

Nonprofit organizations such as the World Radiography Educational Trust Foundation have been working to collect and distribute radiographer-specific educational resources throughout the developing world since 1969. However, the costs of shipping donated educational resources such as textbooks and journals to the organization’s storage site and from the storage site to imaging departments or other recipients in need have proven prohibitive. Furthermore, in an effort to maximize the impact of funds dedicated to cover shipping, the Foundation set a rule limiting the donation of educational materials to items published in the past 5 years. The result has been a limited stock of suitable donated materials.

Applegate investigated the potential roles of mobile electronic devices (MEDs) in radiographer education, including completing clinical logs, archiving data, accessing reference material and evaluation tools, and providing course materials. In addition to evaluating the advantages and disadvantages of MEDs, he addressed factors for selecting an MED. Most importantly, Applegate suggested that MEDs are particularly valuable as an information delivery tool. In their report on instructional technology in radiologic science education, Martino and Odle mentioned several radiography programs using MEDs to evaluate students’ clinical skills; however, no literature is available describing the successful use of MEDs in atypical educational settings. A study by Robinson focused on incorporating iPads (Apple) into the radiography curriculum to enhance student learning about theoretical digital imaging principles using innovative hands-on interactive software. A survey of students’ satisfaction following completion of the study demonstrated that their experience had been overwhelmingly positive.

To date, however, no studies documenting the use of MEDs in delivering radiographer-specific educational resources in the developing world have been published. For this reason, a multicase study using a convenience sample was coordinated, with the following primary aims to:

- Compare the costs of MEDs with traditional postal delivery of educational resources.
- Assess the feasibility of international Wi-Fi transfers of additional educational content.
- Investigate potential uses of an MED-based delivery tool as a philanthropic model.

**Methods**

Several MED options were evaluated for this project. The primary factors considered were price, ability to perform wireless delivery of additional content, and compatibility with various digital formats. The Kindle Fire (Amazon Inc) was chosen because of its relatively low cost, ability to store and distribute digital content via a Web-based cloud archive for up to 4 registered devices, and ability to display PDF and Flash files on a color screen (see Figure 1). Four MEDs were purchased for project participants. Each device was distributed to a different country to test the feasibility of this delivery method on an international scale and identify potential logistical challenges in different regions.

To ensure that a comprehensive selection of educational content was loaded onto the MEDs, e-books were selected from the Amazon Web site and loaded onto all 4 devices based on the content areas identified in the 2007 American Society of Radiologic Technologists (ASRT) Radiography Curriculum, the most current
version at the time. The curriculum consisted of 17 content areas reflecting a common body of knowledge essential for entry-level radiographers (see Table 1). The comprehensive radiography curriculum was used rather than the limited x-ray machine operator curriculum to provide a robust educational resource that would likely meet the needs of all radiographers around the world, regardless of their scope of practice and prior level of academic training. When multiple e-book editions were available, preference was given to the most recently published and lowest-priced item. In addition, the ASRT Professional Development Department donated 5 educational PDFs on various imaging topics, which also were loaded onto the MEDs (see Table 2). No content older than 5 years was included in accordance with the World Radiography Educational Trust Foundation’s preference to distribute up-to-date resources.

The following criteria were used to select MED recipients:

- Association with either an imaging department or radiologic sciences academic program, so that the devices would be available to a diverse audience of technologists and students.
- Location in a developing country and in a resource-poor community where obtaining radiography-specific educational material appeared to be difficult.

- Access to a reliable Wi-Fi network within a 60-minute commute to facilitate delivery of additional educational content in a timely manner and reduce the cost of access to additional resources.
- Students or staff proficient in the English language. Restricting the educational material to English enabled the use of readily available e-books, reducing the cost of each e-book by 75% compared with the cost of providing hardcopy textbooks in other languages. If this project were to be implemented on a larger scale, with distribution of multiple MEDs in a single country, efforts to provide educational content in the native language should be considered.

The initial target population for the project sample was technologists at imaging departments located in resource-poor communities in the developing world. The United Nations Human Development Index combines indicators of life expectancy, educational attainment, and income into a single statistic, which serves as a frame of reference for both social and economic

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**Table 1**

<table>
<thead>
<tr>
<th>Content Areas in the 2007 ASRT Radiography Curriculum</th>
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<tr>
<td>1. Introduction to Computed Tomography</td>
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<tr>
<td>2. Clinical Practice</td>
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<tr>
<td>3. Digital Image Acquisition &amp; Display</td>
</tr>
<tr>
<td>4. Ethics &amp; Law of Health Care</td>
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<tr>
<td>5. Fundamentals of Radiologic Science and Health Care</td>
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<tr>
<td>6. Human Structure &amp; Function</td>
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<tr>
<td>7. Image Analysis</td>
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<tr>
<td>8. Imaging Equipment</td>
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<tr>
<td>9. Medical Terminology</td>
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<tr>
<td>10. Patient Care in Radiologic Sciences</td>
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<tr>
<td>11. Pharmacology and Drug Administration</td>
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<tr>
<td>12. Radiation Biology</td>
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<tr>
<td>13. Radiation Production &amp; Characteristics</td>
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<tr>
<td>14. Principles of Imaging</td>
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<tr>
<td>15. Radiographic Pathology</td>
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<tr>
<td>16. Radiographic Procedures</td>
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<tr>
<td>17. Film-Screen Image Acquisition and Processing</td>
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**Figure 1.** A Kindle Fire (Amazon Inc) mobile electronic device used for the study.
development. The WHO updates the tool annually, and each country is categorized into one of 4 classifications: low development, medium development, high development, and very high development.\textsuperscript{11} For the purpose of this study, resource-poor communities were defined as countries with a Human Development Index designation of either “medium” or “low,” according to 2011 data. The difficulty of obtaining radiographer-specific educational resources was assessed via evaluation of the 5 most-used textbooks immediately available within the imaging department or educational program. Sites in resource-poor communities with the most outdated textbooks or lacking radiographer-specific textbooks were deemed to have the greatest need.

Multiple case study participants were recruited using 2 convenience-sampling methods. Initial participant recruitment involved asking a team member from the international radiology outreach organization, RAD-AID International, to deliver MEDs to imaging departments during project site visits when potential imaging aid was being evaluated. The team members were provided with the inclusion criteria and asked to assess whether the project site was an appropriate match for the MED study. Unfortunately, this method yielded only one successful device delivery out of 3 site visits. A recipient from the imaging department in Korle Bu Teaching Hospital in Accra, Ghana, was selected as the first project participant. An in-service about key MED functions, care, and use of device content was provided to the participant. Because of time constraints in using a third party to assess and select potential study participants, the remaining subjects were selected from among attendees from developing countries at the 2012 ISRRT biannual conference in Toronto, Canada. E-mail invitations to apply for project participation were sent with a digital application included as an e-mail attachment to 81 conference registrants from countries that met the target population criteria. After excluding partially completed applications from consideration, 10 applications were evaluated from representatives of imaging departments in the following countries: China (1), India (1), Iran (1), Korea (1), Nepal (1), Nigeria (3), Sri Lanka (1), and Taiwan (1). Of these, the imaging facilities of Tribhuvan University Teaching Hospital in Kathmandu, Nepal; National Orthopedic Hospital in Lagos, Nigeria; and

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<th>Table 2</th>
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<tr>
<td><strong>Educational Content Uploaded to Medical Electronic Devices</strong></td>
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<tr>
<td><strong>PDFs</strong></td>
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<tr>
<td>■ Digital Mammography: An Update (Brusin JH, 2006)</td>
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<td>■ Radiation Protection and Procedures in the OR (Chaffins J, 2008)</td>
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<td>■ Contrast Studies (Blumenthal S, 2006)</td>
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<td>■ Chest Radiography for Technologists (Hobbs D, 2007)</td>
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<tr>
<td>■ Renal Disorders (Bourey P, 2008)</td>
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<tr>
<td>■ Esophageal Cancer: Diagnosis &amp; Treatment (Furlow B, 2006)\textsuperscript{*}</td>
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<tr>
<td>■ Linguistic &amp; Cultural Competency (Shams-Avari P, 2005)\textsuperscript{*}</td>
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<tr>
<td>■ Improving Communication for Better Patient Care (Scott A, 2007)\textsuperscript{*}</td>
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<tr>
<td>■ Imaging in Podiatry (Church E, 2008)\textsuperscript{*}</td>
</tr>
<tr>
<td>■ Spinal Curves &amp; Scoliosis (Anderson S, 2007)\textsuperscript{*}</td>
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<tr>
<td><strong>E-Books</strong></td>
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<tr>
<td>■ Learning Radiology: Recognizing the Basics (Herring W, 2011)</td>
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<tr>
<td>■ Lange Q &amp; A Radiography Examination, 8th ed. (Saia DA, 2011)</td>
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<tr>
<td>■ Radiology Strategies (Fielding J, 2009)</td>
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<tr>
<td>■ Pocket Atlas of Radiographic Anatomy (Moeller TB, Reif E, 2010)</td>
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<tr>
<td>■ Paediatric Radiography (Hardy M, Boynes S, 2003)</td>
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<tr>
<td>■ Radiographic Image Production &amp; Manipulation (Shephard C, 2002)</td>
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<tr>
<td>■ Pocket Atlas of Radiographic Positioning (Moeller T, Reif E, 2009)</td>
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<tr>
<td>■ Churchill Livingstone Pocket Radiography &amp; Medical Imaging Dictionary (Gunn C, 2007)</td>
</tr>
<tr>
<td>■ An Introduction to Radiography (Easton S, 2009)</td>
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<tr>
<td><strong>Apps</strong></td>
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<tr>
<td>■ Gray’s Anatomy Mobile</td>
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<tr>
<td>■ Medical Words</td>
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<td>■ Speed Anatomy</td>
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<tr>
<td>■ NIH: Flu Information</td>
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<td>■ NIH: Obesity Information</td>
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<td>■ NIH: Arthritis Information</td>
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\textsuperscript{*} Content delivered via Wi-Fi.

Abbreviation: NIH, National Institutes of Health.
Post Graduate Institute of Medical Education and Research in Chandigarh, India, were deemed as having the greatest need for support and were invited to participate in the project (see Tables 3 and 4).

Three registrants—one from India, one from Nigeria, and one from Nepal—were selected as project participants and were notified via follow-up e-mail, and arrangements were made to meet during the 2012 ISRRT conference. The devices were distributed at the conference, and training similar to the initial in-service offered by RAD-AID was provided.

No instructions were given about how to implement the device into clinical practice, with hopes that innovative approaches would evolve organically with less oversight of device use. Three months after the MEDs were distributed, additional educational content was uploaded to the Amazon cloud network to which the 4 devices were registered. The additional content consisted of another 5 educational PDFs on various imaging topics donated by the ASRT Professional Development Department (see Table 2). The 4 users were notified of the additional content available for download, with instructions on how to complete the download process.

<table>
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<th>Participating Countries’ Human Development Index Scores</th>
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<tr>
<td>Recipient Country</td>
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<tr>
<td>Ghana</td>
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<tr>
<td>India</td>
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<tr>
<td>Nigeria</td>
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<td>Nepal</td>
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<tr>
<th>Participants’ Most Used Texts</th>
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<tbody>
<tr>
<td>Facility</td>
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<tr>
<td>Korle Bu Teaching Hospital, Accra, Ghana</td>
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<tr>
<td>Diagnosis of Bone &amp; Joint Disorders</td>
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<tr>
<td>Handbook of MRI Technique</td>
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<tr>
<td>MRI Parameters and Positioning</td>
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<tr>
<td>Post Graduate Institute for Medical Education and Research, Chandigarh, India</td>
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<tr>
<td>Skeletal Anatomy</td>
</tr>
<tr>
<td>Principles of Radiographic Imaging: An Art and A Science</td>
</tr>
<tr>
<td>Introduction to Radiologic Sciences and Patient Care</td>
</tr>
<tr>
<td>Ball and Moore’s Essential Physics for Radiographers</td>
</tr>
<tr>
<td>Tribhuvan University Teaching Hospital, Kathmandu, Nepal</td>
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<tr>
<td>Chesneys’ Care of the Patient in Diagnostic Radiography</td>
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<tr>
<td>Basic Anatomy &amp; Physiology for Radiographers</td>
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<tr>
<td>Clark’s Positioning in Radiography</td>
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<tr>
<td>Orthopedic Imaging: A Practical Approach</td>
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</table>
Simultaneously, user feedback was solicited on their experience with the MED as a delivery tool for educational content, as well as recommendations for improving the program. User feedback was collected from the study participants through e-mail–based, open-ended dialogue with each recipient. These qualitative data were analyzed by the lead investigator.

For comparison, the World Radiography Educational Trust Foundation was solicited for its 2012 data regarding the countries that received support in the form of radiographer-specific educational books and other printed material delivered by mail. This included data on the average number of support packages delivered, average number of items per support package, and average cost of shipping per package. These data served as a reference for evaluating the cost and effectiveness of traditional vs alternative methods of educational content delivery.

**Results**

Four Kindle Fire devices were purchased for this feasibility study at a cost of $200 each, for a total expense of $800. The 4 devices were registered to a single Amazon user account at no additional cost. Nine e-books were purchased for a total of $402.03. In addition, 9 apps and 10 ASRT educational PDFs were obtained at no cost, and all of this material was stored in the Amazon cloud project account. Because of the ability to sync up to 4 devices to a single Amazon user account and push shared digital files (eg, e-books, apps, and PDFs) to the registered devices at no additional cost, the price of educational content was reduced to $100.51 per device. A total of $1202.03 was spent on the devices and educational content combined, resulting in a final cost of $300.51 per device.

Not considering the free content loaded to the devices, the average per-book expense was $30.05, including the cost of the device. If subsequent e-book deliveries had been sent via Wi-Fi transmission, the cost would have averaged $10.05 per book. These subsequent e-book downloads would be less expensive because the MEDs had already been purchased and therefore would no longer be factored into the cost.

Data provided by the World Radiography Educational Trust Foundation regarding expenses related to distribution of educational materials indicated a total cost of $396.21 to ship 17 support packages. An average of $23.31 was spent to ship each support package, which contained approximately 3 books per package. Packages were shipped from the Foundation’s storage facility in London, England, to imaging departments in Argentina, Malawi, Nepal, Rwanda, Sierra Leone, Uganda, and Zambia. The average shipping expense per book was calculated to be $7.78 for delivery from the Foundation’s storage facility to the recipient. The cost of international shipping for the acquisition of textbooks from initial donors was not available but was assumed to be equivalent to the cost of shipping textbooks from the Foundation’s storage facility to the recipients. This increased the average shipping expense per book to $15.56.

All 4 participating imaging departments successfully received the additional educational resources via Wi-Fi delivery during the 3-month follow-up period. When prompted by e-mail for user feedback on their experience with the MED as a tool for delivering educational content, recipients were unanimously positive. Given the diversity of settings where the MEDs were used, open-ended dialogue yielded the most meaningful qualitative data. No specific problems with device implementation were mentioned. When asked to provide possible areas for improvement in the MED-based philanthropic model, 3 distinct themes emerged: concerns regarding device security and maintenance, the desire to use the device as a teaching aid vs simply as a clinical reference resource, and requests for customized educational content specific to department needs.

**Discussion**

The investigators are uncertain as to whether the intended target population of interest was truly reached with all 4 devices. The RAD-AID International team members tasked with evaluating facilities for potential project participation encountered some radiographers who were seemingly apathetic about self-directed learning. There appeared to be a lack of encouragement for professional development and an absence of requirements for continuing education in some less developed areas where the radiography profession is not formally recognized. Consequently, an all-too-common lack of
incentive exists for radiographers to seek professional development on their own. In contrast, the majority of ISRRT conference registrants solicited through the alternate recruitment process came from academic medical institutions and expressed a high level of interest in participating in the study.

Regardless of the inability to place devices in the most resource-poor imaging departments, value remains in investigating the feasibility of an MED-based educational resource delivery tool. Initiating a sustainable grass-roots style of disseminating educational resources, via a relationship with an urban-based academic setting extending to more remote imaging departments within the country, is potentially a better method for future studies.

An initial average per-digital-book expense of $30.05 (including the cost of the device) compared with $15.56 for traditional postal delivery of hard-copy materials remains attractive because the subsequent expense would be reduced to an average of $10.05 for future e-book deliveries. The MED devices essentially pay for themselves over time. This expense could hypothetically be reduced even further with more time and attention spent on selecting e-books that cover multiple areas of study and negotiating a lower price per e-book for large orders. As was the case with this project, donations of additional content from professional organizations that offer educational resources also can be pursued, adding further value with no additional expense.

Corruption related to questionable holding fees can be common in certain countries with limited government oversight and regulation. Coordination with a trusted and established local contact is necessary to overcome such obstacles. The choice to hand deliver the MEDs through a conference participant averted a potential logistical difficulty in this study. Corruption also affects the delivery of printed materials, and hand delivery of printed items is much more burdensome, given the weight of books and airline baggage restrictions. For a large and long-term sustainable philanthropic model, the investigators suggest MEDs as the best option, especially if GPS-based tracking technology compatible with the MEDs can be used to mitigate potential loss or theft. MEDs might require greater initial investment; however, their portability and security outweigh the inconvenience of books and the additional cost of confiscated shipments of printed materials, which could not be readily estimated for this study.

At a minimum, the investigators anticipated that the devices could serve as a point-of-care tool for answering clinical questions in the imaging department. However, after considering user feedback, it was apparent that there was a desire to use the MEDs as a teaching tool as well as a clinical reference. A single MED, by itself, would not be very useful in a classroom educational setting, so addressing this desire would likely involve additional resources. Future studies on the use of MEDs to deliver educational content should consider options more suited to a group educational format, such as an MED-projection system for classroom use. Although multiple devices would enable students to take the materials home for review, an MED-projection system would be more affordable. Since the acquisition of the MEDs used in this study, newer device models have been released at a similar cost that offer micro-USB ports that allow syncing with a variety of external devices and might result in a more effective and efficient content delivery process.

Another theme identified in the user feedback was the desire for customized educational content. Although the educational content loaded to the devices was specifically selected for its comprehensive coverage of radiography-related topics, it did not cover more specialized topics unique to specific locations or imaging departments. In the future, recipient imaging departments could be paired with academic and clinical imaging departments from the developed world, encouraging a sustained exchange of information beyond that found in standard textbooks. The ability to prepare customized PDF documents and transfer them to the MEDs via Wi-Fi transmissions might be the best arrangement for affordable and mutually beneficial sharing of best practices.

More research is needed to assess the effectiveness of MEDs as a reference and teaching tool for radiography students and professionals within the clinical setting in diverse practice environments. Furthermore, the effectiveness of digital educational devices within the developing world should be compared with more
traditional paper-based resources. The use of MEDs as an evaluation or data collection tool has not been sufficiently researched either. Given the limited sample size of 4 participants for this study, future similar research should attempt to expand the number of participants. Evidence on outcome measures related to these areas of study is critical to justify upfront expenditures on digital educational tools, as well as to ensure that device content is optimized for long-term success and sustainability of this philanthropic model.

Conclusion

The use of MEDs as an alternative delivery method for radiography-specific educational content appears to be more cost effective on a long-term basis than the traditional method of postal delivery of hard-copy materials. MEDs also offer a more efficient option for providing updates to educational material. Customizing content to department needs and using inexpensive MED-compatible projectors could enhance the benefits of MEDs for radiographer training. Although MEDs require an initial investment greater than the cost of one-time delivery of printed material, the expense equalizes over time as more resources are made available for download. Hand delivery of the MED also improves the likelihood that the intended recipient actually receives this resource, which can be problematic with postal delivery in developing, resource-poor countries.

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5. International survey on radiological technologists and radiographers. WHO Collaborating Center for the Training of Medical Radiologic Technologists & the Japan Association of Radiologic Technologists. Published July 17, 2009.
Preoperative Breast MR Imaging: Its Role in Surgical Planning

Ashley Barrett, BS, R.T.(R)(MR)

**Purpose** To explore the role and usefulness of preoperative breast magnetic resonance (MR) imaging in surgical planning and to determine whether routine use of preoperative breast MR imaging benefits patients.

**Methods** Searches were conducted to locate literature, specifically clinical studies, discussing the effect preoperative breast MR imaging has on altering surgical plans. Selected articles encompassed topics including additional biopsies, wider excisions, mastectomies, and re-excisions. The results of these studies were examined for the purpose of supporting or refuting the notion that preoperative MR imaging is beneficial.

**Results** Consensus is lacking about the role of preoperative MR imaging in surgical planning for patients with breast cancer. Some studies support the use of the technique, while others do not.

**Discussion** Preoperative breast MR imaging influences surgical planning for patients with breast cancer. When used before surgery, MR imaging can lead to changes in the surgical plan. Changes include additional biopsies, a more extensive lumpectomy, or the potential for a mastectomy. Certain research studies conclude that MR imaging improves surgical planning, while others disagree.

**Conclusion** The current available literature does not reach a sole conclusion. Some studies suggest that MR imaging is beneficial, while others declare that it leads to unnecessary surgical changes. Additional studies do not reach a decision either way and instead call for further research. The lack of consensus indicates that more research is needed before the usefulness of breast MR imaging for surgical planning can be determined.

Magnetic resonance (MR) imaging did not become a common diagnostic tool in detecting breast cancer until the 1990s. The application of this tool was sparked by the promising results reported by Heywang et al in 1986.¹ Their study evaluated the usefulness of gadolinium-based contrast in imaging breast lesions and found that contrast-enhanced MR imaging can help differentiate between dysplastic tissue and carcinoma.² Since then, numerous studies have been conducted to evaluate the role of MR imaging in breast cancer screening and diagnosis. Because of the relative novelty of MR imaging and its ever-increasing use in planning and evaluating medical treatments, the role of breast MR imaging in surgical planning is not clearly defined. Studies yield differing conclusions, and a common assumption is that the increased sensitivity of MR imaging would improve lesion detection and, thereby, improve the surgical plan and patient outcome. For example, an improved surgical plan would be one that does not require a re-excision to remove positive resection margins. Multiple studies have shown that preoperative MR imaging can reduce the need for additional surgeries.³-⁵

However, not every clinical study supports the assumption that MR imaging is beneficial for all patients with breast cancer. The discussion often centers on the choice between breast-conserving surgery (BCS) and mastectomy. Until the 1970s, the standard treatment was a radical mastectomy that removed the breast tissue, surrounding lymph nodes, and often some muscle from the chest wall. In 1975, researcher Bernard Fisher published 2 studies that demonstrated how a less extensive surgical procedure, used in conjunction with chemotherapy, was just as effective as
a radical mastectomy in improving patient survival.\(^{5,7}\) Over time, the less extensive BCS gained popularity over mastectomy as a means of treating breast cancer. Today, treatment for breast cancer usually consists of a lumpectomy, which removes only the cancerous lesion and a little surrounding tissue, and radiation therapy, chemotherapy, or both. As this literature review will discuss, both BCS and mastectomies are commonly performed in patients with breast cancer. Some studies refute the benefit of breast MR imaging, indicating that preoperative MR imaging leads to unnecessary surgical upgrades, namely mastectomies over BCS.\(^{5,8}\)

This comprehensive review considers the array of evidence in the current literature that both supports and refutes the benefit of MR imaging in surgical planning for patients with breast cancer.

**Methods**

A database search was conducted via the University of North Carolina Health Sciences Library using the following databases: Medline Plus, PubMed, CINAHL, Google Scholar, and the Wiley Online Library. When accessing the Wiley Online Library, the key term MRI was used to search The Breast Journal, which yielded 362 useful results. The key search phrases for the remaining databases were:

- Breast MRI.
- Role of breast MRI in surgical planning since 2012.
- Role of breast MRI in preoperative surgical planning.
- Surgical planning.
- Breast MRI surgical changes.

When searching Medline Plus, breast MRI yielded 445 results that gave a general idea of what breast MR imaging is and what it is used for, but the articles were too broad to be useful in this review. When searching PubMed, modifiers—including clinical trial, journal article, human only, 5 years, and review—were used in conjunction with the term breast MRI, yielding 2561 results. The most useful search phrase in Google Scholar was role of breast MRI in surgical planning since 2012, which yielded 7970 results compatible with the purpose of this literature review. Filtering out articles that were published before 2012 allowed for quicker and easier access to the most current literature available about the use of preoperative breast MR imaging in surgical planning. Articles were excluded if they were published before the year 2000; articles published within the past 5 years were given preference for inclusion. Articles also were excluded if they did not reference specific case studies with numerical values that could be assessed or if they were literature reviews.

The available literature revealed disparities among the 29 published studies included in this review. Some studies supported the use of preoperative breast MR imaging because of its benefits. These benefits were divided into 4 subcategories:

- Detection of contralateral lesions.
- Additional biopsies that confirm occult cancer.
- Visualization of dense breast tissue.
- Mediation of the choice between BCS and mastectomy.

Other studies concluded that preoperative MR imaging could lead to unnecessary upgrades in surgical plans, including mastectomies and additional biopsies. Still other studies concluded that it is presently unclear whether preoperative breast MR imaging leads to beneficial or to unnecessary changes in surgical plans. Further analysis of the literature also revealed disagreement about the role of MR imaging in reducing the rate of multiple surgeries.

**Beneficial Changes in Surgical Planning**

**Detecting Contralateral Lesions**

Preoperative breast MR imaging can be beneficial for patients with breast cancer when it leads to changes in previously established surgical plans that result in a surgery better suited for an individual patient.\(^{4,5,9-18}\) Bilateral MR imaging examinations are helpful in detecting lesions of the contralateral breast.\(^{9,11,12,14}\) For example, after a breast cancer diagnosis, 425 women at the Mayo Clinic in Jacksonville, Florida, underwent bilateral breast MR imaging that yielded the recommendation for biopsies of suspicious lesions in the contralateral breast of 72 patients.\(^9\) All 72 patients underwent biopsies of their suspicious lesions; cancer was confirmed histopathologically in 16 patients.\(^9\) Upon review of the 16 women’s mammographic images, only 2 of the carcinomas detected by MR imaging were visible in the
mammograms. In effect, preoperative MR imaging demonstrated the need for additional biopsies that were beneficial for the patients whose occult contralateral cancerous lesions were detected with the technology. The benefit was especially evident for 3 of the 16 patients who were diagnosed with ductal carcinoma in situ (DCIS). Patients with DCIS are likely to develop metastases if their tumor is left untreated, so it was beneficial that preoperative MR imaging detected DCIS in the contralateral breast in these patients.

In a study by Fan et al, preoperative MR imaging was used to detect contralateral malignancies in 22 patients, including 12 who were diagnosed with DCIS. The surgical plan for each patient was altered based on the characteristics of the additional lesions. Eight women underwent a contralateral mastectomy for their confirmed malignancy in the contralateral breast. The remaining 14 women underwent a lumpectomy of a lesion in the contralateral breast. In another study conducted by Heil et al, MR imaging identified 7 new suspicious lesions in 6 of 92 patients. All 7 lesions were diagnosed as cancerous, either by a preoperative biopsy or by postoperative histopathological analysis.

Based on the research studies cited, preoperative breast MR imaging provides valuable information about lesions in the contralateral breast that conventional imaging can overlook. In each of the studies discussed, multiple patients benefited from preoperative MR imaging, which identified at least one additional occult malignancy in the contralateral breast. Surgical plans were changed to include the additional lesions, thereby improving surgical treatment. When contralateral lesions are detected by MR imaging, a biopsy is performed to confirm the histopathology of the lesions (see Table 1).

**Additional Biopsies**

Using breast MR imaging often results in additional biopsies in patients who would not otherwise have had those biopsies. The composition of a lesion—whether it is malignant or benign—plays a crucial role in developing a surgical plan. The usefulness of additional biopsies was demonstrated in a 2010 study by Bernard et al in which 72 contralateral biopsies were performed because of suspicious findings detected by preoperative MR imaging. Sixteen of the biopsies were positive for early-stage breast cancer (stage 0 or 1) and did not exhibit invasion of the lymph nodes. Detection of breast cancer in these early stages is beneficial to the physician, because it permits better surgical planning. Early detection is beneficial to the patient as well because early-stage disease has a better prognosis, especially if the lymph nodes are unaffected. In the study conducted by Bernard et al, preoperative MR imaging and additional biopsies resulted in a diagnosis of early stage breast cancer in 16 women.

In the study by Heil et al, breast MR imaging detected larger cancerous lesions in 14 of 29 patients and 17 additional cancerous lesions in 15 of 29 patients. A biopsy confirmed the malignancy of at least 10 suspicious lesions, while the malignancy of 7 other lesions was confirmed postoperatively. Four of the suspicious lesions were proven to be benign. In a separate study by Grobmyer et al, 79 patients underwent preoperative breast MR imaging; 25 had suspicious findings and underwent a biopsy. Eleven of the biopsies were positive for cancer, 5 disclosed DCIS, and 6 disclosed invasive ductal carcinoma. The remaining biopsies yielded negative results. The findings of both studies underscore the importance and benefits of confirming the malignancy of suspicious lesions before proceeding with surgery.

**Dense Breast Tissue**

While the literature has demonstrated the benefits of preoperative MR imaging and biopsy, MR imaging might be of greater benefit among certain patient subgroups, particularly those who have dense breast tissue. A study by Duygulu et al supports this contention. They characterized the breast parenchyma of 68 patients based on mammographic images and the BI-RADS classification method. Fourteen patients were found to have category 4 (extremely dense) breast tissue, 36 were found to have category 3 (heterogeneously dense) breast tissue, and 18 were found to have category 2 (fat containing scattered fibroglandular elements) breast tissue. The results of preoperative MR imaging effected changes in the surgical plans for multiple patients, including half (n = 18) of the patients with category 4 breast tissue. Fewer
### Preoperative Breast MR Imaging: Its Role in Surgical Planning

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample Size</th>
<th>Findings</th>
</tr>
</thead>
</table>
| Bernard et al⁹     | 2010 | 425 MR      | - 72 contralateral biopsies were performed on the basis of MR imaging findings.  
- 16 additional cancerous lesions were identified. |
| Duygulu et al⁸     | 2012 | 68 MR       | 13 surgical plans were upgraded from BCS to mastectomy because of:  
- a contralateral mass.  
- invasion of the pectoral muscle.  
- multicentric, multifocal, or larger lesions. |
| Fan et al¹¹        | 2013 | 445 MR      | 105 changes were made in surgical plans including:  
- 55 upgrades to mastectomy because of ipsilateral lesions.  
- 9 upgrades to mastectomy because of contralateral lesions. |
| Fancellu et al¹²    | 2013 | 109 MR 128 non-MR | 12 surgical plans were upgraded from BCS to mastectomy because of additional biopsy-confirmed malignant lesions in the ipsilateral breast or a larger tumor size as disclosed by MR imaging.  
- Reoperation rate higher in the non-MR group (8.6%) vs the MR group (4.1%). |
| Grobmyer et al¹⁰   | 2008 | 79 MR       | Additional 25 biopsies were performed on the basis of MR imaging findings; 44% positive for malignancy, leading to changes in 15 surgical plans.  
- Rate of mastectomy increased for patients with malignant biopsies and patients with abnormal MR imaging findings and no biopsy.  
- Rate of mastectomy decreased in patients with benign biopsies and normal MR imaging findings. |
| Heil et al¹⁴       | 2012 | 92 MR       | 23 surgical plans were altered; 20 were beneficial, and 3 were deemed to be overtreatment based on final pathology. |
| Killelea et al¹³    | 2013 | 628 MR      | 257 patients had one or more biopsies after MR imaging.  
- Rate of mastectomy increased for patients with malignant biopsies and patients with abnormal MR imaging findings and no biopsy.  
- Rate of mastectomy decreased in patients with benign biopsies and normal MR imaging findings. |
| Mameri et al¹⁶     | 2013 | 628 MR      | 44.4% of surgical plans were altered.  
- Included 25 upgrades from BCS to mastectomy and changes in the surgical approach.  
- All changes were based on true-positive MR imaging results. |
| Obdejin et al⁴     | 2013 | 123 MR 119 non-MR | 42 surgical plans were upgraded after MR imaging and included 29 mastectomies.  
- Fewer MR imaging patients had tumor-positive resection margins than did the non-MR imaging control group.  
- MR imaging patients underwent fewer reoperations than did the non-MR imaging control group. |
| Pediconi et al¹⁷    | 2012 | 203 MR      | Of 388 suspicious lesions, 229 were detected by initial conventional imaging; 159 were detected by MR imaging.  
- Surgical plans were changed for 24.6% of patients after MR imaging; leading to 38 upgraded surgeries and 12 downgraded surgeries. |
| Teller et al¹⁸      | 2012 | 92 MR       | 28 surgical plans were altered, with 75% deemed favorable.  
- None of the unfavorable results were full mastectomies. |
| Thibault et al⁵     | 2010 | 95 MR       | Surgical plans derived from conventional imaging were compared with plans aided by MR imaging. MR imaging would have led to beneficial changes in surgical plans for 6 patients, including:  
- avoidance of chemotherapy in 5 cases.  
- one postchemotherapy mastectomy in a patient for whom BCS would have been unsuccessful. |

**Abbreviations:** BCS, breast-conserving surgery; MR, magnetic resonance.
patients with category 3 breast tissue \((n = 5)\) and only one patient with category 2 required changes in her surgical plans.\(^{10}\)

**Breast-Conserving Surgery vs Mastectomy**

A widely discussed aspect of preoperative breast MR imaging is its effect on the decision between BCS and mastectomy. Multiple studies show that preoperative MR imaging leads to an increase in mastectomies.\(^{4,12,16,17}\) More extensive surgery is associated with a more favorable outcome for most patients.\(^{18}\) In a study conducted by Mameri et al, for example, 93 of 99 patients were scheduled to undergo BCS. Based on the results of preoperative MR imaging, the surgical plan of 25 patients was changed to mastectomy because of additional or larger lesions undetected previously by the conventional imaging techniques of mammography and ultrasonography. These 25 patients were found to have multifocal lesions \((n = 13)\), multicentric lesions \((n = 6)\), a larger lesion \((n = 3)\), pectoral muscle or skin involvement \((n = 2)\), and DCIS \((n = 1)\).\(^{16}\) Obdeijn et al reported similar findings among 123 patients with breast cancer. After preoperative breast MR imaging, 25 patients underwent a unilateral mastectomy and 4 underwent a bilateral mastectomy.\(^{6}\) The reasons for these changes in their surgical plans were patient preference because of contralateral disease \((n = 4)\), a larger lesion than previously observed \((n = 10)\), and multicentric lesions, multifocal lesions, or the “central position of a relatively large lesion” \((n = 7)\).\(^{4}\) In their study, Fancellu et al justified the change from BCS to mastectomy in 12 cases based on additional biopsy-confirmed malignant lesions in the ipsilateral breast or a larger tumor size as disclosed by preoperative breast MR imaging.\(^{12}\)

In contrast to the previous studies, Pediconi et al investigated the correlation between preoperative MR imaging and the rate of mastectomies and the role of MR imaging in downgrading surgical plans. Overall, 50 (24.6%) of 203 patients who underwent preoperative MR imaging had a change in their surgical plan.\(^{17}\) Altogether, an additional 159 occult lesions were detected that previously had not been visualized by conventional mammography or ultrasonography. A biopsy was performed for all the newly detected lesions, thereby preventing overtreatment. Based on positive biopsy results, 38 patients required more extensive surgery, including 16 unilateral mastectomies and 2 bilateral mastectomies.\(^{17}\) Preoperative MR imaging also disclosed that 12 patients had less extensive disease than originally thought, and their surgical plans were downgraded.\(^{17}\) Surprisingly, a study by Killelea et al suggested that some women still choose to have a lumpectomy rather than a mastectomy even after MR imaging discloses more extensive disease.\(^{15}\)

Teller et al characterized changes in surgical plans prompted by preoperative breast MR imaging as favorable or unfavorable. Circumstances were considered favorable if:\n
- An additional biopsy was confirmed histopathologically to be malignant.
- A total mastectomy was performed because of a large tumor, multifocal lesions, or multicentric lesions that would not have been fully removed by a partial mastectomy.
- A wider excision was made for a larger lesion with histopathological confirmation of cancer in the extra resected tissue.
- A benign lesion identified with MR imaging saved the patient from undergoing a biopsy.
- MR imaging showed smaller lesions than suspected, sparing the patient from a total mastectomy.
- MR imaging showed less extensive findings and, therefore, the patient received a less extensive partial mastectomy.

Of 95 patients who underwent MR imaging, 28 had a change in their surgical plan based on the results.\(^{18}\) Most (75%) of the changes in the surgical plans were categorized as favorable for the reasons listed above.\(^{18}\)

A retrospective study by Thibault et al examined hypothetical situations in which preoperative breast MR imaging was considered before surgery and compared the actual surgical plans of 30 patients to what those plans would have been had MR imaging been performed. Results showed that 6 patients would have benefited from preoperative MR imaging.\(^{4}\) The technique would have identified multicentric lesions in 5 patients, allowing them to avoid chemotherapy by undergoing an initial total mastectomy, and one patient would have avoided multiple BCSs by undergoing a mastectomy after chemotherapy.\(^{4}\) For an additional 14 patients, MR...
imaging would have helped their surgeons create a more detailed surgical plan by providing valuable information about the size, shape, and multifocality of the lesions, confirming that 5 patients were solid candidates for a standard lumpectomy, while the other 9 were better suited for a wider excision such as a quadrantectomy or mastectomy.¹

Unnecessary Changes in Surgical Planning

While some studies report that preoperative breast MR imaging is beneficial to surgical planning, others report that it can prompt unnecessary changes in surgical plans. For example, the retrospective study by Thibault et al found that 2 patients would have had unnecessary mastectomies, rather than successful BCSs, had MR imaging been used to plan their surgery. Both patients were free of recurrent disease at 29 and 34 months after BCS.⁵ Although this study reports hypothetical changes in surgical plans, the same unnecessary changes can and do occur in practice, as reported by Ayoola et al in a study of 160 patients with breast cancer. The patients were divided into 2 groups—those who underwent mammography only (n = 60) and those who underwent both mammography and MR imaging (n = 100).⁸ Of 59 patients who had a mastectomy, 78% had undergone both mammography and MR imaging.⁸ Although Ayoola et al recognized the accepted practice of screening “high-risk patients and patients with very dense breast tissue” with MR imaging, they suggested that the use of MR imaging is not justified in about 60% of cases because it fails to effect substantial improvements over the use of mammography only.

Preoperative breast MR imaging does not only result in unnecessary mastectomies. In a study by Yau et al, for example, MR imaging specifically for the clinical indication of problem solving disclosed suspicious or highly suspicious findings in 42 of 204 patients.¹⁹ Biopsies were performed in 36 patients, yielding 14 cancer diagnoses and 22 benign lesions.¹⁹ The remaining 6 patients chose not to undergo a biopsy, and “none of these 6 patients were identified as having a breast malignancy through the regional tumor registry in the year following the breast MRI.”¹⁹ Although the MR imaging results were classified as negative, benign, or probably benign in 62 of the 204 study patients, a biopsy was still recommended for 28 of the patients in this subgroup within 12 months of MR imaging.¹⁹ Only one biopsy confirmed malignancy; the other 27 were benign.¹⁹ Yau et al concluded that preoperative breast MR imaging leads to multiple unnecessary biopsies.

While Teller et al listed 6 circumstances that were categorized as favorable changes, they also listed 6 surgical changes that were deemed unfavorable. Changes were considered unfavorable if:

- An additional biopsy was performed and was confirmed to be benign.
- A total mastectomy was performed because a larger tumor, multifocal lesions, or multicentric lesions were suspected and the postoperative pathology showed benign tissue in the suspicious areas.
- A wider excision was made for a perceived larger lesion with histopathological confirmation of benign tissue.
- A lesion appeared to be benign on the MR image but was malignant.
- MR imaging underestimated the multifocality, or multicentricity, of a lesion and led to a mastectomy not being performed when it should have been.
- MR imaging underestimated the size of a lesion that resulted in the need for additional surgeries to fully remove the malignancy.

Of the 28 surgical changes made with the aid of preoperative MR imaging, Teller et al characterized 7 changes as being unfavorable, including 3 biopsies of a benign lesion, 2 wider excisions that included benign tissue, one false-negative assessment of the extent of the malignancy, and one false-negative benign lesion that was ultimately confirmed as being malignant (see Table 2).¹⁸

Unclear Benefit

Although there is no consensus about the advantages and disadvantages of preoperative breast MR imaging, researchers agree that it does impact surgical planning.⁴,⁵,⁶,⁹ In their study of 267 patients who were originally slated for BCS, Bedrosian et al found that MR imaging led to changes in the surgical plans of 69 patients, including wider excisions, additional biopsies, and ultimately 44 mastectomies.²⁰ The changes were
justified by histopathologic confirmation of malignancy in all but 20 patients. Of the 20 patients who had unjustified changes in their surgical plans, only 2 underwent mastectomies and 18 had wider excisions and additional biopsies. It appears that MR imaging is a useful tool because it led to beneficial changes in the surgical plans of 49 patients (18.4%), but it cannot be ignored that 20 patients (7.5%) were overtreated because of their MR imaging findings.

A study conducted by Law et al examined 97 patients whose surgical plans were upgraded after preoperative breast MR imaging. Although false-positive MR imaging findings led to 12 more extensive surgeries, none of the surgical upgrades were mastectomies. The remaining 85 patients had appropriate changes to their surgical plans. This study raises the question of how many successful surgical changes it takes to justify a few unnecessary changes.

Another question raised about the potential benefit of MR imaging is its effect on surgical timing. Sardanelli showed that preoperative MR imaging can delay treatment for as long as 22.4 days. Delays in surgical treatment might not be in the best interest of certain patients; however, a new and improved surgical plan might be worth the delay for others. Unfortunately, the benefit of preoperative breast MR imaging vs the risk of treatment delay remains unclear.

Some studies suggest that surgical plans devised after preoperative breast MR imaging are similar to those devised after conventional imaging only. Ko et al found that 14 (4.5%) of 310 patients had a mastectomy even after MR imaging did not show any additional occult lesions. When compared with 33 (6.9%) of 475 patients who had a mastectomy after conventional imaging alone, it could be argued that MR imaging was beneficial because more women were spared from having a mastectomy. Unfortunately, the percentages of patients in the MR imaging group and the conventional imaging group are too similar to suggest a definite correlation. In another study, Petrillo et al identified 4 unnecessary mastectomies; 2 resulted from false-positive MR imaging findings, and 2 resulted from false-positive conventional imaging findings (see Table 3).

### Occurrence of Multiple Surgeries Reduced Rate

Some studies suggest that preoperative MR imaging reduces the rate of multiple surgeries in patients with breast cancer. Grady et al discovered that 27 (26%) of 105 patients in their study who did not have preoperative MR imaging required at least one extra surgery to fully remove their cancerous lesion. The rate was dramatically less for patients who were staged with preoperative MR imaging, with only 11% of patients (9 of 79) requiring additional surgeries. In a study of 267 patients with invasive lobular carcinoma of the breast, Mann et al found a re-excision rate of 27% for patients who did not have preoperative MR imaging (n = 168). Alternatively, the re-excision rate for patients who underwent preoperative MR imaging (n = 99) was only 9%. When the rate of mastectomies was compared with those who did not undergo additional biopsies before surgery, differences were not statistically significant.

### Table 2

**Unnecessary Changes in Surgical Plans Because of Preoperative Breast MR Imaging**

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Sample Size</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ayoola et al</td>
<td>2011</td>
<td>100 MR</td>
<td>- MR imaging detected lesions that were not cancerous according to final pathology.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 non-MR</td>
<td>- Of the 59 patients who received a mastectomy, 46 had preoperative MR imaging, and 13 had mammography only.</td>
</tr>
<tr>
<td>Thibault et al</td>
<td>2004</td>
<td>30 MR</td>
<td>- In 2 cases, successful BCS was ultimately performed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Evaluation of MR imaging screening images would have upgraded surgeries to unnecessary mastectomies.</td>
</tr>
<tr>
<td>Yau et al</td>
<td>2011</td>
<td>204 MR</td>
<td>- 36 biopsies found 14 cancers; 11 were deemed suspicious on mammograms or sonograms before MR imaging.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Overall, 189 unnecessary MR examinations were performed.</td>
</tr>
</tbody>
</table>

*Abbreviations: BCS, breast-conserving surgery; MR, magnetic resonance.*
In the number of tumor-positive resection margins between the 2 groups. If tumor-positive resection margins are found postoperatively, it means that not all of the cancerous cells were removed and additional surgery is likely required. Patients in the preoperative MR imaging group had about half as many tumor-positive resection margins as those in the non-MR imaging control group (15.8% and 29.3%, respectively). In addition, about half as many patients in the preoperative MR imaging group required re-excision. Obdejin et al asserted that reoperation should be a rare occurrence to spare the patient from an “emotional and physical burden.” The results of this study suggest that preoperative MR imaging can help prevent excess reoperations by decreasing the incidence of tumor-positive margins after initial surgical intervention.

**No Reduction in Rate**

The current literature contains studies that argue that preoperative breast MR imaging does not have a

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**Table 3**

**Summary of Studies in Which the Advantages or Disadvantages of MR Imaging Are Unclear**

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Sample Size</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrosian et al</td>
<td>2003</td>
<td>267 MR</td>
<td>- 69 patients originally considered for BCS either had more extensive surgery (including 44 mastectomies) or an additional biopsy because of abnormal MR imaging findings. - Malignancy confirmed in 49 of 69 patients; the remaining 20 had unnecessary surgical procedures not justified by malignancy.</td>
</tr>
<tr>
<td>Ko et al</td>
<td>2003</td>
<td>310 MR 475 non-MR</td>
<td>- Rate of re-excisions was essentially the same in both study groups—6.3% in the non-MR imaging group and 6.1% in the MR imaging group. - 4.5% of the MR imaging group who had no additional lesions underwent mastectomy; 6.9% of the non-MR imaging group had a mastectomy. - No obvious benefit in terms of survival rate was reported for either study group.</td>
</tr>
<tr>
<td>Law et al</td>
<td>2013</td>
<td>204 MR</td>
<td>- 66% of surgeries were upgraded. - 12 upgrades were deemed inappropriate because of false-positive MR imaging findings. - None of the 12 upgrades were mastectomies.</td>
</tr>
<tr>
<td>Petritto et al</td>
<td>2013</td>
<td>122 MR 124 non-MR</td>
<td>- 65 patients who underwent MR imaging and 46 patients who did not undergo MR imaging had mastectomies. - 2 patients in each group had a mastectomy because of false-positive images.</td>
</tr>
<tr>
<td>Sardanelli</td>
<td>2010</td>
<td>N/A</td>
<td>- MR imaging delays treatment an average of 22.4 days. - MR imaging can lead to false-positive results and unnecessary mastectomies. - MR imaging can lead to identification of true-positive larger lesions or multiple lesions.</td>
</tr>
</tbody>
</table>

**Abbreviations:** BCS, breast-conserving surgery; MR, magnetic resonance; N/A, not applicable.
substantial effect on decreasing the rate of re-excisions. In fact, Bleicher et al found that patients who underwent preoperative MR imaging were more likely to have tumor-positive resection margins after an attempted lumpectomy and therefore undergo a final mastectomy. In their study, more patients who underwent MR imaging rather than conventional imaging alone had positive margins after the first attempt at BCS. Tumor-positive margins most likely mean that the patient requires an additional wider lumpectomy or a total mastectomy. An evaluation of the final surgical method revealed that 5 of 51 patients who underwent MR imaging required an upgrade to mastectomy and that 14 of 239 patients who did not undergo MR imaging required a final mastectomy. The difference in the percentages between these 2 groups was not statistically significant, which prompted Bleicher et al to conclude that preoperative MR imaging does not help to reduce the rate of re-excisions in patients with breast cancer.

Similarly, Fancellu et al, in their study of 237 patients with invasive breast cancer, also achieved statistically insignificant results. They found a re-excision rate of 4.1% in 128 patients who did not undergo MR imaging and 8.6% in 109 patients who underwent MR imaging; the difference between the excision rates was too close to reach statistical significance.

Ko et al also investigated the rate of re-excision among patients with breast cancer who underwent preoperative MR imaging (n = 310) and those who did not (n = 475). They found that 6.1% of the patients who underwent MR imaging and 6.3% of those who did not required re-excision, indicating that preoperative MR imaging did not substantially reduce the rate of re-excision. Similarly, Wang et al agreed that preoperative breast MR imaging does not consistently reduce the rates of re-excision. In their study of 2997 women age 66 and older with early-stage breast cancer who had a preoperative breast MR imaging evaluation, they found that patient demographics such as age and tumor type can result in multiple surgeries.

**Discussion of Findings**

**Implications for Practice**

Although preoperative breast MR imaging can result in false-positive findings and lead to unnecessary mastectomies, MR imaging has proven to be useful in identifying larger or multiple lesions that might require upgrading of surgical plans. Physicians who choose to schedule preoperative MR imaging must histopathologically confirm the malignancy of suspicious lesions before performing a radical mastectomy or a larger excision. In their study of 441 newly diagnosed breast cancer patients, Pettit et al found that 36 patients underwent a mastectomy instead of BCS based on the findings of preoperative MR imaging. However, 23 of these patients did not undergo a confirmatory biopsy before surgery, which means that 23 mastectomies were performed without histopathological confirmation that the lesions detected with MR imaging were in fact malignant. Because MR imaging clearly can result in false-positive results, physicians should perform biopsies of suspicious lesions to avoid potential overtreatment.

**Suggestions for Further Research**

The lack of consensus regarding the usefulness of MR imaging in surgical planning indicates that more research is needed. The studies discussed in this review were retrospective in methodology, making it difficult to determine causality. In a study of mastectomy trends at the Mayo Clinic in Rochester, Minnesota, Katipamula et al found multiple factors that can contribute to an upgrade to mastectomy or an additional excision. Even the year a patient was diagnosed influenced surgical planning. For example, between 2003 and 2006, the rate of mastectomies after preoperative MR imaging remained constant, but the rate of mastectomies increased in patients who did not undergo MR imaging. Because preoperative MR imaging is not the sole reason patients receive particular surgical treatments, additional research is needed that takes other factors such as tumor characteristics and the makeup of the surgical team into account. This type of research would be more effective were its methodology prospective instead of retrospective.

The American Cancer Society has developed guidelines for using breast MR imaging as a screening tool (see Table 4). The American Cancer Society concedes that there is “insufficient evidence to recommend for or against” MR screening for patients of certain demographics, including those with a lifetime risk of 15% to
20% and those with dense breast tissue. Additional research is needed to create guidelines for patients with these demographics. Furthermore, it would be helpful to have a comprehensive set of guidelines that physicians could use to make decisions about preoperative MR imaging. Having such comprehensive guidelines would be a springboard for other research to determine whether physicians are using the guidelines and, if so, how helpful the guidelines are.

Most of the studies included in this review involved small numbers of patients who were treated at a single facility. For this reason, it might be beneficial to examine larger numbers of patients who received treatment in different facilities. Such a study could provide a more comprehensive overview of the trends in the use of preoperative MR imaging in various locations. Furthermore, most of the studies included in this review were conducted at a university hospital. University hospitals might be more likely to use MR imaging and determine the benefits of MR imaging in the same way. A worthwhile study might compare the use of preoperative MR imaging in university hospitals with its use in smaller clinics and private facilities. While preoperative MR imaging is becoming more common, further research is needed before a consensus can be reached about the role of this technique in surgical planning for patients with breast cancer.

**Conclusion**

This literature review reveals inconsistent findings regarding the effectiveness of MR imaging in surgical planning for patients with breast cancer. Some studies support the use of preoperative MR imaging because it leads to beneficial changes in surgical planning such as additional biopsies and wider excisions. Other studies have contradictory findings, indicating that MR imaging results in unnecessary procedures such as additional biopsies and wider excisions. Further research is needed before a consensus can be reached about the role of this technique in surgical planning for patients with breast cancer.

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**Table 4**

**American Cancer Society Recommendations for Breast MR Imaging Screening as an Adjunct to Mammography**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence Basis</th>
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<tr>
<td>Recommend annual MR imaging screening (based on evidence)</td>
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</table>
- BRCA mutation  
- First-degree relative of BRCA carrier, but untested  
- Lifetime risk ~20%-25% or greater, as defined by BRCAPRO software or other models that are largely dependent on family history |
| Recommend annual MR imaging screening (based on expert consensus opinion) |  
- Radiation to chest between ages 10 and 30 years  
- Li-Fraumeni syndrome and first-degree relatives  
- Cowden and Bannayan-Riley-Ruvalcaba syndromes and first-degree relatives |
| Insufficient evidence to recommend for or against MR imaging screening |  
- Lifetime risk 15%-20%, as defined by BRCAPRO software or other models that are largely dependent on family history  
- Lobular carcinoma in situ or atypical lobular hyperplasia  
- Atypical ductal hyperplasia  
- Heterogeneously or extremely dense breast on mammography  
- Women with a personal history of breast cancer, including ductal carcinoma in situ |
| Recommend against MR imaging screening (based on expert consensus opinion) |  
- Women at <15% lifetime risk |

*aEvidence from nonrandomized screening trials and observational studies.*  
*bBased on evidence of lifetime risk for breast cancer.*  
*cPayment should not be a barrier. Screening decisions should be made on a case-by-case basis, as there may be particular factors to support MR imaging. More data on these groups are expected to be published soon.*  

biopsies, wider excisions, and mastectomies.5,8,29 Still other studies gave inconclusive findings about the benefit of MR imaging in surgical planning.10-24 Ultimately, the physician must decide whether to use MR imaging in surgical planning. Additional research is needed about this important and controversial topic.

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References


Radiation Protection Education in Fluoroscopy

Marlene M Johnson, MEd, R.T.(R)

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

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

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

Deterministic effects from radiation exposure are biological changes that occur in the body and manifest after a relatively short latent period of days, months, or years. Latent period refers to the time after exposure during which there are no signs of illness or damage. With deterministic effects, the severity of the biologic response increases as the dose increases. A threshold dose of radiation generally exists, meaning the radiation dose level must be reached before the damage is observed.

Deterministic effects include local tissue damage, hematological depletion, cytogenic damage, and, in severe cases, acute radiation syndrome. Acute radiation syndrome seldom occurs as a result of fluoroscopically guided procedures; however, local tissue damage in the form of skin burns, dermatitis, and epilation is possible.

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

**Factors That Affect Radiation Protection Goals**

In clinical practice, a complicated set of issues affects the overall goal of radiation protection. Health care professionals should seek a balance between the dose delivered and the reason for the procedure, including how the procedure is likely to affect the patient outcome. The greatest benefit to the patient should result in the lowest risk of radiation exposure to the patient. In addition, radiation protection practices also affect the amount of radiation exposure to medical personnel during procedures.

The physician must assess the technology available and evaluate how the technology affects the outcome of the procedure and the overall radiation dose to the patient, as well as all personnel participating in the procedure. Modern fluoroscopic equipment offers a variety of modes and image quality options and can deliver very high radiation doses for long periods of time. Decisions about mode selection and the type of image quality sufficient to perform the procedure influence the amount of radiation used. For example, the anatomical area of interest can be magnified, but magnification results in an increase in dose. Also, images can be recorded at different rates, with various levels of image quality on a variety of recording devices.

The use of pulsed fluoroscopy or last-image hold can decrease patient dose. Exposure to the patient, operator, and personnel assisting with the procedure can be affected greatly by the availability of these options and, more importantly, by whether the operator understands the equipment and uses these options appropriately. For example, a cardiologist would never consider placing a stent in a patient using an extremity C-arm, nor would an orthopedic surgeon need to use a fluoroscopic unit that records rapid frames per minute and magnifies the anatomy tenfold.

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

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

**Historical Background**

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

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

Radiation protection practices were lacking prior to 1950, and as a result occupational radiation exposures were higher than they are reported to be today.14,15 Radiographers regularly held patients during exposures to decrease motion, and many radiographers reported holding patients during 50 or more exposures. In addition, radiographers could begin working in the field before the age of 17 years, and fluoroscopic radiation exposure equipment regulations were not in force.6,16 Skin injuries due to overexposure to radiation were common before the 1930s.9 In 1949, the first study was published demonstrating an increased incidence of cataracts in physicists who worked with cyclotrons, devices capable of increasing charged particles to very high energies.2

Over time, radiation protection concepts changed significantly as the National Council on Radiation Protection and Measurements (NCRP) became active, publishing 19 reports regarding protection practices.8,16 The 5 rem (0.05 Sv) annual dose limit for radiation workers was established in 1959 by the International Commission on Radiological Protection (ICRP) and remained unchanged until 1977.12

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

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

Recent Developments

In 2006, the U.S. population received 7 times more exposure to ionizing radiation from medical imaging when compared with the early 1980s. Medical exposure accounts for nearly one-half the total radiation exposure that individuals receive in a lifetime.17 Fluoroscopically guided procedures are being performed for a variety of diagnostic and therapeutic purposes by many different specialties and medical personnel and in a number of settings (see Box 1).8

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

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**Box 1**

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

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

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

In the past 14 years, the focus on radiation protection has shifted, with attention directed toward the following concerns: \(^1,\)\(^3\)\(^-\)\(^6,\)\(^9,\)\(^11,\)\(^13\)\(^-\)\(^15,\)\(^18\)\(^,\)\(^19\)\(^,\)\(^22\):

- How the educational background of personnel in fluoroscopy might contribute to overexposure of patients and personnel.
- Quality management of education and equipment.
- Long-term, low-level occupational exposure.
- Radiation-induced cataracts in fluoroscopy operators.
- Skin injuries acquired during fluoroscopy.

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

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

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

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

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

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

**Occupational Exposure Risk**

**Low-Level Dose Risks**

Most occupational exposure of diagnostic imaging personnel occurs during fluoroscopy and mobile radiography, especially during interventional and other fluoroscopically guided procedures. \(^2\) Radiographers who operate fluoroscopy equipment receive higher exposures than do other radiographers primarily because of longer exposure times and close proximity to the radiation source. \(^2\)
Radiation-Induced Cataracts

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

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

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

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

**Fluoroscopy Education**

Lack of education and training for a variety of health care professionals can affect fluoroscopy radiation exposure to patients and personnel. Referring physicians, medical students, specialty physicians, residents in training, all medical personnel assisting with fluoroscopy procedures, equipment manufacturers, and medical physicists contribute directly or indirectly to patient and personnel exposures.¹,⁶,¹⁰ Routine performance of fluoroscopy procedures in areas other than medical imaging departments has evolved over time and might have outpaced the standards, licensing, and granting of fluoroscopic privileges.⁵ As a result, some fluoroscopy operators have not received proper training in radiation protection and the principles of balancing image quality with the examination or procedure being performed.⁵

If fluoroscopy operators place a higher value on image quality than minimizing radiation dose when selecting or using fluoroscopy equipment, the practice can unnecessarily increase the amount of radiation exposure to patients and staff involved with the procedure. The personnel operating the equipment might not have had any training in radiation protection practices or could underestimate the amount of exposure received.⁵ Radiation exposure levels from the same procedure and with similar patient conditions can differ dramatically between institutions.⁷ Referring physicians might select the procedure that delivers the highest amount of radiation exposure without considering other, nonionizing procedures; radiology residents might not be supervised properly or trained on the operation of fluoroscopic equipment as it relates to dose; and other medical personnel who are involved with the procedures might not practice basic radiation protection skills.⁶

**Improving Education in Fluoroscopy**

The ICRP, FDA, NCRP, NCI, and the American Association of Physicists in Medicine (AAPM) are focusing efforts on reducing unnecessary radiation exposure through radiation education, certification, and compliance by establishing initiatives, recommendations, standards, and guidelines.⁵,⁶,¹⁰,¹⁵-¹⁷

NCRP recommendations for all facilities performing fluoroscopic procedures include ensuring that all¹⁰:

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

In October 2010 an ICRP committee specifically addressed education and training in radiation protection for diagnostic and interventional procedures. Its recommendations included topics in each area of radiation protection, suggested number of teaching hours, and syllabi examples.⁶,¹⁸ The education and training must be planned, clinically relevant, and ensure that optimal radiation protection for patients and medical personnel emphasizes performing procedures competently. This is an invaluable guide for any educational institution, medical school, or department that performs fluoroscopic procedures.⁶

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

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

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

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

Educational Needs of Professionals Involved in Fluoroscopy

Medical Students and Referring Physicians

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

<table>
<thead>
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<th>Box 2</th>
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<td><strong>Resources for Health Care Personnel Involved in Fluoroscopy Procedures</strong></td>
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the appropriate examination and considering nonionizing options are critical responsibilities of the physician. The physician must be knowledgeable about the procedure and have some understanding of the radiation dose amount. Research has demonstrated that a large number of physicians of various backgrounds need to improve their knowledge of radiation exposure.34,38,41

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

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

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

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

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

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

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

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

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

Physicians Operating Fluoroscopy Equipment

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

The ACR standard states that physicians performing the most complex interventional procedures should have the most fluoroscopy-specific radiation protection education. According to the ICRP, education ideally should start with basic background knowledge in medical school for all physicians. This education should progress to comprehensive radiation protection practice skills for advanced practitioners delivered throughout physicians’ careers by required continuing medical education.

Implementing radiation protection education requires long-term planning with involvement from regulatory agencies, educational institutions, and medical facilities. The plan must address how the curriculum can be developed, who will teach the courses, and in what format the education will be offered.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The Joint Commission adopted the sentinel event policy in 1996 to help hospitals that report serious adverse effects improve patient safety and learn from the events. A sentinel event is a patient safety event that is not primarily related to the natural course of the patient’s illness or condition. The event is an unexpected occurrence involving serious physical or psychological injury to a patient that results in death, permanent harm, or severe temporary harm requiring an intervention to sustain life. The terms *sentinel event* and *error* are not synonymous because not all events occur as a result of error and not all errors result in sentinel events.\(^4\)\(^7\)

Even though The Joint Commission granted the prerogative for medical institutions to decide which types of occurrences are to be considered sentinel events, the ICRP recommends that hospitals categorize patient skin burns from fluoroscopy as sentinel events.\(^1\)\(^1\)\(^1\) For a procedure to qualify as a sentinel event, the radiation exposure level must reach a predetermined absorbed dose amount or period of time the fluoroscopy unit was being operated. The sentinel event report must be reviewed by a departmental or institutional quality team, which completes a follow-up report that might require additional training for the fluoroscopy operator.\(^4\)\(^7\)

**Registered Radiologist Assistants**

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

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

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

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

Lack of compliance with established radiation safety practices could lead a radiographer to contribute to increases in radiation dose. 18,19,21,48 Previous research has shown variation in adherence to radiation protection practices among radiographers, along with concern about complacency and apathy toward protection practices.19,20 Research conducted by the ASRT in November 2013 showed that in states that require licensing of radiologic technologists, 4.3% of radiographers surveyed did not know whether their facilities had policies in place to minimize radiation exposure to personnel. However, in states that do not require licensing of technologists, 8% did not know about occupational exposure policies in their facilities. 49

When asked to rate their own knowledge of radiation safety, more than 45% of cardiovascular technologists, vascular-interventional technologists, and R.R.A.s considered themselves very knowledgeable, and about 35% rated themselves knowledgeable. More than 40% of radiographers rated themselves as very knowledgeable and 40% as knowledgeable. 49 Professional ethics and standards emphasize that radiologic technologists should seriously consider their responsibilities to patients and the medical community, as well as their role in assuring their own personal radiation protection.18,50

Improving radiation safety begins with a personal evaluation of radiographers’ own routine practices.18,20,47 The ARRT is considering different approaches to recertification for radiologic technologists who were certified after 2011 and might address any lack of compliance with protection practices through radiography recertification requirements. Research suggests that involving professional associations and health care organizations, along with educational interventions in the form of in-services or incorporating dose feedback systems into radiography practice, can be effective.18,51-54 Radiographers should ensure that they are incorporating best practices into their daily routines, seeking continuing education in radiation protection, and actively participating in the Image Wisely campaign.54

Radiographers have some control over the greatest source of unnecessary patient dose, which is repeated or unnecessary examinations.10,11,17 Radiologic technologists should acquire relevant patient history regarding previous examinations and radiation exposure history when available. Repeat examinations have been estimated to account for as much as 10% of all examinations, and most repeat examinations are caused by radiographer errors.2

Radiographers also can contribute to the educational process. They can coach, serve as role models, suggest radiation protection management skills to residents in training, and volunteer to assist in delivering fluoroscopy continuing education.5,55

Accreditation standards for programs that educate entry-level radiographers who assist during fluoroscopy mandate that radiation protection be taught throughout the required cognitive and psychomotor knowledge and skills set.19 The assumption should be that certified radiographers have received instruction in the recommended topics, including the following6,56:

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

A certified radiographer also understands topics such as atomic structure, x-ray production and interaction of x-rays with matter, nuclear structure and activity, radiological quantities and units, fundamentals of radiation biology, biological effects of radiation, and national and international standards.6

The major focus of radiographers’ education should be specific to their job and roles.6 Once radiographers expand their role to include interventional fluoroscopy procedures, they should be required to achieve a higher level of understanding of radiation protection practice and be included in the fluoroscopy privileging system.1,6 The ARRT offers secondary certification in interventional radiography and cardiology that requires this type of advanced knowledge.57
Other Personnel

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

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

Physicists

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

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

Equipment Manufacturers

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

A well-managed imaging department that values dose reduction strategies should have frequent in-service training with information and reminders about radiation protection practices. Advanced clinical application specialists can be valuable contributors to these in-service sessions. New equipment installation education and training provided by clinical applications professionals is essential, and the competency of staff members should be evaluated and documented at the
Radiation Protection Education in Fluoroscopy

Completion of training. All users must be aware of any changes with dose implications or new features that affect dose.6

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

Patients

Patients can affect their overall radiation exposure by ensuring they are providing members of the health care team with information about previous radiological studies and by becoming aware of the potential harm that long-exposure fluoroscopy studies can present (see Box 3).6 A general understanding of radiation and the potential exposure from fluoroscopy examinations and procedures can help patients better participate in their care and decision making. Information for the public and patients should be balanced and reflect scientific literature and findings.4

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

Fluoroscopy Education Methods

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

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

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

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

Box 3

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

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

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

Conclusion

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

Marlene M Johnson, MEd, R.T.(R), has been a certified radiographer for 40 years, with a career emphasis in teaching the radiologic sciences, directing radiography programs, and serving as a site visitor for the Joint Review Committee on Education in Radiologic Technology for 10 years. In her final position she developed and improved educational programs in nuclear medicine, magnetic resonance imaging, and computed tomography at the University of Utah, where she developed a bachelor of science program. Retired since 2014, she plans to enjoy her leisure time and make periodic contributions to the continuing education of radiographers and other professionals involved with medical imaging.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

continued on next page
15. Radiation exposure levels from the same procedure and with similar patient conditions can differ dramatically between institutions because:

   1. referring physicians might select the procedure that delivers the highest amount of radiation exposure without considering other, nonionizing procedures.
   2. radiology residents might not be supervised properly or trained on the operation of fluoroscopic equipment as it relates to dose.
   3. other medical personnel who are involved with the procedures might not practice basic radiation protection skills.

16. The ______ has the responsibility to ensure that physicians comply with all applicable state and federal laws and institutional policies for fluoroscopy licensure and certification.

   a. radiology department
   b. medical board
   c. private group practice
   d. medical physicist

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

   a. true
   b. false

18. Which of the following is false regarding computerized decision support systems?

   a. They are difficult to use.
   b. They improve physicians’ clinical decisions.
   c. They ensure procedures are covered by Medicare.
   d. They can serve as a learning tool for physicians.

19. According to the ICRP, education and training in fluoroscopy should:

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

20. Which of the following practices in fluoroscopy optimizes radiation protection during procedures?

   a. using the magnification mode throughout the entire procedure
   b. acquiring large numbers of images
   c. obtaining the best possible quality images
   d. using pulsed fluoroscopy

21. Which of the following groups of physicians requires the strictest adherence to dose reduction strategies?

   a. pediatric interventionalists
   b. cardiologists
   c. general practice radiologists
   d. vascular surgeons

22. Which of the following statements is false about sentinel events?

   a. The event is an unexpected occurrence involving serious physical or psychological injury to a patient.
   b. These events result in death, permanent harm, or severe temporary harm requiring an intervention to sustain life.
   c. The terms sentinel event and error are synonymous.
   d. A sentinel event is a patient safety event that is not primarily related to the natural course of the patient’s illness or condition.
23. In a recent survey from ASRT, more than ______% of radiographers rated themselves as either knowledgeable or very knowledgeable about radiation safety.
   a. 24
   b. 30
   c. 60
   d. 80

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

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

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

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

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

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

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

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1 ○ ○ ○ ○ ○  2 ○ ○ ○ ○ ○  3 ○ ○ ○ ○ ○  4 ○ ○ ○ ○ ○  5 ○ ○ ○ ○ ○  6 ○ ○ ○ ○ ○  7 ○ ○ ○ ○ ○  8 ○ ○ ○ ○ ○  9 ○ ○ ○ ○ ○ 10 ○ ○ ○ ○ ○ 11 ○ ○ ○ ○ ○ 12 ○ ○ ○ ○ ○ 13 ○ ○ ○ ○ ○ 14 ○ ○ ○ ○ ○ 15 ○ ○ ○ ○ ○ 16 ○ ○ ○ ○ ○ 17 ○ ○ ○ ○ ○ 18 ○ ○ ○ ○ ○ 19 ○ ○ ○ ○ ○ 20 ○ ○ ○ ○ ○ 21 ○ ○ ○ ○ ○ 22 ○ ○ ○ ○ ○ 23 ○ ○ ○ ○ ○ 24 ○ ○ ○ ○ ○ 25 ○ ○ ○ ○ ○ 26 ○ ○ ○ ○ ○ 27 ○ ○ ○ ○ ○ 28 ○ ○ ○ ○ ○ 29 ○ ○ ○ ○ ○ 30 ○ ○ ○ ○ ○

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Meditation, Stress Relief, and Well-Being

Julie Dunlop, MA

As the pace of life increases, stress is becoming endemic, and in the radiologic sciences, stress is keenly felt by technologists and patients. Meditation, a potential remedy to stress, is the subject of an increasing number of medical studies that often rely upon radiologic imaging scans to determine the physiological effects of meditation on brain activity. A wide range of meditation techniques have beneficial effects on the mind, body, and emotions. Radiologic technologists might find that meditation improves their quality of life as well as their level of job satisfaction, allowing them to provide improved quality of care to their patients.

Radiologic technologists work in a fast-paced environment that demands their complete attention to perform tasks quickly, accurately, and with the utmost concern for patient safety. While multitasking is an important and valued skill, there is a point at which too many simultaneous tasks—or even the thought of too many simultaneous tasks—can cause a system overload. In this unrelenting atmosphere, stress and strain can escalate. Add to this the ordinary pressures of life, and the combination is ripe, ironically, for diminishing the health of those who work to maintain and improve the health of others. Ultimately, the cumulative effects of stress on health care providers can have significant impact on patients’ testing experiences and their personal well-being. Reducing the stress levels of health care providers might increase efficiency, reduce burnout, and improve the overall quality of life for health care workers.

After completing this article, the reader should be able to:
- Define stress and burnout.
- Identify causes of stress in the medical imaging workplace.
- List strategies for reducing stress in patients.
- Explain the limbic system’s role in stress and meditation.
- Describe the role of medical imaging in meditation research.
- Discuss medical research about the effects of meditation.
- Describe mindfulness meditation practice and its effects on the body.

Radiologic technologists might experience stress when asked to take on multiple roles because of staff reductions caused by financial cutbacks. This money-saving move can lead to a drop in patient satisfaction and bigger economic woes. Romano explains that if patients are satisfied with the service during a radiologic examination in a low-stress setting, they are more likely to recommend the facility to others. In contrast, those who have a stressful experience will not. Patients’ stress can result from feeling as if their needs are not important to the staff or that they are a burden to the staff.

Beach et al suggest that a mindful approach allows health care providers to enhance patient-clinician communication.

A study of 45 clinicians interacting with 437 patients infected with HIV at 4 clinic sites across the United States found a clear correlation between mindfulness in clinicians and patient satisfaction, as reported in patient...
interviews. The ability to be available (mentally and emotionally) to patients at a time when the health care system is being challenged by increased demands to treat more patients in a day is of great value for radiologic technologists as well. For example, if technologists are experiencing stress or burnout in the workplace, they must change how they manage these common stressors or they could continue the cycle of stress buildup and burnout.

Medicine and meditation have a common root, mederi; the deep Indo-European root of mederi means “to measure.” Medicine restores a body’s disturbed inward measure, and meditation is “the direct perception of right inward measure and the deep experiential knowing of its nature.” Medical studies provide increasing evidence of the ability of stress-reducing approaches, such as meditation, to improve physical and psychological health in patients and health care providers.

**Stress**

While stress is a familiar term, the many psychophysiological aspects of stress are still not fully understood. Stress is brought on by a complex mixture of factors and forces. Long hours, anxious patients, and a demanding work environment are some of these factors. Stress can be described as short-term (acute) or long-term (chronic) and can include positive stress as well as negative stress. Spanning a range of possibilities, stress can be caused by something as common as a life change such as a promotion or job change or as dramatic as an injury or loss of a loved one. In addition, stress can be classified as mental, emotional, physical, financial, or environmental. Depending on the nature of the stressor, specific physiological functions including digestion, excretion, reproduction, and immunity can be affected. When stress is left untreated, conditions such as depression, anxiety, and insomnia might develop.

Butler defined stress as a response to pressure or a response to aversive stimuli and lists Seyle’s description of a general adaptation syndrome in response to stress that includes a 3-stage process:

1. The body is alerted and alarmed.
2. The autonomic system is triggered.
3. The body becomes exhausted.

More recent definitions of stress in clinical practice describe stress as a dynamic process characterized by internal and external factors. In this model of stress as a dynamic process, there is a great deal of diversity in what is perceived as stressful by different people, as well as in the capability to respond effectively to these perceived stressors; however, everyone is exposed to multiple sources of stress.

In addition to the automatic physiological responses to stress, people can experience cognitive effects such as distractibility, deterioration in short-term and long-term memory, increased error rate, and reduced ability to plan and organize. Chronic stress might lead to hyper-vigilance, which results in exhaustion and sometimes periods of denial regarding the effects of the stress. At extreme levels of stress, thought patterns can become irrational, leading to difficulty staying grounded in reality. In addition to cognitive effects, emotional reactions to stress include frustration, anger, anxiety, fear, and irritability. In chronic stress, these emotions can progress to depression, hypochondria, and demoralization; moreover, people might become controlling, indifferent, or have sudden outbursts of emotion.

The cognitive and emotional effects often eventually manifest in behavioral changes, such as diminished enthusiasm at work resulting in increased absenteeism. Stress also can cause changes in eating patterns and use of substances such as caffeine, nicotine, alcohol, and drugs. Speech problems, such as difficulty finding words and muddled articulation, also can occur, and sleep patterns might be disrupted.

Some people under stress will fight, some will flee, and some will feel paralyzed and do nothing at all. Those who fight the stress might do so by adding more responsibilities, further contributing to overload. Those who flee stress through denial often will miss the opportunity to address the causes of stress. However, coping strategies often can exacerbate stress because people choose options for immediate relief rather than long-term solutions.

The cumulative effect of minor stressors can have an erosive result. People might feel they are failures if they admit to being stressed because of the accumulation of many smaller issues instead of a major calamity. Furthermore, events in the past can contribute to a
present state of stress. All these factors require a comprehensive approach to assessing an individual’s stress, including past and present welcome and unwelcome major life changes as well as repetition of minor stressors. Responding to stress before it reaches a state of distress is vital because chronic stress that gets locked into the second stage of Seyle’s model (triggering the autonomic nervous system) can lower a person’s threshold for stress, making recovery slower, so that more than a day or 2 off might be needed to recover. Therefore, it is possible that responding to stress sooner rather than later can prevent physiologically damaging effects from taking hold and avoid a person’s decline into fatigue and demoralization, which requires a more involved recovery.

**Stress and Health Care Providers**

Health care professionals work within challenging environments, and there are high expectations for their performance. Being rushed only adds to the stress level. For decades, the issue of time pressure has been cited as one of the top causes of physician dissatisfaction. In addition, scheduling more than 3 or 4 patient visits per hour can cause a reduction in patient satisfaction as well as in the quality of the visit. While communication techniques can be honed to heighten efficiency of these brief appointments, the general overload and accumulation of being bound by the clock can be an additional causative factor in stress for health care providers, including radiologic technologists.

**Stress and Radiologic Technologists**

Many radiologic technologists must cope with packed schedules, long shifts, and malfunctions of equipment along with the behaviors of stressed coworkers or managers. In addition, they must assist patients, whose stress might affect their ability to follow testing instructions and who might not understand why the technologist cannot share what is seen on diagnostic images. These factors can contribute to frustration, misunderstanding, or even error.

New technology also can be a stressor for radiologic technologists. Having to learn to use new devices and software programs can create resistance simply because the familiar processes are being changed, and as employees they do not have control over these changes. This can be compounded by low levels of computer literacy, lack of sufficient communication and training, and overdependence on the technology. The stress from these changes might be expressed in indirect, rather than direct, ways. For example, apathy or ambivalence can surface when employees outwardly accept the changes in machinery or protocol but were not fully on board with the changes that were imposed on them and their work.

Stress in the radiology department is not limited to any one particular role. Staff technologists experience stress because of busy schedules, new technology, and patient care, while managers encounter additional challenges. DiPaola explained, “In a setting of layoffs, cutbacks, increasing regulation, competition, and patient satisfaction scores, the radiology manager will find it difficult to be free from anxiety.” Reduced flexibility in scheduling and tightened budgets require radiologic technologists to struggle to find time in their off-duty hours to complete continuing education, and managers strive to free their employees’ schedules to allow for training on new or upgraded equipment. Support from managers in scheduling training on new equipment is key to ensuring that staff is highly qualified on an ongoing basis. When technologists’ training is up to date, they can feel confident, less stressed, and provide the highest level of care to their patients.

These financial and managerial issues challenge managers in all fields, but the awareness that patients’ health is directly affected by their decisions and actions magnifies stress for a manager in health care. Indicators of job stress often are physical, such as headache, sleep disturbance, upset stomach, and fatigue; however, they also can emerge as frustration, short temper, anxiety, depression, irritability, apathy, and loss of confidence.

As early as 1992, a survey of 198 radiologic technologists conducted by Sechrist and Frazer found that the top stressors in radiologic technology are:

1. Disrespectful physicians.
2. Inadequate pay.
3. Performing unnecessary examinations.
4. Inadequate numbers of staff.
5. Lack of respect.
6. Abusive patients.
Additional stressors include uncooperative radiologists, overwork, malfunctioning equipment, and work scheduling.9

Stress often can begin for radiologic technologists even before they enter the job market. A 2006 study of students in 2-year community college radiography programs found that students were stressed the most by the following10:

- Fear of making a mistake.
- Feeling unprepared.
- Feeling intimidated by staff or instructors.
- Having difficult or critically ill patients.
- Experiencing hurtful criticism.
- Having too much supervision.
- Receiving negative responses to requests for help.

Four techniques mentioned most often to ease the stress were more frequent feedback, availability of personnel, assurance that mistakes happen, and the opportunity to make mistakes and learn from them. Although the authors note that a follow-up study is needed to further assess these results, their findings suggest that some of the same clinical stressors, such as work overload and lack of respect that radiologic technologists and other health workers encounter, also were experienced by the radiography students in this sample.10

Even when the health care professional is healthy, on-the-job stressors such as an adverse event or medical error can catapult stress levels to a dangerous level. Seys et al pointed out that the organization should provide access to mental health resources and support. They also refer to a study by Engel et al advocating reducing stigmas related to medical errors and the associated shame or loss of respect.11 Engel et al also encouraged development of “error conferences” to discuss errors—even those that did not result in negative consequences—and the impact of the error on patients and other health care professionals.11 Holding an error conference can create a valuable opportunity for learning and might prevent and reduce stress.

In a time when many solutions for day-to-day stress seem to come in the form of innovative technological inventions, it is interesting to consider that an ancient and technology-free method such as meditation could support health care workers in the 21st century.

**Stress and Patients**

Imaging examinations are not a stress-free experience for patients. Obvious stressors are the symptoms that prompted the procedure in the first place and concern about the results, but other factors can come into play depending on the procedure and the patient’s individual situation. The unfamiliar nature of the testing procedure can cause a significant level of anxiety, and the noise of the machines used in testing can put a strain on the nervous system. Enders et al reported that between 1% and 15% of all patients scheduled for magnetic resonance (MR) imaging cannot be imaged because of claustrophobia, and some require sedation to complete the imaging. Approximately 2 million MR procedures worldwide cannot be performed or are prematurely terminated as a result of claustrophobia.12

Lang reported that claustrophobia, panic, or other factors that interfere with a patient’s ability to remain still prevent an estimated 2.3% of patients from completing MR scans, resulting in losses of hundreds of thousands of dollars.13 In addition, anxiety caused by fear of the results often creates more stress for patients than the procedure. Lang’s study measured the distress level of 214 women in a radiology waiting room and found that those patients awaiting breast biopsy had a much higher degree of anxiety and perceived stress than those awaiting a chemoembolization for liver cancer.13

Practices for anxiety relief, such as breathing and relaxation techniques, visualization, and mental exercises, have been shown to reduce stress for patients undergoing an MR scan.13 These practices echo the earlier but often unknown use of relaxation and hypnotic techniques used primarily with MR in the 1980s.13

**Pediatric Patients**

Children might express stress through crying, fear, and lack of cooperation. Radiologic examinations can be a difficult experience for children because of the unfamiliar sounds of the equipment, uncomfortable positions, and sometimes painful procedures.14 The use of devices for immobilization, such as the Pigg-O-Stat, can be distressing to parents, and procedures such as the voiding cystourethrogram can be distressing for children. In addition, the needle sticks used in lumbar punctures, cardiac catheterization, and contrast-enhanced MR or computed
Tomography (CT) scans can be painful for children. Current methods used in pediatric radiology departments to reduce stress include:

- Parental involvement.
- Preprocedural preparation.
- Distraction.
- Sedation.
- Involvement of a child-life specialist.
- Hypnosis.
- Consideration of the child’s sense of modesty.
- Positive reinforcement.

Although current methods don’t involve meditation, perhaps some form of meditation will be used for these patients in years to come.

Reducing Patient Stress

Radiologic technologists often are the only health care professionals to interact with patients undergoing medical imaging. Media coverage of radiation concerns and the wealth of information available online might cause patients to have fear and anxiety. The radiologic technologist should be equipped to answer patients’ questions and demonstrate current knowledge related to their concerns so they can calm patients and acquire accurate diagnostic images. Romano suggests that technologists maintain eye contact, show a caring attitude, and provide detailed explanations of procedures to increase patients’ trust in the medical care they are receiving. Studies indicate that when health care providers are able to exude a caring attitude to patients, patient satisfaction increases, which decreases patient stress. One method of expressing care is listening carefully, answering questions, and providing clear information. Offering educational resources and support services also can help in reducing long-term stress for patients. In the midst of a packed schedule, it might be easy to forget that each interaction with a patient has potential for healing, and it is not only the diagnostic quality of the images that matters. According to Adams and Rush, caring radiologic technologists could inspire patients to take better care of themselves, which can lead to patients’ increased compliance with diagnostic and treatment regimens because of an improved sense of self-worth.

Patients or the parents of pediatric patients also might harbor unexpressed anxiety because of the potential for exposure to radiation during imaging scans. Technologists can reduce radiation dose by shielding sensitive areas, such as the thyroid and gonads. Reducing exposure time and beam intensity, collimating properly, and avoiding repeat imaging scans also can reduce patient dose. Taking time to explain to patients the benefits of shielding to reduce patient exposure to ionizing radiation can help diminish their anxiety.

Although sedation can be used to calm some patients undergoing imaging tests, there are additional issues and complications that can result from this approach. For example, in the MR suite, extra time, effort, and additional staff are required to check for compatibility between sedation equipment and monitoring devices and the magnetic field and radiofrequency emissions. In addition, sedation can cause some patients to experience complications such as vomiting, apnea, hypoxia, and the need for assisted ventilation. Furthermore, if sedation is inadequate, the procedure might be cancelled and the patient might need to make additional hospital visits.

Hypnosis has shown success as a nonpharmacological approach to stress reduction for pediatric patients in radiology as well as emergency medicine. A study by Butler et al of pediatric patients who previously had a distressing experience with a voiding cystourethrogram procedure and then were provided hypnosis for a subsequent voiding cystourethrogram procedure “showed significant improvements in stress compared to the previous procedure. Parents reported that undergoing the procedure with hypnosis was significantly less traumatic for the child.” Using hypnosis to reduce distress has been helpful for pediatric patients undergoing radiologic tests, and meditation has potential to provide similar benefits as well.

In 2013, Zeidan et al suggested that mindfulness meditation can reduce anxiety and is demonstrated by activation of the anterior cingulate cortex, ventromedial prefrontal cortex, and the anterior insula. This study used MR imaging to compare the brain region activity of participants who received four 20-minute sessions of mindfulness training to those who had not been trained but were paying attention to their breath. Those who received training in mindfulness (observing the breath,
noticing thought patterns, returning to the breath) experienced diminished states of anxiety, as measured by cerebral blood flow.\textsuperscript{16}

Thus, the fear of the unknown weighs heavily on people and can manifest in measurable anxiety in patients waiting for a radiologic examination. One study found that when radiologists shifted their language to neutral terms, such as “I will give you the local anesthetic,” vs terms that suggest discomfort, such as “Just a sting and a burn,” they significantly reduced patient anxiety. Similarly, radiologic technologists could potentially reduce patient anxiety by explaining to patients which procedure will come next and how long the patient will need to hold a position during an imaging examination. Increasingly, medical institutions are providing alternative approaches to respond to the public’s interest in these methods. Within the radiologic technology profession, one study found that “many MRI patients combatted anxiety on their own using breathing and relaxation techniques, visualizing pleasant scenes, and performing mental exercises.”\textsuperscript{17}

**Burnout**

The medical profession draws highly intelligent, motivated, and caring individuals who often find themselves experiencing increased stress on the job. High expectations, a high level of competition, the emotional nature of the work, and the relentless pace contribute to burnout in health care workers. Burnout is a psychological state of physical and emotional exhaustion and is a result of prolonged occupational stress.

According to a 2002 study by Akroyd et al, radiographers experience higher-than-average levels of emotional exhaustion as measured by the Maslach Burnout Inventory (MBI). The study compared the results to data on other health professionals and national norms. Nurses who worked with certain patient populations had higher levels of burnout, but burnout in radiographers was at a similar level with nurses in general.\textsuperscript{18,19}

The MBI is a survey tool originally designed for use by professionals working in human services such as health care; it has been adapted for use by educators and workers in other occupations. The survey measures emotional exhaustion, depersonalization (treating people as objects), and personal accomplishment at work.\textsuperscript{20}

Technologists’ ongoing interaction with patients presents emotional challenges for technologists who want to offer patients support while simultaneously maintaining professional boundaries.

Another contributor to burnout in health care professionals is irregular scheduling, which can create or exacerbate stress. Eldevik et al cited the negative physical and emotional effects that can result from shift work, irregular hours, and quick returns (short breaks) in their study of nurses having fewer than 11 hours between shifts. Effects such as anxiety, insomnia, and fatigue can result, as well as shift work disorder.\textsuperscript{21} Shift work disorder is characterized by\textsuperscript{22}:

- Excessive sleepiness.
- Insomnia.
- Difficulty concentrating.
- Fatigue.
- Irritability or depression.
- Difficulty with personal relationships.

In Europe and the United States, shift work has been associated with increased incidences of cancer, gastrointestinal disorders, rheumatoid arthritis, and other health issues.\textsuperscript{21}

Radiologist and former Stanford Medical School professor Peter Moskowitz, MD, is an advocate for health care professionals. After coping with the results of his own work-related stress and how it affected his family, he founded the Center for Professional and Personal Renewal. Moskowitz noticed how prolonged and untreated chronic irritability or personal conflicts at work can manifest physically as hypertension and gastrointestinal disorders, as well as symptoms of coronary distress.\textsuperscript{23} According to John-Henry Pfifferling, the founder of the Center for Professional Well-Being, although stress has always been a part of working in medicine, a disconnect between expectations and reality is growing, with a resulting shift in what is considered to be an acceptable level of stress, leading to “emotional exhaustion.” Ahnna Lake, MD, a senior associate at Pfifferling’s center, describes a “depletion syndrome” in which, starting in college, health care professionals push themselves, often staying up all night more than once a week, and this intensifies at the professional level where they often can feel like they are weak if they acknowledge the limits of their body.\textsuperscript{23} Larry Vickman,
MD, noted that interventions for burnout by colleagues or family are rare, and usually care is sought only when the issues have become so extreme that they jeopardize patient care. Prior to the point of crisis, physicians and other health care professionals might use coping mechanisms such as overeating, substance abuse, gambling, and extramarital affairs, while further along the continuum they might exhibit depression, reduced attention span, and an inability to concentrate and work effectively.\textsuperscript{23}

Burnout also affects radiologic technologists. In 2002, Akroyd et al surveyed more than 2000 full-time staff radiographers and found that “radiographers had significantly higher levels of emotional exhaustion when compared with the MBI norms.”\textsuperscript{19} Emotional exhaustion can have “detrimental effects on patients and employee morale”\textsuperscript{19}; however, this study found that radiographers were still able to “view their patients with a positive and caring attitude.”\textsuperscript{19} The authors also compared radiographers to radiation therapists and found that radiation therapists experienced higher levels of emotional exhaustion and depersonalization. They noted this difference might be caused by the type of care that radiation therapists provide and the types of patients they treat.\textsuperscript{19} Chronic high levels of stress without intervention can lead to depression, frustration, and job dissatisfaction.\textsuperscript{24}

**Coping with Burnout**

Health care professionals clearly need stress prevention as well as treatment for stress and burnout. To cope with stress and burnout in positive ways, radiologic technologists can\textsuperscript{25}:

- Rest, relax, and reconnect with family.
- Reassess purpose and values.
- Exercise, have fun, and eat a healthy diet.
- Get sufficient sleep.
- Praise coworkers for a job well done.
- Cultivate friendships outside of the medical field.

Managers can help by reassuring staff of their worth, such as honing radiographers as valuable members of a work team through formal awards and ceremonies or informal ways through praise. Managers also can provide guidance as sources of knowledge, advice, expertise, and social support to mitigate burnout. Keeping watch over employees’ workload can help reduce burnout because, for radiographers, an increased workload is related to an increase in burnout.\textsuperscript{19} Oore et al found that workshops to enhance civility were shown to improve colleague relations, help patients, and improve patient care and safety.\textsuperscript{24}

It also has been shown that short-term intervention programs for health care professionals can have long-term benefits. One 8-week intervention program that offered training in mindfulness (body scans, sitting meditation, walking meditation, and mindful movement) for primary care physicians resulted in short-term and long-term improvements in the physicians’ well-being and their attitudes associated with patient-centered care.\textsuperscript{25} Body scans are simply the act of “noticing bodily sensations and the cognitive and emotional reactions to the sensations without attempting to change the sensations.”\textsuperscript{25} In their study of internists, Krasner et al found that physicians “being present” with their patients “correlated more strongly with finding meaning in their work than diagnostic and therapeutic triumphs.”\textsuperscript{23} Being present meant understanding that their patients were unique individuals and fellow humans and that the physicians had “an awareness of the patients’ (and their own) emotions,” which are often experienced during difficult clinical situations.\textsuperscript{25}

The mindfulness practice of scanning the body has clear parallels to the technological scans that radiology professionals use on a regular basis. It is possible that visualizing the internal anatomy while performing a mindfulness body scan can assist health care professionals with becoming more aware of sensations such as physical tension, aches, and strains that accumulate from work-related (or personal) stress. Krasner et al stated that “[s]elf-awareness can assist practitioners in becoming more attentive to the presence of stress, to their relationship with the sources of stress, and to their own personal capacity to attenuate the effects of stress.”\textsuperscript{25}

As health care providers and health care organizations seek ways to address employee burnout, meditation might be an avenue to explore. While radiology has long been associated with diagnosis of pathology, newer and more subtle capabilities of technology allow the detection of healing potential in the brain via imaging. In fact, Sato et al reported that people who meditate can be identified by brain scans alone 94% of the time.\textsuperscript{26}
Anatomy and Physiology of the Brain

To understand the findings of recent studies that examine meditation’s effects on the brain, it is necessary to understand the complex terrain of this organ, specifically the limbic system, which includes the amygdala, the diencephalon, the hypothalamus, and the hippocampus (see Figure 1).

The term **limbic system** derives from the word *limbus* meaning “ring” because its cerebral structures encircle the upper part of the brain stem. It is located on the medial aspect of each cerebral hemisphere and diencephalon and includes part of the rhinencephalon (septal nuclei, cingulate gyrus, parahippocampal gyrus, dentate gyrus, and C-shaped hippocampus), as well as part of the amygdala. The main limbic structures in the diencephalon are the hypothalamus and the anterior nucleus of the thalamus. Two parts of the limbic system that have a primary connection to our emotions are the amygdala and the anterior cingulate gyrus. The amygdala, an almond-shaped set of neurons deep in the medial temporal lobe, is part of the limbic system and is associated with the emotions; conditions such as anxiety, depression, and post-traumatic stress disorder have been linked to abnormal functioning of the amygdala. When an individual encounters a stressor such as physical danger, information travels via the eyes and ears to the amygdala for emotional processing of the sights and sounds. If a threat is perceived, the amygdala sends a distress signal to the hypothalamus.

At the core of the forebrain and between the cerebral hemispheres lies the diencephalon, which consists primarily of 3 paired structures: the thalamus, hypothalamus, and epithalamus. These are areas of gray matter that enclose the third ventricle of the brain. The hypothalamus lies beneath the thalamus and atop the brain stem, extending from the optic chiasma to the posterior margin of the mammillary bodies. The hypothalamus is imperative to the overall homeostasis of the body and influences nearly all tissues in the body. Its key functions of homeostasis include: autonomic control center, center for emotional response, body temperature regulation, regulation of hunger and satiety, regulation of water balance and thirst, regulation of sleep-wake cycles, and control of endocrine system functioning. The hypothalamus communicates with the autonomic nervous system and, during stress, activates the sympathetic nervous system. In turn, the sympathetic nervous system activates the adrenal glands, releasing epinephrine (commonly known as adrenaline) into the bloodstream, triggering physiological changes such as increased pulse rate, increased blood pressure, highly activated sensory perception, and release of glucose. Marieb explained that the hypothalamus is the “neural clearinghouse for both the autonomic (visceral) function and emotional response”; therefore, when people are exposed to acute or chronic emotional stress, they can develop “visceral illnesses, such as high blood pressure and heartburn.”

The hippocampus is a horseshoe-shaped paired structure in the limbic system associated with memory, emotion, and spatial orientation. Stress has significant effects on the hippocampus through adrenal steroids and excitatory amino acids. Stress also causes hippocampal neurons to retract.

**Figure 1. The limbic system.**
**Default Mode Network**

The term *default mode* was first used in 2001 by Martin Raichle, MD, to describe resting brain function. Essentially, waves of electricity associated with an MR signal can be seen on a functional magnetic resonance imaging (fMRI) scan when the patient is in resting mode. When these waves are synchronized, functional connectivity can be determined; this means that parts of the brain that are far apart can be in synchrony as a result of receiving signals from a specific region of the brain. “The default mode network (DMN) involves low frequency oscillations of about one fluctuation per second. The network is most active when the brain is at rest, but when the brain is directed toward a task or goal the default network deactivates” (see Figure 2).³²

The DMN might actually include many smaller networks. In the past 10 years, increasing attention has been focused on understanding networks in the brain, such as the DMN, that are related to specific activities. The DMN comprises the medial temporal lobe, the medial prefrontal cortex, and the posterior cingulate cortex, as well as the ventral precuneus and parts of the parietal cortex. Although the complexity of the DMN makes it difficult to study, abnormalities in the network, such as increased or reduced activity, have been linked to many diseases, including Alzheimer disease, schizophrenia, autism, bipolar disorder, and depression.³³ The DMN also has shown aberrations in the resting state of patients with post-traumatic stress disorder, suggesting that it can indicate particular forms of stress.³³

**Meditation Research**

**Radiology’s Role**

Radiology’s initial purpose was to aid in the diagnosis of pathology. Today, medical imaging continues to assist in diagnosis in increasingly sophisticated ways, and it also is being used to document brain changes that occur from meditation practice. The diversity of meditation techniques and traditions can support as well as impede neuroscience research on meditation. For example, the fact that so many different techniques have produced measurable changes in neurological images supports the correlation between meditation and physiological response, yet the diversity of meditation techniques also can make interpretation of results difficult. Even so, many medical researchers have documented a correlation between meditation and the functioning of specific regions of the brain using medical imaging.

Functional MR imaging measures brain activity by detecting changes in blood flow and oxygenation that occur during neural activity. When used to assess brain activity in experienced and novice meditators who practiced 3 different meditation techniques, fMRI showed that regardless of the type of meditation, decreased activity was seen in the brain’s DMN associated with attention lapses and disorders like anxiety, attention deficit hyperactivity disorder, and buildup of beta amyloid plaques linked with Alzheimer disease.³⁴
Proton magnetic resonance spectroscopy can detect and measure metabolite concentrations in the brain, and diffusion tensor imaging can be used for functional anatomy mapping of the brain.\textsuperscript{35,36} Using these modalities, Fayed et al found that meditation results in higher myoinositol, a sugar alcohol compound that might act as an osmoregulator, intracellular messenger, and detoxification agent in the posterior cingulated gyrus, as well as decreased glutamate, N-acetylaspartate, and N-acetylasparate/creatine in the left thalamus. N-acetylasparate, one of the most abundant amino acids in the central nervous system, is found most commonly in neurons, axons, and dendrites. Glutamate is one of the most commonly evaluated metabolites in magnetic resonance spectroscopy, and creatine, the most stable cerebral metabolite, is used as an internal reference value.\textsuperscript{37}

The Fayed study compared results from MR imaging, proton magnetic resonance spectroscopy, diffusion-weighted imaging, and diffusion tensor imaging from 2 groups: hospital staff who had no meditation experience and Zen Buddhist monks. The authors concluded that MR spectroscopy and diffusion tensor imaging are “excellent tools for examining training-related plasticity and the neural mechanisms underlying meditation” and that long-term meditation modifies the white fiber microstructure and resting state regional neural activity.\textsuperscript{37}

The concept of neuroplasticity suggests that brain functions are malleable and can improve over time. Medical imaging is at the forefront of documenting these capabilities using scientific methods, and advances in CT and positron emission tomography (PET) “make it possible to physically observe how the brain works and how the neural pathways in the brain change.”\textsuperscript{38} Increasingly, neurological imaging, such as single-photon emission CT, PET, and fMRI, is being used to pinpoint the regions of the brain that are activated and deactivated through meditation.\textsuperscript{39} According to Fayed et al, these areas include the anterior cingulate cortex, posterior cingulate cortex, medial prefrontal cortex, insula, temporoparietal junction, hippocampus, and amygdala.\textsuperscript{37}

A recent meta-analysis of 123 brain morphology differences from 21 neuroimaging studies examining approximately 300 meditators, found 8 brain regions to be consistently altered as a result of meditation: areas of meta-awareness (frontopolar cortex), areas of exteroceptive and interoceptive body awareness (sensory cortices and insula), areas of memory consolidation and reconsolidation (hippocampus), areas of self and emotion regulation (anterior and midcingulate, orbitofrontal cortex), and areas of intra- and interhemispheric communication (superior longitudinal fasciculus, corpus callosum).\textsuperscript{40}

Furthermore, Cohen et al performed pre- and post-program baseline single-photon emission CT scans of the right and left dorsal medial frontal lobes, right prefrontal cortex, right sensorimotor cortex, and right frontal lobe in 4 subjects who underwent a 12-week iyengar-style yoga program with meditation.\textsuperscript{41} Iyengar-style yoga is a form of hatha yoga that focuses on the alignment of the body as well as regulation of the breath.

The authors found that all areas were activated more significantly after the meditation training than they were before the training (see Figure 3). The connection of amygdala and sensorimotor cortex to emotions and perception of sensory data and the baseline changes are consistent with other clinical studies that have shown meditation improving emotional responses and depression, as well as affecting perception of sensory stimuli. Although this was a limited study of 4 individuals with stage 1 hypertension, the results of increased cerebral blood flow can perhaps be expanded upon in a future study.\textsuperscript{42} Cohen et al noted that the diversity and complexity of meditation techniques can lead to possible confusion when comparing results of studies related to meditation; however, Schoormans and Nyklicek suggest that the frequency rather than the type of meditation may be what matters most.\textsuperscript{42}

One form of meditation studied by Kalyani et al is the practice of chanting. Functional MR scans have shown that chanting Om was shown to deactivate limbic regions—an effect similar to vagal nerve stimulation. Vagal nerve stimulation has been used to treat depression and epilepsy, suggesting a positive effect from chanting on behavior and mood. For example, PET imaging has shown decreased blood flow to limbic brain regions during direct vagal nerve stimulation as a result of meditation. In the study by Kalyani et al, subjects performed 10 cycles of resting for 15 seconds,
followed by chanting *Om* for 15 seconds, followed by resting for 15 seconds. Blood oxygenation level-dependent scans showed significant deactivation in the orbitofrontal, anterior cingulate cortex, parahippocampal gyri thalami, hippocampi, and right amygdala in comparison to the resting brain state.  

Newberg et al also conducted an 8-week study of the effects of chanting *Sa Ta Na Ma*, a Kirtan Kriya meditation (chanting), for 12 minutes daily. They found that this form of meditation has the potential to improve memory, which could have significant benefits for patients with Alzheimer disease and also could hold value in stress relief because reduction in short-term and long-term memory can result from chronic stress. This meditation technique resulted in improved cerebral blood flow in the prefrontal, superior frontal, and superior parietal cortices, as demonstrated by a single-photon emission CT scan, as well as improved verbal fluency and memory, as measured by neuropsychological tests.  

Meditation also can be practiced silently. Though often the term *mantra* is associated with specific cultural and spiritual phrases, it can refer to any word or phrase that is repeated. In this study, the neutral phrase “table and chairs” was used during silent repetition to prevent an emotional response from the words. Subjects meditated and silently repeated the given phrase as indicated while in the MR scanner. In this study of subjects with less than 2 years of meditation experience, Engstrom et al used fMRI and demonstrated that activation of the hippocampi, regions of the brain related to memory, occurs during silent mantra meditation practice (see Figure 4). This finding also has been shown in previous studies with experienced meditators. Engstrom et al noted that the role of hippocampal activity needs to be further clarified in future studies.  

The technological advances of medical imaging and the emerging patterns documented by researchers about the efficacy of meditative practices are aiding scientific understanding of the healing properties of meditation.  

**Medical Research**  
There is a growing body of medical research aimed at understanding the specific effects of meditation in areas such as cognition, pain control, management of disease symptoms, emotion, and behavior. A review of research on mindfulness by Jeffrey Greeson in 2009 indicated that mindfulness is associated with more positive states of mind and can benefit the brain, the autonomic nervous system, stress hormones, and the immune system, as well as improve behaviors related to health, including eating, sleeping, and substance abuse.  

Chung et al studied the effect of *Sahaja* yoga meditation on aspects of participants’ quality of life,
anxiety, and blood pressure. Participants were divided into 2 groups: 67 in the meditation group and 62 in the control group. The participants in the control group had not practiced meditation for at least 3 months prior to the study. The meditation group followed a daily schedule of individual and collective meditation throughout each day and showed significant improvements in all areas after one week of the regimen. Moreover, the control group had greater anxiety, a decline in quality of life, and no improvement in blood pressure after 2 weeks. The authors concluded that even a short-term treatment of 1 to 2 weeks can yield measurable improvement (see Figure 5). “

Similarly, Geary et al reported that an 8-week MBSR course decreased stress in academic health care employees, citing psychoneuroimmunological benefits sustained for at least one year as charted by biomarkers such as pulse rate variability and a series of questionnaires assessing self-report measures of stress. “ MBSR teaches participants to pay attention through meditation practices such as yoga, walking and sitting meditation, and mindfulness in everyday activities; the essence of these activities is living in the moment and being open to change, which equips people to cope with the unexpected changes in their personal and professional lives.

The results of the 2012 National Health Interview Survey (the most current, comprehensive, and reliable source of information on the use of complementary health approaches by U.S. adults and children) suggest that “:

- Approximately 21 million adults (nearly double the number from 2002) and 1.7 million children practiced yoga.
- Nearly 20 million adults and 1.9 million children had chiropractic or osteopathic manipulation.
- Nearly 18 million adults and 927 000 children practiced meditation.
- The increase in yoga has occurred across all age, racial, and ethnic groups.

The high rates of use might be partly due to a growing body of research showing that some mind and body practices can help manage pain and reduce stress.

Another study of the effects of meditation using chanting focused on caregivers of family members.
with dementia. Chanting *Sa Ta Na Ma* for 12 minutes a day for 8 weeks lowered stress and improved cognitive function, as measured by the Hamilton Depression Rating Scale and the Mental Health Composite Summary score. The authors also measured telomeres, the “caps” at the end of DNA strands that protect chromosomes. Telomeres affect how human cells age and have been identified as psychobiological markers for psychological stress. Telomerase is an enzyme that prevents the shortening of telomeres. Shortened telomeres are associated with health risks and premature mortality. In this study, telomerase activity increased. This was the first study to show an effect on telomerase dynamics levels in distressed caregivers who practiced *Kirtan Kriya* meditation.

### Mindfulness Meditation for Stress Relief

While some consider mindfulness training to be separate from meditation, the term and practice called *mindfulness meditation* merges the 2 approaches, suggesting that they are, at times, intrinsically related. Beach explained that mindfulness is “attentiveness, curiosity, presence, and the ability to adopt multiple perspectives simultaneously—all qualities that promote greater awareness of self and others.” Mindfulness training teaches skills to lower an individual’s reactivity and improve responses to stressful situations. Moreover, mindfulness might free clinicians’ attention so that they are better able to attend to others’ experience, less likely to distance themselves from distressing situations, and more likely to consider a variety of explanations in complex situations.

According to Newberg et al, “[m]editation, in general, is a complex neurocognitive task that is often associated with alterations in the brain physiology and neuropsychological measures.” Contributing to the complexity are the many forms, definitions, and techniques of meditation. Some of these techniques are the ancient Buddhist tradition of *Vipassana* (menthal training),
chanting *Om*, repeating mantras silently, focusing on the breath, and even mindfulness-based stress reduction courses. Some forms of meditation include movement, usually walking.

The diversity of meditation techniques often makes it possible to match a meditation technique with an individual’s cultural and religious preferences and physical abilities. For example, the University of California, San Francisco offers a 4-step meditation technique to breast cancer patients (see Box 1). Mindfulness meditation helps the individual focus on being in the moment instead of dwelling on the past or thinking about the future. It slows down the body and the mind and temporarily removes the temptation to react to our surroundings.

The Mayo Clinic offers guidance on a range of meditation techniques including mindfulness meditation, guided meditation, yoga, Qigong, and tai chi, stating that the most common elements of meditation practices are focused attention, relaxed breathing, a quiet setting, and a comfortable position. Suggested approaches include breathing deeply, scanning the body for sensations of temperature and touch, repeating a prayer or mantra, walking, reflecting upon poems or sacred texts, and focusing on love and gratitude. The benefits range from reduced stress to increased self-awareness and improved management of symptoms of asthma, heart disease, and cancer. However, the National Center for Complementary and Alternative Medicine has stated that there have been “rare reports” that meditation might worsen symptoms in people who have certain psychiatric problems, but that these claims have not been fully researched. Hickey stated that although “meditation may not be sufficient or appropriate for some people (eg, those suffering from severe post-traumatic stress, major depression, or psychosis), mindfulness, in conjunction with medication, does seem to be helpful to those who have difficulty regulating their emotions.” Nevertheless, those who wish to start a meditation program should consult with a health care provider about their condition before beginning.

Because a medical imaging test can create anxiety in patients for days leading up to the examination, the Cancer Support Community of Philadelphia has found that cancer patients benefit from classes that teach deep breathing to cope with uncertain futures. They also teach patients that learning to control their thoughts and accept their emotions can reduce the stress associated with radiological tests and related diagnoses and prognoses. In addition, a controlled study of 90 patients who meditated for 7 weeks yielded a 65% reduction of mood disturbance episodes and 31% reduction in stress symptoms.

Patricia Ann Sealy, RN, suggested that autoethnography, a written narrative that focuses on the universal emotions of loss, grief, shame, fear, and anxiety, can be combined with meditation to provide deep healing when a health care professional encounters illness or trauma. Healing from these personal sources of stress can allow health care professionals to support their patients instead of being triggered into reactivity when a patient issue, or stress in general, brings an unresolved emotional experience to the surface. Meditation can promote emotional healing if people can find ways to integrate understanding and self-compassion with past wounds. Meditation, therefore, moves healing beyond what the brain can think itself through, offering a pathway for stress relief that does not depend solely upon intellect and logical thinking but instead offers a holistic integration of the body’s most subtle resources.

However, in addition to being used as treatment, meditation also can be used as a preventive approach to stress. Mohan et al studied a group of young men who had never meditated. They were provided 20 minutes of instruction and 20 minutes of practice prior to interacting with a stressor. Measurements of their stress included:

**Box 1**

**The Process of Meditation**

1. Posture — Find a comfortable posture, sitting or lying down.
2. Begin to meditate — Observe the details of your body, such as the soles of your feet touching the floor and your spine against the back of the chair.
3. Focus on breathing — Notice your breath as it moves through your nostrils, as it rises and falls in your body.
4. Work with the mind — Watch the movement of your mind. If your thoughts have moved away from the breath, notice that, and again return the focus to the breath.
Galvanic skin response – evidence of a person’s emotional state as measured by changes in perspiration and electrical resistance of the skin.\(^{57}\)

Heart rate – the release of adrenaline causes the heart rate to increase.\(^{58}\)

Electromyography – records muscle activity, which is elevated during stress.

Sympathetic reactivity – the responses of glands, smooth muscle, and cardiac tissue during stress.\(^{57}\)

Cortisol levels – the release of cortisol during stress increases glucose levels in the blood.\(^{57}\)

Acute psychologic stress scores – assesses mental and emotional stress.\(^{57}\)

Wechsler memory scale – a neuropsychological test to measure memory function, which can be affected by stress.\(^{57}\)

Visual-choice reaction time – measures the time required for an individual to make a choice based on visual input.\(^{59}\)

The authors found that meditation prior to a stressor more effectively reduced the stress levels of subjects than did meditation after the stressor.\(^{57}\) Although it seems that benefits might not be available in a short-term meditation program for those who have never meditated, Manzaneque et al found incidences of hormonal regulation and decreases in depression and anxiety from a 2-month study in individuals who had never meditated.\(^{60}\)

Some might resist implementing a meditation program because of the need for preparation and resources of time and money. However, Prasad et al, who designed a “dose-ranging feasibility study,” concluded that one dose (one introduction session) plus 4 weeks of 30-minute-per-day practice of meditation was sufficient to reduce anxiety and perceived stress and to improve perceived quality of life.\(^{61}\) Therefore, considering the low cost, the small amount of time required, and the documented potential for positive behavioral, mental, and emotional benefits, encouraging meditation practices might relieve patients’ stress and reduce staff burnout and employee turnover.

As health care professionals work to keep up with ever-increasing demands on their time and attention, meditation might provide an inexpensive treatment with a beneficial return in increased concentration and cognitive abilities. Zeidan et al conducted a study in which participants completed four 20-minute sessions of meditation training. Using the State Anxiety Inventory, they found that anxiety was reduced: “20 min of meditation reduced anxiety by as much as 22% in healthy subjects.”\(^{16}\) Zeidan et al postulated that “if the benefits of mindfulness meditation can be realized after a brief training format, then patients might feel more inclined to continue to practice and clinicians may not feel as reluctant to recommend mindfulness meditation to their patients.”\(^{16}\)

In addition to short-term benefits to cognition, the accumulation of meditation practice has the potential to increase brain activation in areas connected with response inhibition and attention while decreasing activity in regions associated with discursive thoughts and emotions, which suggests that meditation might increase a person’s ability to resist inappropriate actions and focus better. In a study by Brefczynski-Lewis et al, brain activity in experienced meditators was compared to that of novice meditators. The brains of experienced meditators showed greater activation in the areas related to response inhibition and attention, such as the frontoparietal regions, the cerebellar, temporal, and parahippocampal regions, and the posterior occipital cortex. Furthermore, the authors suggest that meditation might strengthen a person’s self-control, especially “cognitive and emotional mental processes such as rumination that can lead to or exacerbate stress, anxiety, or depression.”\(^{62}\)

Hasenkamp and Barsalou examined how meditation assists with problems such as mind wandering, awareness of mind wandering, shifting attention, and sustained attention. The ability to sustain attention and reduce mind wandering can benefit radiologic technologists and all health care professionals. In this study, fMRI was used to measure the neural activity in those participating in focused attention meditation. Specifically, researchers considered how meditation affects functional connectivity in the default mode network and other attention networks associated with mind wandering. Those with experience in meditation showed increased connectivity within attentional networks, as well as between attentional and medial frontal regions. The researchers pointed out that the study was
small and the results could have multiple causes, but they noted growing evidence for neuroplasticity, with benefits in connectivity associated with meditation that could yield cognitive, behavioral, and emotional gains.63

Of particular relevance to the field of radiology is a study of perceptual motor awareness by Naranjo and Schmidt who found that an 8-week mindfulness-based stress reduction program resulted in slower motions, as well as increased accuracy in motions. This hand movement study extends the studies of meditation beyond its cognitive and emotional benefits to examine visuo-motor and sensorimotor performances.64 Radiologic technologists rely on the stability and accuracy of their hands in positioning patients and using equipment to procure accurate images; thus, meditation might help improve accuracy of motion while performing radiologic examinations.

Meditation can have other physical benefits for patients besides stress relief, including pain relief, immune system support, increased concentration, and perceptual motor awareness (see Box 2). Because pain relief is one of the leading reasons Americans turn to complementary health approaches such as yoga, massage, and meditation, the National Center for Complementary and Integrative Health has made it a priority to study these complementary approaches to managing pain and symptoms not consistently addressed well by drugs and other conventional treatments.48

**Neuroscience Offers Hope**

Scientific studies repeatedly show reduced activation in brain regions of interest as a result of meditation, suggesting that meditation has healing effects regardless of a person’s cultural, religious, or spiritual background. Given the complexity of biomarkers as well as the complex nature of stress itself, Halsband et al suggested that stress hormones and neurotransmitters could be used in conjunction with imaging tests to document and illustrate the effects of meditation on the brain. In addition, they suggest that a blend of PET and fMRI, along with electroencephalography/magnetoencephalography, might be useful in measuring regional activation effects in the brain.73

Additional research is needed to further corroborate initial findings on meditation research, to understand more fully how meditation affects the brain, and to point out gaps or inconsistencies in previous studies. Hickey notes a need for increased funding for research and expansion of definitions in the realm of imaging scans so that reference to a typical brain scan accounts for variables of race, gender, age, and left-handedness, which can produce differing results. Other factors to consider include the time of day scans are performed, recently ingested substances such as caffeine and nicotine, the variation in colored images of scans, and small sample sizes due to the expense of imaging technology.74

Although meditation might seem too intangible to have merit in the medical profession, research suggests otherwise. Furthermore, in 2014, the National Institutes of Health renamed the National Center for Complementary and Alternative Medicine to the National Center for Complementary and Integrative Health. The integrative approach to health has continued to grow in the United States in facilities such as hospitals, hospices, and military health settings, and the center’s research priorities include meditation and other therapies such as spinal manipulation and massage to manage pain and other symptoms not always sufficiently addressed by conventional treatments.74 The Center lists meditation as one of its research priorities, which indicates that medical research has substantiated the value of this modality as worthy of federal dollars, and the Center’s name change suggests that approaches such as meditation will be increasingly integrated into the health care system.

**Conclusion**

The cartography of the brain is a work in progress. While the brain’s structures have been mapped for decades, much is unknown about neural circuitry, communication between regions of the brain, and communication between the environment and the brain. The radiologic sciences are at the forefront of using neuroimaging to reveal evidence of a cause-and-effect relationship between meditation and brain health. With much of the research on meditation focused on its effect on patients, the effect of meditation on health care professionals is poised for further exploration. It would be interesting to examine, for example, MR scans of health care professionals who meditate regularly, as well as their perceived stress levels.
### Additional Benefits of Meditation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Research</th>
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<tbody>
<tr>
<td>Cardiac problems</td>
<td>A 2009 study examined the potential for a meditation-based stress management intervention to reduce depression, hostility, anxiety, and perceived stress, all of which can be precursors or risk factors for adverse cardiac events. The intervention program introduced participants to guided seated meditation, guided body scan meditation, and mindful Hatha yoga. In addition, participants were encouraged to remain aware of informal practices (eg, remaining aware of cooking while cooking, walking while walking, showering while showering) and meditate daily for 20 minutes. Hostility and anxiety were not statistically affected during the 4-week study, but depression and perceived stress were reduced significantly. Thus, meditation-based stress reduction might have a positive impact on psychological health that could reduce the progression of coronary heart disease.</td>
</tr>
<tr>
<td>Chronic illness</td>
<td>In a study by Pritchard et al, 12 patients with multiple sclerosis and 10 cancer participated in 90-minute Yoga Nidra (meditation and deep relaxation) classes for 6 weeks. Participants’ stress levels were measured by the Perceived Stress Scale, an instrument that has been successfully used to assess stress in patients with multiple sclerosis and cancer, through noninvasive, low-cost means. The authors found a reduction in participants’ stress levels after the program and concluded that the Yoga Nidra exploration of sensations, emotions, and thought patterns can be especially helpful to those experiencing chronic pain and trauma.</td>
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<tr>
<td>Chronic pain</td>
<td>In one study, a heat device was used to induce pain response in 15 volunteers. With just 80 minutes of meditation (4 sessions of 20 minutes each), the volunteers experienced pain reductions of 11% to 93%. Meditation increased activity in the anterior cingulate cortex, anterior insula, and orbitofrontal cortex. These areas influence how the brain creates an experience of pain from nerve signals coming into the body. Pain sensation was reduced as meditation stimulated these areas, suggesting that meditation can relieve stress associated with pain.</td>
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<tr>
<td>Epilepsy</td>
<td>In 2006 Rajesh et al conducted a study on the topic of drug-resistant chronic epilepsy. Treatment of these complex cases with a yoga meditation protocol yielded promising results. For the 12-week program, patients began in a seated position (sukhasana) and practiced a specific form of breathing (pranayama) called nadishodana, in which “subjects had to inhale and exhale through alternate nostrils, maintaining a ratio of 1:1 without holding the breath.” They practiced this breathing for 5 to 7 minutes and followed the breathing with silent meditation concentrating over the region between the eyebrows. Patients continued these sessions once a week for 3 months and also were expected to perform daily meditation for 20 minutes each morning and evening. After 3 months, reduction in seizure frequency was noted in all but one patient, and 6 patients had 50% or greater seizure reduction. Of 16 patients who continued the practice for more than 3 months, 6 of them were seizure-free for 3 months. Three of the patients continuing the practice for more than 6 months were seizure-free for 6 months. The ability of this yoga meditation protocol to improve seizure control, if confirmed through randomized trials involving large numbers of patients, could make this intervention a valuable, low-cost treatment with no adverse effects for patients with difficult-to-control epilepsy.</td>
</tr>
<tr>
<td>Immune system</td>
<td>A 2012 study by Fernandes et al suggested that pranic meditation can bolster the immune system specifically by improving function and metabolism of phagocytes. Pranic meditation uses breathing and visualization techniques to quiet the mind. Twenty-nine individuals who had never meditated before participated in a 10-week program of 3-hour weekly sessions (along with 20-minute daily individual sessions) of meditation theory and practice. Venous blood and saliva samples were collected. The venous blood was used to measure phagocytes and saliva was tested for melatonin levels. Although in this study cortisol and melatonin levels were not altered by meditation, the authors found improvement in phagocytic health as well as a reduction in plasma levels of corticotropin—a hormone secreted by the pituitary gland that stimulates the adrenal gland, and a key component in the circuitry of stress.</td>
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and their patient-centeredness as reported in patient questionnaires in comparison to the MR scans of health care professionals who do not practice meditation. It also could be useful to compare MR scans of health care professionals who meditate vs those who use other forms of stress reduction.

Radiologic technologists might consider spending 10 to 20 minutes a day meditating given the depth and breadth of the benefits to well-being that medical science suggests it can bring. Furthermore, it could be valuable for health care providers to offer short training programs on meditation to patients and employees. As the speed of life increases exponentially, perhaps slowing to meditate, even briefly, can create a helpful counterbalance to the frenetic pace that increasingly characterizes modern society.

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References


Meditation, Stress Relief, and Well-Being

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*Your answer sheet for this Directed Reading must be received in the ASRT office on or before this date.

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

1. Stress can be classified as:
   1. mental.
   2. physical.
   3. emotional.

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

2. Physiological functions that can be affected by stress include:
   1. reproduction.
   2. excretion.
   3. immunity.

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

3. In the 3-stage process that Seyle describes, the third stage is:
   a. short-term memory loss.
   b. physical exhaustion.
   c. hypervigilance.
   d. an alert and alarmed body.

4. People can experience cognitive effects of stress, such as:
   1. distractibility.
   2. demoralization.
   3. increased error rate.

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3
5. Cognitive and emotional effects often manifest in behavioral changes, such as:
   1. anxiety.
   2. diminished enthusiasm at work.
   3. increased absenteeism.
   
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

6. For radiologic technologists, the stressors from introducing new technology into the workplace can be compounded by which of the following?
   1. low levels of computer literacy
   2. lack of sufficient communication and training
   3. lack of dependence on the technology
   
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

7. Indicators of job stress include which of the following?
   1. frustration
   2. fatigue
   3. loss of confidence
   
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

8. In a 2006 study, which of the following techniques were mentioned most often to ease stress in the students studied?
   1. frequent feedback
   2. fewer personnel in the area
   3. assurance that mistakes happen
   
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

9. After an adverse event or medical error, some suggest holding (a)n ______ to discuss the event’s impact on patients and health care professionals.
   a. error conference
   b. team huddle
   c. formal inquiry
   d. organizational investigation

10. According to Enders et al, what percent of patients scheduled for magnetic resonance (MR) imaging cannot be imaged because of claustrophobia?
   a. 1 to 15
   b. 15 to 30
   c. 20 to 40
   d. 30 to 50

11. Practices for anxiety relief, such as breathing and relaxation techniques, visualization, and mental exercises, have been shown to reduce stress for patients undergoing an MR scan.
   a. true
   b. false

12. Pediatric radiology departments employ all of the following methods to help reduce patient stress except:
   a. sedation.
   b. hypnosis.
   c. parental involvement.
   d. deconditioning.

continued on next page
13. According to Romano, which of the following can help technologists increase patients’ trust in the medical care they are receiving?
   1. maintain eye contact
   2. show a caring attitude
   3. provide detailed explanations of procedures
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

14. ______ is one of the possible adverse effects of sedation.
   a. Hyposmia
   b. Hypoxia
   c. Hypotoxia
   d. Hypovola

15. Shift work disorder is characterized by all of the following except:
   a. insomnia.
   b. fatigue.
   c. diabetes insipidus.
   d. difficulty with personal relationships.

16. To cope with stress and burnout in positive ways, radiologic technologists can do which of the following?
   1. get sufficient sleep
   2. praise coworkers for a job well done
   3. cultivate more friendships within the medical field
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

17. One 8-week intervention program that offered training in mindfulness included:
   1. being intellectual by using critical thinking and analysis skills.
   2. walking meditation and mindful movement.
   3. doing body scans and sitting meditation.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

18. The mindfulness practice of scanning the body involves:
   a. changing one’s bodily sensations.
   b. shortening telomeres.
   c. noticing bodily sensations.
   d. being in synchrony with the mind.

19. The ______ is an almond-shaped set of neurons deep in the medial temporal lobe, is part of the limbic system, and is associated with the emotions.
   a. hippocampus
   b. hypothalamus
   c. prefrontal cortex
   d. amygdala

20. The default mode network is most active when the brain is:
   a. involved in a task.
   b. at rest.
   c. synchronized.
   d. creating neural pathways.

21. Which of the following modalities can help determine the parts of the brain that are activated and deactivated during meditation?
   1. single-photon emission computed tomography (SPECT)
   2. positron emission tomography (PET)
   3. functional magnetic resonance imaging (fMRI)
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

*continued on next page*
22. According to Fayad et al, the parts of the brain that are affected by meditation include all of the following except the:
   a. cerebral cortex.
   b. amygdala.
   c. anterior cingulate cortex.
   d. hippocampus.

23. In a study by Kalyani et al that involved chanting meditation, PET imaging showed increased blood flow to limbic brain regions during direct vagal nerve stimulation as a result of meditation.
   a. true
   b. false

24. In Newberg et al’s study on the effects of chanting Sa Ta Na Ma, which of the following modalities demonstrated improved cerebral blood flow in the prefrontal, superior frontal, and superior parietal cortices?
   a. computed tomography (CT)
   b. PET
   c. fMRI
   d. SPECT

25. Engstrom et al used _______ to demonstrate that activation in the hippocampi occurs during silent mantra meditation practice.
   a. SPECT
   b. CT
   c. fMRI
   d. PET

26. Chung et al demonstrated that physiological effects of meditation include:
   1. decreased blood pressure.
   2. decreased anxiety.
   3. increased quality of life.

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

27. _______ affect how human cells age and are psychobiological markers for psychological stress.
   a. Hormones
   b. Telomeres
   c. Enzymes
   d. Centromeres

28. Which of the following is not part of mindfulness meditation practice?
   a. making mental lists
   b. observing the details of your body
   c. focusing on your breath
   d. watching the movement of your mind

29. The National Center for Complementary and Alternative Medicine has stated that there have been “rare reports” that meditation might worsen symptoms in people who have certain psychiatric problems.
   a. true
   b. false

30. People who wish to start a meditation program, especially those with mental health disorders, such as post-traumatic stress disorder or major depression, should:
   a. begin immediately.
   b. start with 20 to 30 minutes of meditation per day.
   c. consult a health care provider.
   d. avoid meditation altogether.
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Carefully cut or tear here.
New Software Application Assesses Lung Tissue Damage

Imbio’s Lung Density Analysis (LDA) software can distinguish locations within the lungs that have abnormally low density during both inspiration and expiration from locations that have abnormally low attenuation during only expiration using computed tomography (CT). The technique, available only with this software application, reveals functional information about a patient’s lungs that can help clinicians personalize treatment planning for patients with chronic obstructive pulmonary disease (COPD).

COPD is a combination of emphysema and obstructive bronchitis, which limits a patient’s ability to breathe. The disease is progressive and although there is no cure, lifestyle changes and treatment can help patients remain active and slow the disease’s progress. Meilan Han, MD, of the Women’s Respiratory Health Program and co-director of Pulmonary Rehabilitation at the University of Michigan explains, “Assessing the extent and type of lung tissue damage in COPD is key to understanding the disease process at an individual patient level.” The new software application should help clinicians improve treatment and therapy for COPD patients.

Once a paired inspiration and expiration CT series is acquired, the LDA runs automatically in a hospital’s data center. No user input or intervention is required, and results are sent directly to the PACS; therefore, the radiological workflow is uninterrupted. The software makes adjustments to the lungs’ changing size and shape during respiration and reveals details about how the CT density fluctuates during inspiration and expiration.

High-resolution CT imaging is performed for cardiac and thoracic imaging and is used for lung screening in high-risk smokers. Imbio’s LDA software might be used to analyze these patients’ CT studies to identify those at risk for COPD. An inspiration-only study can reveal areas of lower than normal density, which might suggest emphysema and could be used to evaluate low density areas for interventions such as lung volume reduction surgery. In inspiration-only processing, LDA software calculates a volumetric percentage of low density areas for sections of each lung and plots a histogram of Hounsfield Units (see Figure 1).

All-in-one Technology Integrates CT Scanner With Interventional Radiology

Toshiba America Medical Systems Inc.’s Infinix 4DCT integrated system puts patient care first by providing the features and tools clinicians need to perform safer, faster, and more accurate interventions. This new technology, which integrates interventional radiology and CT into a single system, saves time and improves workflow by giving health care providers the ability to plan, treat, and verify treatment success in the same room. This ability provides better patient care by eliminating the need to transfer patients between departments, which could risk infection and extend procedure times (see Figure 2). In addition, the system’s SUREGuidance technology...
Infinix 4DCT received U.S. Food and Drug Administration clearance with the Infinix Elite cardiovascular x-ray system and Aquilion ONE ViSION Edition CT system configuration. The all-in-one system delivers real-time CT images of target anatomy during procedures, providing interventionalists with more information. For example, they can see CT images of liver tumors and more precise views of the heart and stent placements. The technology provides clinicians the ability to adjust the procedure based on the real-time studies instead of relying on CT images taken at an earlier time. Performing a CT scan immediately before an operation provides more current and accurate information than a scan that is done days before. And a scan done immediately following the procedure helps confirm results quickly and eliminates the need for the patient to spend additional time at the hospital for CT postrecovery.

Besides reducing procedure times and infection risks, Toshiba reports that using Infinix 4DCT also could allow clinicians more time to focus on providing quality care, which could contribute to higher patient safety and satisfaction levels.

Infinix 4DCT debuted in December 2014 at the 100th Scientific Assembly and Annual Meeting of the Radiological Society of North America.

Siemens’ SOMATOM Scope Mobile CT
Siemens’ new mobile CT imaging vehicle is designed to bring low-dose CT lung imaging to areas of need, including rural and remote settings. No commercial driver’s license is required to drive the vehicle, which is ready to scan within minutes of parking and includes a diesel generator and high-speed wireless connection. Patients can enter the vehicle by stairs or wheelchair lift and watch videos prior to the examination on an installed TV/DVD player. The patient is scanned on Siemens’ SOMATOM Scope CT system using the low-dose lung imaging protocol (see Figure 3).
Brain Imaging Studies Can Help Educators

Theresa Ann Licari, MA, R.T.(R)

Brain-based learning or brain-compatible education is a neurolearning theory that places the brain in the forefront as the essential organ and foundation of education. As clinicians, we have studied brain structure (anatomy) and functionality (physiology), allowing us to think in depth about the truth of this statement. As educators, we can proactively benefit from our understanding of brain structure and functionality. Brain imaging studies can help educators visualize the anatomical makeup and function of the brain as well as see differences in the ways individuals learn. For example, learning differences (eg, dyslexia and autism) and evidence of psychological conditions (eg, depression and post-traumatic stress disorder) are visible on imaging studies. This evidence validates learning differences and helps to eliminate stereotyping.

Brain-Based Learning

Brain-based learning (neurolearning) research indicates individual differences in the ways people receive, process, and communicate knowledge. We receive information through 3 distinct modes: sight, sound, and touch or movement. Although individuals have different information input capacities, all information is translated into neurochemical impulses by the various senses. The brainwave takes on its own designated processing pattern and thus defines different learning styles. Sight recognition occurs in the brain posteriorly; sound recognition occurs in the brain laterally. Touch is recognized in the brain superiorly. Besides different information-receiving modes, individuals can process information differently too. This is seen in dyslexic individuals. People have different modes of communicating information, and they can have psychological conditions such as depression or emotional trauma that can temporarily alter the normal function of the brain.

Brain-based learning considers 12 proven brain learning principles. The principles that relate to patterning also can be affected. Brain-based learning stresses that meaning exists by matching observed events to past events creating a pattern, which is defined as “the brain’s way of organizing and categorizing enormous amounts of information in a way so the brain can find meaning in identifying interrelated information.” Patterning can be further explained in comparison to locating similar concepts efficiently from a rapid sequence of notes, which in learning needs to be completed to help generate new concepts or ideas.

Emotions are critical to patterning, and the following 6 principles have a direct effect on psychological conditions:

- Anything that affects physiological functioning affects our capacity to learn.
- Search for meaning occurs through “patterning.”
- Emotional components affect patterning.
- Learning involves both focused attention and peripheral perception.
- Learning involves conscious and unconscious processes.
Learning is enhanced by challenge and inhibited by threat.
In addition to helping us understand the different ways in which individuals receive, process, and output information, brain-based learning also considers psychological impediments to learning.

Radiologic Technology and the Brain
Radiologic technology provides the capability to study brain physiology and anatomy. Computed tomography, magnetic resonance imaging, positron emission tomography, single-photon emission tomography, diffusion tensor imaging, and magnetoencephalography often are used in conjunction with each other, providing additional information to health care providers as to what is happening in the human body. Each imaging technology provides either anatomical visualization or prolific data on functionality. A recent technological focus is combining 2 imaging modalities to show anatomical and functional information in one image to improve diagnostic abilities.

Functional magnetic resonance imaging (fMRI) is one such technology. The techniques of fMRI are referred to as functional (rather than structural) because participants are asked to perform specific tasks or stimulants are introduced while imaging occurs. For example, if the study's objective is to visualize the portion of the brain activated when music is played, then music is added to the environment at a specific point. As a result, analysis of the images permits conclusions about activation of the functioning brain rather than the anatomy of the resting brain. Brain activity generates increased blood flow to the area of activation. An increase in blood flow is then visualized on fMRI. The specific anatomical region where the task occurs can be identified by combining and overlaying single-photon emission tomography images to provide both anatomical and physiological information.

Brain Imaging and the Learning Process
Brain imaging studies also can be used to understand the brain in the learning process, which can help educators understand the essential organ of learning. Imaging studies show noticeable differences in people with learning disabilities. These differences can result from problems in receiving, processing, or communicating information.

Dyslexia is a disorder of language processing with different functional brain activity indicated on brain imaging scans. People with dyslexia usually struggle with decoding phonemes into meaningful words. Some experience difficulty holding sounds in short-term memory, which is needed to combine them into words, while others can decode phonemes but need extra time. People with dyslexia also have difficulty processing visual information into spoken language, which can result in reading, writing, and spelling difficulties. Consequently, people with dyslexia often struggle with low self-esteem. Brain-based learning stresses the importance of the students' psychological and emotional state in the learning process. Brain studies demonstrate that dyslexia is a brain-based disorder that responds to instructional interactions.

Comparing brain images of people with and without dyslexia confirms a disturbance in brain activity, including decreased blood flow to the parietal and posterior temporal regions of the brain in people with dyslexia. Imaging studies also confirm that after phonologically driven treatment to remove error patterns in a child's speech, fMRI scans reveal that the brains of children with and without dyslexia are not significantly different. Adults with characteristics of dyslexia also demonstrate changes in functional neuroanatomy as a result of training (see Figure 1).

Depression is another obstacle to learning that demonstrates disturbance of brain function that can be visualized on imaging studies. Depression can affect the learning process of the 6 brain-based learning principles identified previously. Advances in neuroimaging studies have reinforced the idea of depression as a disorder of brain structure and function, and psychological findings emphasize the importance of cognitive and emotional processes.

Brain-based learning acknowledges that physiological health is imperative to learning. Depression is believed to impair much of the brain, including the cerebral cortex, amygdala, hippocampus, hypothalamus, and other regions. People with depression exhibit shrinkage of the hippocampus, a brain region that regulates stress. Major depression also affects the frontal lobes,
lowering the person’s ability to reason and, “as a result, emotion overrides thinking.”

Disturbances of melatonin also are associated with depression. Findings suggest that melatonin is likely significantly associated with the regulation of memory, cognition, and emotional processes. Comparing brain images of people with and without depression confirms a disturbance in brain activity among people with depression. Evidence of clinical depression on brain imaging studies consists of a diminished blood supply in the lobes of the front and side (temporal region) of the brain (see Figure 2). Imaging studies also confirm that after taking an antidepressant such as fluoxetine, positron emission tomography scans reveal that the brains of depressed people start to reset to a normal balance of limbic vs cortical activity.

**Health Care Education and Brain-Based Learning**

Educators in health care programs work with students for a substantial amount of time and get to know their students on an individual basis. Educators are challenged by their students’ learning differences and psychological conditions and must develop strategies to intervene and promote learning. Instructional pedagogy also becomes as much about the educational culture of understanding, empowerment, and learner dignity as it does about content.

Brain-based learning enhances educational culture and enriches the classroom environment. Strategies that encourage creative brain processes during learning include activities such as working in groups and hands-on projects. The theory of constructivism has long had a vital role in cognitive learning and validates this type of learning. This theory suggests that students are empowered and gain dignity by exploring and constructing knowledge. Responsibility for learning shifts to the learners, and students extrapolate from their personal experiences to complement the learning agenda.

Personal reflection encourages students with learning differences and psychological conditions to
analyze themselves profoundly. For example, personal journals allow students to self-assess their road to self-improvement and instill a strong sense of professional reflection. One student who identified with clinical depression, as revealed in his program medical form, excelled in his assignment to complete a professional journal during his clinical rotations. He was honest in his self-analysis, revealing his perceptions and insecurities. By recording his experiences, analyzing what he could do better, and reflecting on his strengths and weaknesses he was able to identify opportunities for personal and professional growth. He worked hard at the college, including during evenings and weekends, studying to become the best he could be, and his patient care skills were excellent. He is employed in the facility where he interned, succeeding in the competitive employment market.

Once his depression was revealed, a plan was implemented to make him feel comfortable and assure him that working through difficulties to perform better in one’s role is part of the human condition. Creating a safe and friendly environment and encouraging problem solving through individual experimentation and group projects can all help students “own” their education.

**Conclusion**

Awareness of the learning process, along with knowledge of how the brain makes connections and a thorough understanding of what conditions are needed to best facilitate the process, can be advantageous in
the field of education. Brain-based learning focuses on cognitive practices and enrichment of the classroom environment. Medical imaging validates the functionality of the brain and can help educators become more proactive in adapting their teaching styles. Brain-based learning stresses this perspective and considers the student from a psychological perspective.

Brain imaging technologies are furthering our knowledge of functional brain activities, providing insight into intelligence and brain differences, and helping to advance education through progressive teaching strategies. Brain imaging studies confirm a disturbance in brain activity in learning differences such as dyslexia and autism, as well as psychological conditions such as depression and post-traumatic stress disorder.

An educator’s ultimate goal is to improve each person and society as a whole. Brain imaging studies can help educators achieve this goal by validating brain-compatible education and learning differences so they can implement effective teaching strategies and decrease stereotyping. In this way, instructional pedagogy and the educational environment become as much about the learning process as the content. Every student has the right to a rewarding, progressive, and satisfying education.

Theresa Ann Licari, MA, R.T.(R), has been a radiologic technologist for 32 years. She has worked as a senior special procedures technologist, a technical supervisor, and a clinical coordinator. Her educational research combines right and left brain learning with imaging technologies and displays the use of creativity to enhance learning and understand learning differences. In 2009, Licari earned her master’s degree in education from Goddard College in Plainfield, Vermont. She is a program director and assistant professor at LaGuardia Community College in Long Island City, New York, where she began and refined a new radiologic technology program, which had a licensing examination pass rate of 94% and above for the past 3 years. She also is a New York State public certified art teacher and an active artist.

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Left Ventricular True Aneurysm Following Myocardial Infarction

Mary Frances Sedlacek, R.T.(R)(M)(CT)(MR)

When a myocardial infarction occurs, a portion of the myocardium dies. Myocardial infarctions are classified based on severity. An ST-segment elevation myocardial infarction (STEMI) is a more severe type, occurring when a coronary artery is completely blocked. Coronary arteries supply blood to the heart muscle, or myocardium, and myocardial infarction occurs when a coronary artery becomes partially or totally obstructed by a thrombus or plaque, preventing adequate blood supply to the area of the heart it perfuses. As a result, all the myocardium supplied by the affected artery is infarcted. STEMI usually is recognized on electrocardiogram by its characteristic elevation of the ST segment (see Figure 1). Non–ST-segment elevation myocardial infarction (NSTEMI) is considered a less-severe type.

Left ventricular aneurysms can occur as a complication following myocardial infarction. A true aneurysm of the left ventricle refers to a thin-walled, dyskinetic (having impaired motion) or akinetic (having no motion), out-pouching of the left ventricle (see Figure 2). True aneurysms contain some myocardial elements within their walls, unlike a pseudoaneurysm, which is composed of organized hematoma secondary to rupture of the myocardium. True aneurysms are remnants of ventricular muscle consisting of endocardium, epicardium, and thinned scar tissue. The majority of left ventricular true aneurysms are located apically and develop as a result of wall thinning. Left ventricular true aneurysms occur in 10% to 38% of patients following myocardial infarction, and they occur more often in women than in men.

A ventricular pseudoaneurysm results from a rupture of the ventricle. Its bloody contents are contained within the pericardium as it still maintains communication with the ventricle (see Figure 3). Although ventricle aneurysms can occur in either cardiac ventricle, those resulting in ST-segment elevation are almost
exclusively left sided. This article presents a case of a left ventricular true aneurysm that occurred secondary to a STEMI.

**Case Description**

A 56-year-old man presented to the emergency department of a community hospital with a history of 2 to 3 days of chest pain. The patient was admitted following a diagnosis of STEMI, and thrombolytic treatment was started. The patient underwent coronary angiography, which showed an occluded right coronary artery. A transthoracic echocardiogram also was performed, which showed significant left ventricular dysfunction and a possible left ventricular pseudoaneurysm. Based on these findings, the patient was transferred to our institution for further evaluation.

Soon after his arrival to our facility, a nongated chest computed tomography (CT) angiography was performed on a SOMATOM Definition Flash scanner (Siemens Healthcare). The CT angiogram showed 2 possible aneurysms of the left ventricle, each with characteristics compatible with true aneurysms. There was no evidence of aortic dissection or aortic aneurysm. A transthoracic echocardiogram was performed and showed an aneurysm involving the inferior, posterior, and lateral walls of the left ventricle. A second aneurysm involving the mid-to-distal anterior and lateral walls of the left ventricle also was suspected. In addition, the transthoracic echocardiogram showed moderately reduced left ventricle systolic function and mild hypokinesis (diminished motion) of the right ventricle. The patient was referred for a cardiac magnetic resonance (CMR) examination.

The patient underwent a gated CMR examination on a MAGNETOM Symphony with Tim (total imaging matrix) 1.5T scanner (Siemens Healthcare) for further evaluation and to determine myocardial viability. CMR cine images in horizontal long axis and short axis views showed a large area of akinesis in the anterolateral and lateral walls of the left ventricle, as well as significant hypokinesis to akinesis of the inferolateral right ventricle free wall (see **Figure 4**). Evaluation of left ventricular function revealed moderately to severely reduced left ventricle systolic function, with a left ventricular ejection fraction of 29%. Evaluation of right ventricular function revealed reduced systolic function, with a right ventricular ejection fraction of 32%.

Late gadolinium enhancement imaging showed significant contrast enhancement of the anterolateral and lateral walls of the left ventricle from base to
Case Summary

Left Ventricular True Aneurysm Following Myocardial Infarction

midventricle, in the area of hypokinesis consistent with a large transmural myocardial infarction. The infarcted area was intact, which confirmed the diagnosis of a true aneurysm (see Figure 5). The late gadolinium enhancement images also demonstrated a moderate area of inferior and inferolateral right ventricle free wall contrast enhancement in the area of the hypokinetic segment, suggesting that a significant right ventricle infarct also had occurred.

The patient was discharged under the care of a cardiologist for medical treatment of the left ventricular aneurysm.

Discussion

During the course of this patient’s workup, transthoracic echocardiogram raised the possibility of a pseudoaneurysm, and subsequently the possibility of a second aneurysm. However, only a single, true aneurysm was confirmed. This is not unusual with transthoracic echocardiogram, as it often can have a limited field of view.

CT imaging also can be limited when evaluating the heart because it acquires data in the axial plane only. However, multiplanar reconstructions can be done in planes orthogonal to the acquisition. With CMR, the images are acquired in planes orthogonal to any structure of the heart. CMR also can provide an accurate assessment of both the morphology of the aneurysm and of the function of the heart. Because of the ability of MR to image in any plane, it was confirmed in this case that the patient had one aneurysm, not 2. In addition, CMR allowed differentiation between a true aneurysm and
pseudoaneurysm by demonstrating the continuity of the myocardial wall. With late gadolinium enhancement, the infarcted area was clearly demonstrated and shown to be nonviable. These findings helped determine an accurate course of treatment for this patient.

Treatment of an aneurysm is dependent upon the nature of the aneurysm and the patient’s symptoms. There is a higher risk of spontaneous rupture with pseudoaneurysm, and the catastrophic consequences demand urgent surgical repair. A left ventricular true aneurysm usually can be medically or surgically treated. Medical treatment consists of managing congestive heart failure, ventricular tachycardia, and angina pectoris, and reducing the risk of embolism. Surgical treatment consists of left ventricular reconstruction to restore left ventricle geometry and reduce left ventricular volume.

**Conclusion**

It is crucial to identify and classify left ventricular aneurysms because of their differing associated risks and potentially different courses of treatment. The multiplanar ability of MR affords a more accurate diagnosis of function as well as structural cardiac abnormalities associated with myocardial infarction, including aneurysms.

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**References**

Addressing Magnetic Resonance Safety Using a Modified Preoperative Time-Out Approach

Zachary J Berry, BS, R.T.(R)(MR)
Zachary B Barr, BS, R.T.(MR)(N)

To mitigate risks, the American College of Radiology (ACR) and The Joint Commission recommend that magnetic resonance (MR) imaging facilities be designed and divided into 4 zones. Zone I is open to the general public and is uncontrolled space located outside of the MR environment. Zone II is designated for patients and other individuals inside the MR department who have not yet undergone a thorough MR safety screening by trained personnel. Zone III represents a restricted area for screened patients and other individuals accompanied by qualified MR staff. Movement from zone II to zone III is controlled by MR personnel and limited to only those first screened and cleared in zone II. Finally, zone IV is the MR scan room where the MR unit is physically located. This area represents the greatest risk to patients and staff because of the various energies associated with MR imaging and is highly restricted to screened patients, MR staff, and other screened health care professionals who might assist with the examination.

Continuous assessment of MR safety practices is vital to protecting the integrity of zone IV and to ensuring patient and staff safety. In response to an ever-changing industry, the ACR created several MR safety guidance documents outlining best practices. Each MR facility is responsible for creating and evaluating processes and procedures that meet department needs while complying with industry recognized standards of care.

A 523% increase in adverse MR events was reported from 2000 to 2009. During the same period, MR facilities experienced approximately 90% volume growth. An estimated 85% of reported MR events occurring between 2009 and 2010 could have been mitigated by following the best practices outlined by the ACR. Two best practices essential to ensuring patient and staff safety during examinations are that patients undergo 2 separate safety screenings by qualified staff prior to beginning the MR examination and that staff evaluate each patient’s ferromagnetic risk.

Ferromagnetic detection systems have been demonstrated to be highly effective . . . [in] verifying the successful screen and identifying ferromagnetic objects which were not discovered by conventional screening methods.

A process that establishes documentation of screening is necessary so that MR technologists become accountable for completing their facility’s policies and procedures regarding patient care and safety. The process must incorporate recommendations from the ACR guideline document.

Much effort has been made in mitigating risk and safety concerns in the surgical arena. Perhaps the single biggest improvement to patient safety came through implementing the preoperative time-out, which "reduces communication failures and medical complications and supports development of better safety attitudes."
Effective communication has been shown to improve patient safety and quality of care. Interestingly, 17% of respondents in one study indicated a lack of safety climate in their organization. This is important because “higher levels of safety climate would be associated with higher safety performance.” To leverage the communication and safety benefits inherent in the preoperative time-out, the authors of this study modified the process to meet the unique needs of the MR environment.

**Methods**

The pre-MR time-out process provides a way for technologists to minimize risk to patients and other individuals while simultaneously allowing for written documentation of best practices to increase staff accountability. Technologists who have been designated as level II MR personnel must assume lead responsibility for the time-out.

Incorporated in the pre-MR time-out process are components of The Joint Commission’s universal protocol, such as verifying patient identity using at least 2 patient identifiers. In addition, in accordance with the American Society of Radiologic Technologists Practice Standards, technologists verify the procedure to be performed by reviewing the clinician’s order and the patient’s clinical history.

The pre-MR time-out focuses on mitigating the risks of patient and staff harm in the MR suite (zone IV). Recommendations by the ACR and The Joint Commission suggest patients be safety screened on site twice prior to the MR examination. Typical processes require that patients are screened in zone II upon arriving at the MR facility. To ensure safety standards are met, the pre-MR time-out requires a second safety screening and verifies the accuracy of the information provided by the patient by a review of available patient medical records.

Surgical time-out processes should “be done as close as possible to making the incision” as a means to reduce errors. The same tactic is advised for MR to minimize the time between the time-out and the procedure. Therefore, technologists should repeat the safety screening with the patient immediately prior to their entering zone IV. When reviewing the screening questions, all “yes” responses for which definitive written confirmation regarding the MR safety is not confirmed must be brought to the attention of the covering attending radiologist, the MR safety officer, or MR medical director for review and approval prior to proceeding with the requested MR examination on that patient.

In addition, the technologist completing the time-out must assess external ferrous risk by visually inspecting patients for contraindicated and potentially unsafe items, including personal attire, and by using handheld and wall-mounted ferromagnetic detectors as appropriate before entering zone IV. Finally, given the serious potential effects from nephrogenic systemic fibrosis in patients with compromised renal function, glomerular filtration rate laboratory values should be documented for all patients, when available, regardless of the ordered examination. In doing so, glomerular filtration rate data are readily available if administration of a gadolinium-based contrast agent becomes indicated for the patient.

All patients should undergo a preprocedure time-out to ensure at least 2 patient safety screenings have been performed and to verify patient identity and the examination requested. Ideally, the technologist completing the time-out is the technologist performing the examination; however, understanding operational constraints, this is only a suggestion.

If the time-out process cannot be completed verbally or interactively because of patient condition, staff should use all available means to confirm patient safety. This includes reviewing all available medical records, visually inspecting the patient for evidence of prior surgical procedures, using ferromagnetic detectors if available, and consulting the attending radiologist, the MR safety officer, or the MR medical director. This process is meant to supplement industry recognized standards of patient care and can be tailored for each clinical facility as appropriate. A checklist can be added to patient screening paperwork to document that the process was completed. Surgical checklists have “demonstrated associated improvements in situational awareness, decision-making, [and] teamwork.” Again, by modifying this proven safety tool for use in the MR environment, similar benefits might be realized.
Focus on Safety
Addressing Magnetic Resonance Safety Using a Modified Preoperative Time-Out Approach

To evaluate the effect of a pre-MR time-out on clinical operations, MR staff at 8 locations (7 outpatient centers and a hospital-based facility) were asked to complete an online survey prior to the time-out trial. The actual time-out process was implemented the following week during normal weekday operating hours of 2 MR facilities. The first MR facility is in a 600-bed teaching hospital in Central Pennsylvania that serves inpatients, outpatients, and emergency patients. During August and September 2014, this center averaged 848 patients. The second facility, an outpatient center in the same geographic area, had an average patient volume of 382 patients during the same period. Data were collected via online staff surveys and by using the time-out checklist (see Figure 1). Data regarding length of the time-out process and screening inaccuracies also were collected.

Results
Quantitative
During the trial, the hospital facility performed examinations on 90 patients, with time-out forms being completed for 62. Staff compliance in completing the time-out form was 68.9%. At the outpatient center, 76 patients were scanned and 59 time-out forms were completed for a staff compliance of 77.6%. When averaged between the 2 sites, compliance with the time-out procedure was 72.9%. To provide some context for these results, research indicates that the preoperative time-out is completed before incision in 70% of surgical cases.

Of the time-out checklists completed at the hospital location, 12 contained deficiencies with one or more categories not completed. Similarly, 19 checklists from the outpatient site contained deficiencies. The latter resulted in a 32.2% time-out form deficiency, while the former was deficient 19.4% of the time. Overall, 25.6% of the checklists were deficient in some manner, including 5 cases in which the technologist did not indicate on the checklist that device or implant safety was confirmed, and 8 cases in which external ferrous risk was not assessed.

Because the time-out is designed to address safety concerns, data were collected on screening variances that indicate a difference in patient responses (or discovery of past medical/surgical history in the patient’s medical record) between the first and second safety screenings. At the hospital, 11 patients had screening variances, no data were available for 2 patients, and 18.3% of the time-outs performed discovered a variance. At the outpatient location, one screening variance was found, and no data were recorded for 5 patients, equaling a variance rate of 1.9%. During the course of the trial, 11.5% of total time-out forms completed revealed a screening variance. Table 1 contains the different variance categories that were discovered. Note that some screening forms contained variances from multiple categories. The implant/metallic device variance related to a patient who did not disclose having a total knee replacement during the initial screening but did so during the second safety screening.

One concern of the time-out process is its potential effect on department work flow. The trial found that

Figure 1. Sample time-out checklist. Abbreviation: GFR, glomerular filtration rate.
staff completed the time-out process in an average of approximately 3 minutes (4.6 minutes at the hospital site and 2 minutes at the outpatient facility).

**Qualitative**

Of the MR staff from the 8 locations who were asked to complete an online survey prior to the time-out trial, 42 (57%) responded. Staff overwhelmingly (95%) stated that current safety policies and procedures keep patients safe. However, several mentioned that this is true only if policies are followed, indicating a possible lack of compliance with some items. Similarly, nearly 93% of respondents believe that safety policies and procedures keep staff safe. Survey participants also were asked how often patients are screened 2 separate times after arriving at the facility for their appointment. Patients are “always” screened twice according to 23.8% of respondents, with the same percentage indicating the practice is done “frequently.” Safety screening occurs twice only “sometimes” per 33.3% of respondents and “never” by 19% (see Figure 2). This response highlights the need for a formalized time-out procedure to ensure compliance with the second safety screening requirement.

The facilities at which this trial was conducted implemented a company-wide safety initiative mandating that all patients be changed into hospital attire when feasible. When staff was asked how compliant the group is with this policy, nearly two-thirds of the respondents indicated that patients are “always” changed, another 26% indicated that patients were “frequently” changed, and about 10% said patients were “sometimes” changed. There were no “never” responses. Allowing patients to enter zone IV in their personal attire presents the potential for injury. The vast majority of respondents believe that devices and implants are adequately investigated before the patient enters zone IV; however, staff do note that this is site-dependent (ie, some are more vigilant than others) and is therefore difficult to document.

With the potential dangers present in the MR environment, all staff members must be able to express concerns regarding patient safety. When respondents were asked whether it is easy to come forward with patient safety concerns, roughly three-quarters reported that they “agree” or “strongly agree.” However, 5 respondents “disagree” with that statement. Because evidence suggests that allowing radiologic technologists to lead an interventional radiology time-out can increase technologist empowerment in verbalizing concerns, the potential exists for the pre-MR time-out to have the same effect on MR technologists.

After the time-out trial, staff from the 2 sites involved were invited to participate in a second online survey. Eight individuals (42% of staff involved in the trial) responded to the survey. Two believed the time-out process improved patient safety, 3 believed the second screening was offensive to patients and

![Figure 2. Online survey results.](image-url)
unnecessary, and 7 believed the time-out had no effect on staff safety. Only one individual responded that patients were “always” screened a second time during the time-out trial. The other responses were split between “frequently” (n = 5) and “sometimes” (n = 2). Similar to the other staff survey, less than two-thirds of respondents indicated that patients were changed into hospital attire. Most respondents continue to believe that the presence of implants and devices is thoroughly investigated. Several staff members commented on the survey that the time-out process disrupted the patient experience because of the repeated questioning.

**Limitations and Future Recommendations**

The primary limitation of this study was the lack of patient feedback. An attempt was made to collect qualitative data from patients at both sites regarding their perception of safety procedures and attitudes. Only one-third of patients given a paper questionnaire provided feedback, and several questionnaires were only partially completed, which made it difficult to identify trends in patient safety perceptions. Therefore, this information was not included in the trial assessment. Any future research to evaluate the efficacy of the pre-MR time-out should include patients in the data collection process.

Another limitation was the lack of staff buy-in to the time-out process. This disconnect led to incomplete time-out forms and limited compliance with the process. Formally educating staff on how the time-out process works is vital to getting staff buy-in. Regarding the preoperative time-out, “effectiveness hinges on the ability of implementation leaders to persuasively explain why and adaptively show how to use the checklist.” In addition, it is imperative to provide education through coordinated efforts to secure staff buy-in and therefore compliance with the process.

In response to staff concerns, any adoption of a pre-MR time-out process should include basic service scripts. In the hospitality industry, customers generally perceive task-oriented scripting positively.” Creating scripting that explains the reason and need for repeated screenings could help maintain a positive patient experience. In fact, scripting within a health care setting is “another new area that shows promise of improving the communication and interpersonal interaction of the encounter.”

Finally, the study was limited by the short trial time frame. Although the study’s time constraints served practical purposes, further research could assess the long-term effectiveness of a pre-MR time-out on patient safety outcomes.

**Conclusion**

Incorporating a pre-MR time-out into established MR safety protocols has the potential to strengthen and improve patient safety outcomes as evidenced by the discovery of screening variances in this study. Adding a checklist for accountability and documentation also can provide benefits to patient safety outcomes. Maintaining the integrity of zone IV and managing risk within the MR environment requires constant vigilance on the part of facilities, technologists, and radiologists. Adapting proven patient safety techniques from other clinical areas shows promise as a supplemental tool to ensure that MR safety best practices are in place. This could provide facilities with the best chance of mitigating adverse MR events.

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**References**


Teaching Trauma Radiography

Tammara M Chaffee, MEd, R.T.(R)(M)

Although trauma patient care sometimes requires deviation from “routine” positions, best practices still should be applied. Some best practices in trauma situations include speed, accuracy, quality, proper positioning, practicing standard precautions, anticipating needs, attention to department protocol and scope of practice, and professionalism.¹

Because rapid response time in trauma situations is critical, teaching students to perform trauma radiography efficiently is essential. Students must thoroughly understand the equipment and procedures used in the radiology department under normal conditions, and they should be able to use specialized equipment and appropriately modify regular procedures when imaging a trauma patient.

Mobile Radiography

Some patients cannot be transferred to the radiology department for imaging (eg, because of their injuries or treatment that cannot be interrupted). In these cases, mobile radiography procedures can be performed in the emergency department or elsewhere.¹ Students must be comfortable with regular radiographic procedures, equipment, and techniques so they can operate a mobile radiography unit. Students also must be familiar with optional accessory devices, such as portable grids to produce quality mobile images, and necessary accessories for mobile radiography to ensure no time is wasted retrieving forgotten supplies (see Box).² The mobile radiography unit and image receptors should be kept clean; students should use a hospital-approved disinfectant on the equipment to reduce the spread of infection.

General guidelines for performing radiography on trauma patients include²:

- Do not remove dressings or splints.
- Never remove a cervical collar until the initial cervical spine radiograph is “cleared from injury” by the attending physician.
- Assemble adequate assistance and direction from emergency department staff to provide a safe patient transfer.
- Do not disturb impaled objects.
- Work quickly and efficiently.
- Assess the situation and determine the necessary equipment.
- Explain the procedure to the patient and assess his or her mobility and ability to help.

Box

Required Mobile Radiography Accessories²

- Multiple lead aprons — to protect the technologist, the patient, if possible, and others involved in the procedure.
- Standard precaution supplies — gloves, gown, and mask.
- Image receptor covers — to keep bodily fluids off equipment.
- Image receptors and grids (if required)
- Right, left, and arrow markers
Ensure oxygen is readily available.
Provide protective apparel for everyone in the room or have them step back at least 6 feet during the exposure, if possible.
Keep the central ray and image receptor alignment as close to routine positioning applications as possible, adapting to the patient’s condition.
Include all anatomy of interest.
Take at least 2 radiographs 90° to each other for each body part.

Projections
Whenever possible, the 2 radiographs should be an anteroposterior (AP) or posterioanterior projection and a lateral projection. Students should understand that having 2 radiographs 90° apart is necessary because people are 3-D and images are only 2-D. An AP radiograph shows height and width, but no depth, whereas the lateral projection includes height and depth. These projections are best because physicians are most familiar with viewing the body from these aspects.

If it is impossible to obtain these projections, the radiographer should attempt 2 other projections, 90° degrees apart (eg, 2 oblique projections). A technologist should take only one projection when doing so is routine or necessary (eg, AP abdomen or examination of the kidneys, ureters, and bladder). Students also should be able to explain on the patient’s history any adjustments to routine medical procedures for the interpreting radiologist.

Positioning
Proper radiographic positioning is the key to obtaining a diagnostic radiograph in trauma situations. Students should know that the primary goal of the trauma radiographer is to achieve the desired outcome on the first try, especially when the patient is unable to move into the desired position. Positioning the x-ray tube and the image receptor instead of the patient or the body part minimizes the risk of exacerbating the patient’s condition.

Because trauma patients usually arrive in the emergency department fixed to a backboard and lying supine, the radiographer can increase efficiency by taking all the AP projections of the requested examinations moving from the patient’s head toward the feet. All the lateral projections can then be performed moving from the patient’s feet toward the head. This technique allows the radiographer to move the x-ray tube in the most expeditious manner. This process results in 2 radiographs of each body part 90° from each other.

According to Drafke, the relationship between the part, the central ray, and image receptor is all that matters. This principle is crucial to adapting positions to nonroutine conditions because as long as these 3 relationships are maintained, the position will produce the desired results. Many examinations require that the central ray be perpendicular to the image receptor. This can be difficult to achieve using mobile equipment. Drafke suggests instructing students to stand back from the side of the mobile radiography unit and “adjust the tube until the bottom of the collimator is parallel” to the image receptor. Instructors should explain that the relationship between the central ray and the bottom of the collimator is perpendicular; thus, if the bottom of the collimator is parallel to the image receptor, the central ray automatically will be perpendicular to the image receptor (see Figure). An instructor might use a mobile radiography unit to demonstrate this point in class.

Figure. The collimator base is parallel to the image receptor, ensuring that the central ray is perpendicular to the image receptor. Image courtesy of the author.
Teaching Techniques

Teaching Trauma Radiography

Exposure Factors
Exposure factors are difficult when imaging a trauma patient. Exposure factors used in the radiology department usually are automated. However, a mobile radiography unit requires the technologist to manually set an exposure technique. Explain to students that the automated technique for each body part can be used as a reference when performing a mobile examination. Nevertheless, students should be aware of special concerns that affect exposure factors in trauma imaging.

Trauma radiographers must assess the patient before choosing exposure factors. Trauma patients often are strapped to a backboard, so the radiologic technologist must compensate for the board’s thickness and adjust the radiographic technique accordingly. Pathology also plays a role in selecting technical factors. For example, a patient with internal bleeding in the abdominal cavity would absorb a greater amount of radiation than would a patient with a bowel obstruction. Therefore, an increase in radiation would be required to obtain a diagnostic image on a patient with a bowel obstruction. Patient motion also is a concern. If a patient is thrashing about in pain, he or she might not be able to hold still during the exposure. If the mA is increased, exposure time will decrease; that adjustment can minimize the possibility of motion on the image. The goal is to take a diagnostic image on the first exposure, and that requires practice.

Radiation Protection
Radiation protection is essential in radiography, and students must learn about adjustments they can make while using the mobile radiography unit. The radiologic technologist is responsible for radiation protection for the patient, the patient’s roommate if it is a semiprivate room, any visitors, coworkers (including doctors and nurses), and him or herself.

The 3 principles of radiation protection are distance, time, and shielding. Distance is the most effective means of protection from ionizing radiation. A person receives significantly less radiation exposure by standing farther away from the source of radiation. This principle works for anyone in the immediate area, but it cannot be applied to the patient. Imaging and other personnel are able to distance themselves when the exposure is taken, thus reducing their effective dose. The inverse square law states that “the intensity of radiation is inversely proportional to the square of the distance from the source” (see Table).

The Table demonstrates that when personnel double their distance from the x-ray source, the effective dose will be reduced to 25% of the original intensity. Tripling the distance from the source reduces the effective dose to 11% of the original intensity, and moving 4 times the distance from the source means the effective dose will be reduced to 6.25% of the original intensity. As distance increases, dose decreases.

Time is important for radiation protection as well—especially for the patient. The longer a patient is exposed to radiation for an examination, the higher his or her effective dose will be. Setting a shorter exposure time reduces the patient’s effective dose and reduces the chance of motion on an image, preventing the need to repeat that exposure. The radiologic technologist controls exposure time by selecting the mA setting and the time (in seconds) to produce mAs, which is equal to the quantity of x-rays used in an exposure. Learning how to set these factors for different body parts is difficult and time consuming but essential for radiation safety.

Shielding is another principle of radiation protection, and it is probably the most overlooked. Many radiologic technologists often neglect to use shielding for their patients when using a mobile radiography unit, but they should not. All patients and nearby personnel should be shielded, especially children and patients with chronic conditions who might be receiving daily radiographs. In addition, reproductive organs must be shielded when:

- The x-ray beam comes within 2 inches (5 cm) of the reproductive organs.

Table

<table>
<thead>
<tr>
<th>Distance</th>
<th>Intensity (Quantity of Radiation)</th>
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<tbody>
<tr>
<td>2 × distance</td>
<td>1/4 intensity</td>
</tr>
<tr>
<td>3 × distance</td>
<td>1/9 intensity</td>
</tr>
<tr>
<td>4 × distance</td>
<td>1/16 intensity</td>
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</table>
The patient has reasonable reproductive capability. The shielding will not interfere with the examination.

Other means of radiation protection are removing people from the room or area; directing the x-ray beam away from people or away from walls that might have people on the other side; collimating appropriately; reducing the number of repeat radiographs; and properly selecting grids, screens, and technical factors. In trauma situations, the physician’s decision to order an imaging examination is based on his or her opinion that the examination is necessary to aid in the recovery of the patient. Any exposure to radiation increases the risk of radiation-induced cancer; however, the benefits usually outweigh the risks.

Computed tomography (CT) often is used to image trauma patients. In many cases, a CT examination is the first modality used because image acquisition is almost instantaneous.

Because CT shows not only bone, but soft tissues as well, CT images can help physicians determine a course of treatment more quickly and with more detailed information than can a radiograph. CT scans typically are ordered in trauma situations for head and abdominal injuries to assess for internal bleeding.

The disadvantage of using CT with regard to radiation protection is that the dose for CT is much higher, especially if multiple examinations are required over time. CT examinations produce an average dose range of 3 rem to 5 rem during head imaging and 2 rem to 4 rem during body imaging. In comparison, a chest radiograph produces approximately .01 rem of radiation dose to the patient. Some debate the frequent use of CT because of radiation protection concerns, but students should understand that in a trauma situation, the benefits of CT usually outweigh the risks.

Teaching trauma radiography to students can be challenging because it requires them to think critically while making quick decisions, but it can be an exciting and engaging activity, especially using mock trauma settings in the positioning lab. These lessons give students an idea of the stress involved to think and act quickly to obtain a diagnostic trauma image. The experience also makes students aware of the art of trauma radiography and that it comes down to a matter of life or death.

**References**

Guidelines for Conducting Responsible Research

Christina A Truluck, PhD, R.T.(N), CNMT
James Johnston, PhD, R.T.(R)(CV), FASRT

Codes and oaths guiding health practitioners in caring for patients have existed for centuries. The most famous, the Hippocratic Oath, was written in 400 BCE. Such statements compel us to reflect on our moral values and uphold ethical standards. Throughout history, health practitioners’ interpretations of what is morally correct have varied widely, and codes of practice have evolved. As radiologic technologists, we are familiar with guidelines established by professional radiologic and imaging sciences organizations, such as the Code of Ethics adopted by the American Society of Radiologic Technologists and the American Registry of Radiologic Technologists. These important documents emphasize our moral responsibility. Like physicians, we are trusted and respected by patients for our specialized knowledge. We work with patients who rely on us to keep them safe and to optimize their medical experience.

The basic principles of research ethics are well established now, but this was not always the case. During the 20th century, the media brought to the public’s attention many incidents of unethical medical research practices conducted on patients without their consent and with little, if any, concern for their well-being. After disturbing violations of human rights, ethical standards for research were developed to protect participants. The Nuremberg Code was established in 1949 as a consequence of the Nuremberg trials, where 23 Nazi doctors who had carried out inhumane experiments in the name of medical research were tried for crimes against humanity. It took many years, and many more unethical research incidents (eg, the Tuskegee Study, the Stanford Prison Experiment, and the Cold War radiation experiments), for the legacy of the Nuremberg trials to become part of the ethical review system in the United States. The Nuremberg Code was the first document to formally outline strategies for protecting the rights of human research participants and to include statements on voluntary and informed consent, autonomy in decision making, consideration of risk vs benefit, avoidance of harm, and the right to withdraw from research at any time without repercussion.

The Declaration of Helsinki, developed in 1964 by the World Medical Association, provided recommendations to physicians engaged in biomedical research involving human subjects. The National Research Act, enacted in 1974, led to the creation of the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research to explore means of regulating research involving human subjects. In 1979, the Commission published The Belmont Report, which identified 3 guiding ethical principles for research involving human subjects (see Box 1).

The Belmont Report served as the foundation of current regulations for ethical research: U.S. Code of Federal Regulations, Title 45, Volume 46, titled Protection of Human Subjects, which was issued by the U.S. Department of Health & Human Services in 1981.
and last revised in 2010. Concurrently, the U.S. Food and Drug Administration issued 21 CFR Part 50 concerning protection of human subjects during research involving drugs, devices, biologics, food additives, color additives, electronic products, and other test items subject to the administration's regulation. In 1991 several U.S. departments and agencies adopted these regulations as the Federal Policy for the Protection of Human Subjects, also known as the “Common Rule” (see Box 2). The policy applies to all human subject research supported by any federal department or agency in or outside the United States. Since the mid-1990s, the federal government has established several bioethics commissions to study and provide advice on the ethical, legal, and social implications of biomedical science and research. Currently, this role is fulfilled by the Presidential Commission for the Study of Bioethical Issues. President Barack Obama signed an executive order in 2009 to create the commission because “[a]s our nation invests in science and innovation and pursues

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**Box 1**

**Ethical Principles Guiding Research Involving Human Subjects**

<table>
<thead>
<tr>
<th>Principle</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>Respect for Persons</td>
<td><strong>Autonomy</strong> — Individuals have the right to make their own decisions about participation in a research study, voluntarily, without coercion or fear of penalties.</td>
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<td><strong>Informed consent</strong> — To make a decision about study participation, individuals must be fully informed about all aspects of the research study, including the study’s objectives, nature, and potential benefits; risk of adverse effects, injury, and discomfort; cost to participant in time, travel, and inconvenience; and procedures for handling and disposing of personal information and data.</td>
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<td><strong>Comprehension</strong> — Information must be conveyed in a way that the individual subject can understand. The researcher should use the subject’s primary language and check the subject’s level of comprehension. Participants must have an opportunity to ask questions and receive a copy of the signed and dated written consent form.</td>
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<td><strong>Vulnerable subjects</strong> — Special provision is needed to obtain consent for vulnerable subjects, which includes individuals who are unable to give informed consent for themselves because they are cognitively or communicatively unable (eg, children and comatose patients) and subjects who could be exploited easily or are susceptible to coercion (eg, prisoners and terminally ill patients).</td>
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<tr>
<td>Beneficence</td>
<td><strong>Protection from harm</strong> — The researcher has a duty to protect study participants from physical and psychological harm during and as a result of the research study.</td>
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<td><strong>Assessment of risks and benefits</strong> — The researcher must justify the research by assessing the probability and magnitude of possible harm and the anticipated benefits of the research study. Risks and benefits affecting the research subject are of particular relevance, but risks and benefits to others, such as the subject’s family and the general public, should be considered too.</td>
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<td><strong>Systematic assessment</strong> — Assessment of risks and benefits should be thorough, systematic, and nonarbitrary.</td>
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<td>Justice</td>
<td><strong>Fair treatment</strong> — Research study participants have the right to be treated fairly.</td>
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<td><strong>Equal treatment</strong> — The researcher has a duty to treat people equally regarding the benefits and burdens of the research.</td>
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<td><strong>Selection of subjects</strong> — Individual justice requires the researcher to exhibit fairness when selecting study participants. Selection should not be restricted to a particular (favored) group of individuals. Social justice requires the researcher to select subjects in a manner that avoids the imposition of burden on individuals from social classes who are already burdened.</td>
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advances in biomedical research and health care, it’s imperative that we do so in a responsible manner.

**Institutional Review Board**

To conduct human subject research with federal funding, an institution such as a university or hospital must establish a Federalwide Assurance agreement with the federal government. An institution with a Federalwide Assurance agreement agrees that all research at the institution (irrespective of funding) will adhere to ethical standards and federal regulations concerning human subject research. According to the Common Rule, the institution must set up an institutional review board (IRB), register it with the U.S. Department of Health & Human Services, Office for Human Research Protections, and show compliance with rules of membership, operation, and recordkeeping.

An IRB, sometimes called an ethics committee, exists to protect the ethical and legal rights of research participants. A researcher intending to conduct human subject research must submit a detailed research proposal to an IRB for ethical consideration before enrolling participants and embarking on the research. The IRB members review the proposal and document their findings regarding ethical considerations, scientific merit, and adherence to federal regulations and IRB guidelines. An IRB has the authority to approve or disapprove a research study, require modifications to the research plan, and terminate or suspend a study. Research studies are monitored for continued compliance, and researchers might be required to submit progress reports to the IRB.

Some research involving human subjects is exempt from IRB review, and some might be eligible for expedited review. These research activities are summarized in **Box 3** and **Box 4**, respectively. The Office for Human Research Protections recommends that researchers check with their IRB even if they think the research study will be exempt from review or qualify for expedited review. Receiving IRB approval or exemption is an important procedural step, and reputable publishers of research papers will look for this information in the manuscripts they review.

**Scientific Misconduct**

Scientific misconduct is a serious matter that goes beyond the loss of one’s personal integrity and credibility as a researcher. Such actions can result in federal as well as institutional action against the individual(s) involved and, depending on the nature of the work, legal action to address public harm. The Office of

**Box 3**

**Summary of Research Activities Exempt From IRB Review**

Research conducted in educational settings, involving normal educational practices, such as (i) instructional strategies, or (ii) effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) human subjects can be identified; and (ii) disclosure of the human subjects’ responses could place the subjects at risk of criminal or civil liability or be damaging to the subjects’ financial standing, employability, or reputation.

Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the subjects cannot be identified, directly or through identifiers linked to the subjects.

Research and demonstration projects which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services; (iii) changes in or alternatives to those programs or procedures; or (iv) changes in methods or levels of payment for benefits or services under those programs.

*For complete details, refer to 45 CFR 46, Section 46.101.
Science and Technology Policy provides the following definitions:

Research misconduct is defined as fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results. Fabrication is making up data or results and recording or reporting them. Falsification is manipulating research materials, equipment, or processes, or changing or omitting data or results such that the research is not accurately represented in the research record. Plagiarism is the appropriation of another person’s ideas, ideas, processes, results, or words without giving appropriate credit. Research misconduct does not include honest error or differences of opinion.

Research should not be about the number of publications or grants obtained, but rather about advancing knowledge. On an individual level, research should involve one’s morals, ethics, and integrity. Researchers involved in high-stakes grant-funded projects who feel pressured to produce might be tempted to make up results (fabricate) or manipulate data (falsify). As previously stated, giving into those pressures could result in disciplinary action from the employer institution, withholding or cancellation of funds by the grant-awarding agency, and legal action. This is in addition to irreparable damage to one’s career. Other factors that could contribute to scientific misconduct include competition among researchers working on similar projects or at “rival” institutions and competition among researchers for tenure, promotion, and resources.

Fabrication and falsification of results are egregious, but plagiarism is no less serious. Using another person’s ideas or work without appropriate credit is considered falsification of research. This form of scientific misconduct is easy to commit because of the availability of information on the Internet; it has become a major issue in public and higher education. Other writing practices, such as presenting an unbalanced literature...
review (by selectively using literature favorable to one’s project), might not rise to the level of scientific misconduct in the eyes of some agencies but are unethical nevertheless. Further, fragmenting one’s research to achieve multiple publications, slightly modifying a work and publishing it again, and using a part of one’s previously published work without proper citation are all forms of plagiarism. Authorship credit is another often abused practice. Credit for authorship should be based on substantial contribution to the research project, substantial contribution to the writing of the resultant manuscript, and having a voice in the final version of the manuscript to be published.

It is unlikely that any amount of training will deter or prevent unethical researchers from engaging in scientific misconduct, but measures are available to guide those who want to do the right thing. Institutional policies and best-practice documents that outline and require internal or external audits of results are 2 such measures. Another measure, requiring independent verification of results, is time-consuming and costly but could help avoid problems.

Federal Laws and Policies

A number of laws and regulations address scientific misconduct. Some, such as the Whistleblower Protection Act of 1989 and the Public Health Service Standards for the Protection of Research Misconduct Whistleblowers, include language that protects those who report unethical practices. Others, including federal policies such as the Federal Research Misconduct Policy, require all federal agencies to implement and provide definitions and responses to allegations of research misconduct. These laws and policies are in addition to those established and implemented at the institutional level. Grant-awarding agencies also might have misconduct policies that suspend or revoke funding and possibly bar researchers from applying for and receiving future grants. Further sanctions can include public retraction of research and listing of the individual on public agency Web sites as sanctioned individuals.

Conclusion

This article has provided an overview of the evolution of ethical practices in research, protection of human subjects, and efforts to provide safeguards and consequences for scientific misconduct. Whether an individual is new to research or a seasoned veteran, he or she should always revisit standards and codes of ethics in research as well as policies guiding research conduct. For those new to research, seeking out a reputable, experienced researcher to be a mentor also is a good idea. Many resources are available to guide and further one’s education in the conduct of research, and many are listed as references to this article.

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A Challenging Diagnosis

These 2 axial computed tomography (CT) images of the abdomen were acquired from different patients at the level of the pancreas. A. The arrow points to a normally appearing pancreas. B. A large mass is present in the head of the pancreas (arrow). The radiologist’s finding was probable pancreatic cancer. The pathology report substantiated the radiologist’s interpretation. More CT images of pancreatic cancer will appear in the July/August 2015 CT edition of Radiologic Technology in the Directed Reading, “Computed Tomography of Pancreatitis and Pancreatic Cancer” by Bryant Furlow, BA.

Archive


What an interesting individual the patient should be to the x-ray technician! It is the x-ray technician who has “I” trouble and thinks of himself rather than others who will be purblind to this interesting variety of beings who offer interest and zest to his work. He will forget that besides being a gastro-intestinal, a gall bladder, a retrograde pyelogram, or a simple chest x-ray, the patient is above all a human being, intriguingly complex and unknown.

Click here in the online version of this article to read the full story.

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