DIRECTED READING ARTICLES

Radiation Protection Education in Fluoroscopy
PAGE 511

Breast Intervention and Breast Cancer Treatment Options
PAGE 535M

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
Raise the Profile of Radiologic Technologists

Patients don’t always know that you’re a licensed and credentialed medical imaging or radiation therapy professional. To help you educate patients about your background, follow the ACE campaign’s three easy steps:

- **Announce** your name
- **Communicate** your credentials
- **Explain** what you’re going to do

Show your support – Click To Commit at [www.asrt.org/ACE](http://www.asrt.org/ACE).

---

Click To Commit!

©2014 ASRT. All rights reserved.
**Requirements**

- Registered radiologic technologist, with certification in at least one specialty recognized by the ARRT.
- ASRT member in good standing.
- Bachelor’s or master’s degree.
- Five years’ experience in medical imaging or radiation therapy.
- Experience in a management capacity.
- Advanced knowledge and ability to apply principles, concepts and practice standards.
- Flexibility to work evenings, weekends and some travel, when necessary.
- Required relocation to Albuquerque, New Mexico.

This position offers competitive pay and a generous benefits package in a high-tech, professional work environment.

SEEKING A

**Practice Standards & Chapter Manager**

**Job Description**

The practice standards and chapter manager administers the Office of Practice Standards and provides support, input and facilitates work for the Practice Standards Council as well as providing information on practice issues.

**Requirements**

- Registered radiologic technologist, with certification in at least one specialty recognized by the ARRT.
- ASRT member in good standing.
- Bachelor’s or master’s degree.
- Five years’ experience in medical imaging or radiation therapy.
- Experience in a management capacity.
- Advanced knowledge and ability to apply principles, concepts and practice standards.
- Flexibility to work evenings, weekends and some travel, when necessary.
- Required relocation to Albuquerque, New Mexico.

This position offers competitive pay and a generous benefits package in a high-tech, professional work environment.

For full job description and to apply, visit [www.asrt.org/asrtjobs](http://www.asrt.org/asrtjobs).

---

**Grass-roots Advocacy Action Center**

Check it out at [www.asrt.org/takeaction](http://www.asrt.org/takeaction).

**State Legislative and Regulatory Tracking Tool**

ASRT members can

- Access regulatory and legislative news by state or other searchable criteria.
- Search pending and enacted legislation.
- Keep current on changes affecting your practice and profession.

Learn more at [www.asrt.org/statetracking](http://www.asrt.org/statetracking).

---

**X-RAY CE®**

**Continuing Education for Imaging Professionals**

Order 24 hours a day, 7 days a week at xrayce.com or call 1-866-405-XRAY (9729)

- Free Faxback Service
- Free CME Tracking
- Major Credit Cards Accepted
- Group Discounts Available
- Online Testing

More courses are available on our web site!

---

**Made easy in the comfort of your own home!**

Get your continuing education credits FAST and AFFORDABLE with our home study courses. Most courses also offered in “E-Course” format that can be done completely online without having to wait for a text book in the mail. In a hurry? Try an “E-Course”!

<table>
<thead>
<tr>
<th>Course</th>
<th>CEUs</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiology 101 - NEW!</td>
<td>15.5 A CEUs</td>
<td>$97.95</td>
</tr>
<tr>
<td>Fundamentals of Musculoskeletal Imaging</td>
<td>28 A CEUs</td>
<td>$159.95</td>
</tr>
<tr>
<td>Manual of Radiology</td>
<td>20 A CEUs</td>
<td>$129.95</td>
</tr>
<tr>
<td>Musculoskeletal Imaging</td>
<td>18.5 A+ CEUs</td>
<td>$97.95</td>
</tr>
<tr>
<td>Genitourinary Imaging</td>
<td>18.0 A+ CEUs</td>
<td>$97.95</td>
</tr>
<tr>
<td>Spine Imaging</td>
<td>14.0 A+ CEUs</td>
<td>$89.95</td>
</tr>
<tr>
<td>Breast Imaging... Case Reviews</td>
<td>10.0 A+ CEUs</td>
<td>$89.95</td>
</tr>
<tr>
<td>Radiologic Science for Technologists</td>
<td>28.0 A CEUs</td>
<td>$159.95</td>
</tr>
<tr>
<td>Practical Digital Imaging and PACS</td>
<td>28.0 A CEUs</td>
<td>$159.95</td>
</tr>
<tr>
<td>PACS</td>
<td>27.5 A CEUs</td>
<td>$159.95</td>
</tr>
<tr>
<td>Breast Cancer Imaging</td>
<td>28.0 A CEUs</td>
<td>$184.95</td>
</tr>
<tr>
<td>Sectional Anatomy</td>
<td>32 A CEUs</td>
<td>$159.95</td>
</tr>
<tr>
<td>Radiographic Image Analysis</td>
<td>28.5 A CEUs</td>
<td>$154.95</td>
</tr>
<tr>
<td>Special Radiographic Procedures</td>
<td>22.5 A CEUs</td>
<td>$139.95</td>
</tr>
<tr>
<td>Comprehensive Radiographic Pathology</td>
<td>14.5 A CEUs</td>
<td>$97.95</td>
</tr>
<tr>
<td>Computed Tomography</td>
<td>22.5 A CEUs</td>
<td>$139.95</td>
</tr>
<tr>
<td>Radiation Protection</td>
<td>17 A CEUs</td>
<td>$94.95</td>
</tr>
<tr>
<td>Interventional Radiology</td>
<td>12.5 A CEUs</td>
<td>$89.95</td>
</tr>
<tr>
<td>Radiographic Imaging &amp; Exposure</td>
<td>11.5 A CEUs</td>
<td>$79.95</td>
</tr>
<tr>
<td>Patient Care in Radiography</td>
<td>10.75 A CEUs</td>
<td>$79.95</td>
</tr>
<tr>
<td>Accident and Emergency Radiology</td>
<td>8.0 A CEUs</td>
<td>$84.95</td>
</tr>
<tr>
<td>Pediatric Imaging Case Reviews</td>
<td>15 A CEUs</td>
<td>$89.95</td>
</tr>
<tr>
<td>Mammographic Imaging</td>
<td>13.5 A CEUs</td>
<td>$119.95</td>
</tr>
<tr>
<td>Emergency Radiology</td>
<td>18 A+ CEUs</td>
<td>$97.95</td>
</tr>
</tbody>
</table>

All courses approved as Category A or A+ Credit for ARRT licensure renewal.

---

20% off any course with coupon code “Scanner”
An Official Journal

Radiologic Technology (ISSN 0033-8397) is the official scholarly/professional journal of the American Society of Radiologic Technologists. It is published bimonthly at 15000 Central Ave SE, Albuquerque, NM 87123-3909. Months of issue are January/February, March/April, May/June, July/August, September/October, and November/December. Periodical class postage paid at Albuquerque, NM 87123-3909, and at additional mailing offices. Printed in the United States. © 2015 American Society of Radiologic Technologists.

The research and information in Radiologic Technology are generally accepted as factual at the time of publication. However, the ASRT and authors disclaim responsibility for any new or contradictory data that may become available after publication. Opinions expressed in the journal are those of the authors and do not necessarily reflect the views or policies of the ASRT.

Change of Address

To change delivery address, notify the ASRT at least 6 weeks in advance. Address correspondence to ASRT Member Services, 15000 Central Ave SE, Albuquerque, NM 87123-3909; call 800-444-2778 from 8 AM to 4:30 PM Mountain time; fax 505-298-5063; or e-mail memberservices@asrt.org. ASRT members also can submit changes of address online at www.asrt.org/myinfo.

Claims are not allowed for issues lost as a result of insufficient notice of change of address. ASRT cannot accept responsibility for undelivered copies.

Postmaster: Send change of address to Radiologic Technology, c/o the American Society of Radiologic Technologists, 15000 Central Ave SE, Albuquerque, NM 87123-3909.

Editorial

Editorial correspondence should be addressed to Radiologic Technology, Editor at communications@asrt.org, 505-298-4500, or 15000 Central Ave SE, Albuquerque, NM 87123-3909. Letters of inquiry prior to finished manuscript production are encouraged and may be reviewed by the editor and the chairman of the Editorial Review Board. Submit articles at asrt.msubmit.net.

The initials “R.T.” following proper names in this journal refer to individuals certified by the American Registry of Radiologic Technologists.

Subscriptions

Member subscription is $8.15 per year, included in ASRT member dues. Nonmember subscription of 1 volume of 6 issues is $85 within the United States for individuals; international, $127, including Canada. Institutional rates are available for $100 (U.S.) and $141 (international). Discounted rates apply to 2- and 3-year subscriptions and subscription agencies. A bundled rate is available for those interested in subscribing to both ASRT journals, Radiologic Technology and Radiation Therapist. For additional information, visit www.asrt.org/publications.

Single issues, both current and back, exist in limited quantities and are offered for sale. For prices and availability, visit www.asrt.org/store or phone ASRT Member Services at 800-444-2778.

Advertising

Publication of an advertisement in Radiologic Technology does not imply endorsement of its claims by the editor or publisher. For advertising specifically related to educational programs, ASRT does not guarantee, warrant, claim, or in any way express an opinion relative to the accreditation status of said program.

Rights Reserved

All articles, illustrations, and other materials carried herein are pending copyright under U.S. copyright laws, and all rights thereto are reserved by the publisher, the American Society of Radiologic Technologists. Any and all copying or reproduction of the contents herein for general distribution, for advertising or promotion, for creating new collective works or for resale is expressly forbidden without prior written approval by the publisher and, in some cases, the authors.

Copying for personal use only through application and payment of a per-copy fee as required by the Copyright Clearance Center, under permission of Sections 107 and 108 of the U.S. copyright laws. Violators will be prosecuted.

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.
She’s found her inner superhero. Now find yours.

Support better safety and satisfaction by helping reduce anxiety in pediatric MRI.

www.usa.siemens.com/mriamahero

Here’s a mission you can’t turn down: support the improved safety, comfort, and satisfaction of your pediatric patients by helping reduce anxiety in MRI. It’s what we call the MRI Heroes Kit, which is designed to educate and empower kids who need an MRI exam.

With it, you can help make a powerful impact—you can help maximize the safety of your pediatric patients, while giving them and their families the peace of mind of knowing they can get high quality MRI images. When a healthcare delivery organization like yours takes a small but significant step toward improving the experience of healthcare for their pediatric patients, everyone wins.

As part of our MRlamahero! program, the MRI Heroes Kit is another part of our longstanding commitment to improving the experience of healthcare for patients, and to providing solutions that help improve patient outcomes.

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.

Answers for life.
Submissions

Submissions from radiologic science professionals and researchers are encouraged. Visit asrt.msubmit.net to upload a manuscript. Author guidelines are available at www.asrt.org/authorinformation.
Clinical training and continuing education need to work both for your organization and for every member of your staff. That means learning methods need to be flexible, adaptable, and, most importantly, meaningful.

Siemens Clinical Education Services can help build your staff members’ knowledge, productivity, and efficiency—so they can deliver the high level of patient care and satisfaction you need to provide. By working closely with you and your staff, we provide education and training that answers the specific challenges you may be facing.

We also provide a variety of learning methods to accommodate multiple learning preferences and budgets, including virtual education, onsite or classroom training, workshops, fellowships, and workflow consulting. From our Customized Education Programs and the Siemens Learning Center, to the Healthcare Management Development Series, we provide the education and training that can help support improved patient outcomes and reduced costs. Another example of Sustainable Healthcare Technology from Siemens.

For more information, please call 1-888-221-8010 (option 1).
One of the nation’s few online radiologic-science certificate programs that provide more than 700 hours of hands-on clinical CT and MRI experience.

California State University, Northridge is a regional leader in providing programs for those seeking advanced professional development in both Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) – two of the most widely used medical imaging technologies.

FOUR OPTIONS

• Enrollment in the CT Certificate Program (includes CT clinical placement)
• Enrollment in the MRI Certificate Program (includes MRI clinical placement)
• Concurrent enrollment in both the CT and MRI Certificate Programs (includes CT and MRI clinical placement)
• CT/MRI coursework with Clinical Experience Exemption

TO LEARN MORE

Max Chou
Program Manager
818.677.3332
Max.Chou@csun.edu

programs.csun.edu/rtc

Radiologic Technology:
CT and MRI Online Certificate Programs

Visit our website to view all courses:
www.x-raylady.com

All courses available by mail or eBook. eBook course via email delivery is fast and easy.

X-Ray Lady CE®
6511 Glenridge Park Place, Suite 6, Louisville, KY 40222
Phone: 502-425-0651 Fax: 502-327-7921 E-mail: xrayladyCE@gmail.com

Apply Now for Fall 2015
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.”
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!

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
relies 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.² Seventy-four percent of all imaging examinations are projection radiographs, and radiography represented 85% of all ionizing radiation imaging examinations in children.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.²,⁵-⁸ 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.⁴ This nonthreshold model for stochastic effects means that all doses, regardless of how low, carry risk (see Figure 1).⁴,⁸ 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.²,⁵ 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.²,¹⁴,¹⁵ 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.⁴,⁸,¹⁶

**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 (WT) to explain the relative radiosensitivity of tissues, organs, and structures to determine how tissues are affected by the stochastic nature of ionizing radiation.⁴,¹³,¹⁴,¹⁶ 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 WT, 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 WT for breast tissue represents an average for both sexes and is actually larger for women. In addition, the WT
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. 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).

**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. 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.

**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
Basics" digital radiography key awareness points in 2012 (see Box).3,25 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.24 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.4,26,27

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.3,11,18-30 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.31 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. 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). Other studies have used air kerma-area product, incident air kerma, and entrance surface air kerma measurements for comparison. Regardless of the method chosen, these measured values allow for dosimetric comparison in terms of patient exposure. Specific testing phantoms, such as the Rando phantom (Phantom Laboratory), also have been used to provide accurate data measures of specific organs of interest. 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. 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. 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. 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. 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.

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. Anterior tissues include the breasts, colon, liver, small bowel, stomach, and urinary bladder. 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. 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.\(^\text{14}\) 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.\(^\text{36}\) Brennan and Madigan found that the PA lumbar projection would reduce small bowel absorbed dose by 39%.\(^\text{18}\) 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.\(^\text{17}\) 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.\(^\text{41}\) 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.\(^\text{37}\) These dose-reduction statistics are important as studies begin to link cancers to projection radiography procedures, such as breast cancer and scoliosis radiography.\(^\text{11,14,15,39-41}\)

Although the data sets convincingly reflect that the PA projection inherently limits exposure to anterior radiosensitive structures, they also are relevant for tissue displacement.\(^\text{14,17}\) The PA projection effectively functions to compress the soft tissue when the patient lies prone or tightly abuts the image receptor while erect.\(^\text{42}\) 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.\(^\text{42}\) 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.\(^\text{14}\) 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.\(^\text{34}\) 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.\(^\text{41}\) 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.\(^\text{44}\) Commonly cited rationale for traditionally accepted AP projections largely revolves around reduction in size distortion to improve image quality.\(^\text{14,17,36,45}\) 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.\(^\text{7,42}\) 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.\(^\text{7,14,18,34,39,45}\) 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.\(^\text{44}\) 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.\(^\text{14}\) 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.\(^\text{45,46}\)

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 W\(\text{r}_\text{T}\).\(^\text{22}\) 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%.\(^\text{14}\) 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{15,44}

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{15} Heriard et al\textsuperscript{15} 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.

\textbf{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.

\textit{Quentin T Moore, MPG, R.T.(R)(T)(QM), is the chairman of the bachelor of science in medical imaging program at Mercy College of Ohio in Toledo, Ohio. He can be reached at quentin.moore@mercycollege.edu.}

Received February 17, 2014; accepted after revision April 22, 2014.

Reprint requests may be mailed to the American Society of Radiologic Technologists, Communications Department, at 15000 Central Ave SE, Albuquerque, NM 87123-3909, or e-mailed to communications@asrt.org.

© 2015 American Society of Radiologic Technologists

\textbf{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.

According to the World Health Organization (WHO), 4 billion people—approximately two-thirds of the world’s population—have little or no access to medical imaging services.¹ This is partly due to a lack of equipment. However, there also is a shortage of educationally prepared and clinically competent radiographers. Data from 2004 from developed countries such as Norway, France, and the United Kingdom indicated that there were 444, 350, and 328 radiographers, respectively, per 1 million people.² In contrast, developing countries such as Togo, Tanzania, and Senegal reported ratios of 7, 6, and 5 radiographers, respectively, per 1 million people.³ The shortage of radiographers can be attributed, in part, to the lack of professional recognition (via licensure and certification requirements) in many developing countries and a lack of programs that provide adequate training. According to a paper published by the International Society of Radiographers and Radiological Technologists (ISRRT) in 2008, developing areas such as Jamaica, Barbados, Trinidad and Tobago, Uruguay, Brazil, Kenya, Uganda, Malaysia, and Hong Kong have successfully gained national recognition for their radiologic technology professionals and are moving toward a degree, or equivalent, as an entry to professional practice. In contrast, countries such as...
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

### Table 1

<table>
<thead>
<tr>
<th>Content Areas in the 2007 ASRT Radiography Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction to Computed Tomography</td>
</tr>
<tr>
<td>2. Clinical Practice</td>
</tr>
<tr>
<td>3. Digital Image Acquisition &amp; Display</td>
</tr>
<tr>
<td>4. Ethics &amp; Law of Health Care</td>
</tr>
<tr>
<td>5. Fundamentals of Radiologic Science and Health Care</td>
</tr>
<tr>
<td>6. Human Structure &amp; Function</td>
</tr>
<tr>
<td>7. Image Analysis</td>
</tr>
<tr>
<td>8. Imaging Equipment</td>
</tr>
<tr>
<td>9. Medical Terminology</td>
</tr>
<tr>
<td>10. Patient Care in Radiologic Sciences</td>
</tr>
<tr>
<td>11. Pharmacology and Drug Administration</td>
</tr>
<tr>
<td>12. Radiation Biology</td>
</tr>
<tr>
<td>13. Radiation Production &amp; Characteristics</td>
</tr>
<tr>
<td>14. Principles of Imaging</td>
</tr>
<tr>
<td>15. Radiographic Pathology</td>
</tr>
<tr>
<td>16. Radiographic Procedures</td>
</tr>
<tr>
<td>17. Film-Screen Image Acquisition and Processing</td>
</tr>
</tbody>
</table>
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 ISRRRT 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

Table 2

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

* 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 3
**Participating Countries’ Human Development Index Scores**

<table>
<thead>
<tr>
<th>Recipient Country</th>
<th>Human Development Index Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>0.558 (medium development)</td>
</tr>
<tr>
<td>India</td>
<td>0.554 (medium development)</td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.471 (low development)</td>
</tr>
<tr>
<td>Nepal</td>
<td>0.463 (low development)</td>
</tr>
</tbody>
</table>

### Table 4
**Participants’ Most Used Texts**

<table>
<thead>
<tr>
<th>Facility</th>
<th>Most Used Texts</th>
<th>Author</th>
<th>Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korle Bu Teaching Hospital, Accra, Ghana</td>
<td><em>Fundamentals of Skeletal Radiology</em></td>
<td>Helms CA</td>
<td>1995</td>
</tr>
<tr>
<td></td>
<td><em>Diagnosis of Bone &amp; Joint Disorders</em></td>
<td>Resnick D</td>
<td>2002</td>
</tr>
<tr>
<td></td>
<td><em>Handbook of MRI Technique</em></td>
<td>Westbrook C</td>
<td>2008</td>
</tr>
<tr>
<td></td>
<td><em>MRI Parameters and Positioning</em></td>
<td>Moeller T, Reif E</td>
<td>2010</td>
</tr>
<tr>
<td>Post Graduate Institute for Medical Education and Research, Chandigarh, India</td>
<td><em>Chesney’s Equipment for Student Radiographers</em></td>
<td>Carter PH, et al</td>
<td>1994</td>
</tr>
<tr>
<td></td>
<td><em>Skeletal Anatomy</em></td>
<td>Bryan GJ</td>
<td>1996</td>
</tr>
<tr>
<td></td>
<td><em>Principles of Radiographic Imaging: An Art and A Science</em></td>
<td>Carlton RR, Adler AM</td>
<td>2005</td>
</tr>
<tr>
<td></td>
<td><em>Introduction to Radiologic Sciences and Patient Care</em></td>
<td>Adler AM, Carlton RR</td>
<td>2007</td>
</tr>
<tr>
<td></td>
<td><em>Ball and Moore's Essential Physics for Radiographers</em></td>
<td>Ball JL, Turner S, Moore AD</td>
<td>2008</td>
</tr>
<tr>
<td>Tribhuvan University Teaching Hospital, Kathmandu, Nepal</td>
<td><em>Diagnostic Radiography: A Concise Practical Manual</em></td>
<td>Bryan GJ</td>
<td>1987</td>
</tr>
<tr>
<td></td>
<td><em>Chesney’s Care of the Patient in Diagnostic Radiography</em></td>
<td>Culmer P</td>
<td>1995</td>
</tr>
<tr>
<td></td>
<td><em>Basic Anatomy &amp; Physiology for Radiographers</em></td>
<td>Dean MRE, West TET</td>
<td>1987</td>
</tr>
<tr>
<td></td>
<td><em>Clark’s Positioning in Radiography</em></td>
<td>Whitley AS, et al</td>
<td>2005</td>
</tr>
<tr>
<td></td>
<td><em>Orthopedic Imaging: A Practical Approach</em></td>
<td>Greenspan A</td>
<td>2011</td>
</tr>
</tbody>
</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 inter-

test 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 educa-
tional 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 govern-
ment 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 burden-
some, 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 set-
ing, so addressing this desire would likely involve addi-
tional 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 devic-
es and might result in a more effective and efficient con-
tent 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 cov-
erage 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 clini-
cal 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 radiog-
raphy 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.

Jonathan Mazal, MS, R.R.A., R.T.(R)(MR), is a research technologist for the National Institutes of Health. He is a past board member of the World Radiography Educational Trust Foundation and now serves on the board of the International Society for Radiographers & Radiologic Technologists. He is chairman of the ASRT Foundation’s Community Outreach Review Committee and a 2010 Siemens scholarship recipient. In 2011, he was named a Virtual Symposium on Research Advancing Researcher in 2011, and he received an ASRT Foundation Seed Grant for research. Mazal also serves on the Radiologic Technology Editorial Review Board. This research study was performed in his personal capacity. He can be reached at jrmazal@gmail.com.

Rebecca Ludwig, PhD, R.T.(R)(QM), FAEI RS, FASRT, is dean of the College of Health Sciences at St. Petersburg College in St Petersburg, Florida. Ludwig was a professional research grant awardee in 2001 and a Virtual Symposium on Research awardee in 2010 and 2011 and serves on the Radiologic Technology Editorial Review Board. She can be reached at ludwig.rebecca@spcollege.edu. Funding for the MEDs and e-books was provided through grants from the ASRT Foundation as well as the Ohio Society of Radiologic Technologists. RAD-AID International also provided guidance, information, and volunteer time and effort. Special thanks to the MED recipients Steven Boateng (Korle Bu Teaching Hospital, Accra, Ghana), Subhash Bahnosal (Post Graduate Institute for Medical Education and Research, Chandigarh, India), Ganesh Pokharel (Tribhuvan University Teaching Hospital, Kathmandu, Nepal), and Elizabeth Bologun (National Orthopedic Hospital, Lagos, Nigeria). The investigators deeply appreciate all the support that made this project possible.

Received February 20, 2014; accepted after revision May 27, 2014.

Reprint requests may be mailed to the American Society of Radiologic Technologists, Communications Department, at 15000 Central Ave SE, Albuquerque, NM 87123-3909, or e-mailed to communications@asrt.org.

© 2015 American Society of Radiologic Technologists

References

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.²⁻⁵

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
Preoperative Breast MR Imaging: Its Role in Surgical Planning

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.

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.

**Additional Biopsies**

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 1

**Beneficial Changes in Surgical Planning Resulting From Preoperative Breast MR Imaging**

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

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 Obdejin 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.4 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:

- 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.4

**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.4 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).4 Of 59 patients who had a mastectomy, 78% had undergone both mammography and MR imaging.4 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.4,5,8-19 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.29 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).

### Table 2

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

Abbreviations: BCS, breast-conserving surgery; MR, magnetic resonance.

### 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%.
mastectomies was considered, 48 (48%) of 99 patients who had MR imaging finally had a mastectomy, while 99 (59%) of 168 patients who did not have MR imaging had a mastectomy. These findings showed that MR imaging can decrease the rate of re-excisions without increasing the rate of mastectomy. Consequently, as Grady et al showed, MR imaging can be especially beneficial for patients who are receiving chemotherapy, because a return to the operating room can delay chemotherapy cycles. In yet another study, Thibault et al. reported that 6 of their patients would have benefited from preoperative MR imaging by undergoing the proper surgical method initially and thereby avoiding re-excision.

Obdein et al found a correlation between the use of preoperative breast MR imaging and a reduction in re-excisions. When they compared their subgroup of 94 patients who had preoperative MR imaging and underwent BCS to a control group of 119 patients who did not have breast MR imaging before their BCSs, they found a statistically significant difference ($P < .01$) 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 control group (15.8% and 29.3%, respectively). In addition, about half as many patients in the preoperative MR imaging group required re-excision. Obdein 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

---

**Table 3**

<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>Petrillo 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.\textsuperscript{12,23,25,26} 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.\textsuperscript{25} 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.\textsuperscript{25} 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.\textsuperscript{25} 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.\textsuperscript{12}

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).\textsuperscript{23} 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.\textsuperscript{23} 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.\textsuperscript{26}

**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.\textsuperscript{22} Physicians who choose to schedule preoperative MR imaging must histologically 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.\textsuperscript{27} 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.\textsuperscript{28} 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.\textsuperscript{28} 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, wider excisions, and mastectomies. Still other studies gave inconclusive findings about the benefit of MR imaging in surgical planning. Ultimately, the physician must decide whether to use MR imaging in surgical planning. Additional research is needed about this important and controversial topic.

Ashley Barrett, BS, R.T.(R)(MR), is a magnetic resonance imaging technologist for Newton Wellesley Hospital in Newton, Massachusetts. She received her bachelor’s degree in radiologic science at the University of North Carolina at Chapel Hill in 2014. She can be reached at abarrett1692@yahoo.com.

References


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

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

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.”

Radiation Protection Education in Fluoroscopy

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

Radiation protection practices were lacking prior to 1950, and as a result occupational radiation exposures were higher than they are reported to be today. 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. Skin injuries due to overexposure to radiation were common before the 1930s. 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. 

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. 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. 

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. Fluoroscopic equipment regulations assisted in decreasing radiation exposure during fluoroscopy. 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. 

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). 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. 

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. 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). 

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

| Box 1 |
| Locations Within the Hospital Where Fluoroscopy Is Performed |
| 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.\textsuperscript{5,18-20}

In addition to awareness and knowledge of radiation protection practices, compliance with practices became an issue.\textsuperscript{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.\textsuperscript{18}

In the past 14 years, the focus on radiation protection has shifted, with attention directed toward the following concerns:\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{2}
One of the earlier studies on risk estimates for hematopoietic malignancies in medical radiation workers who had protracted low-to-moderate occupational exposure demonstrated an increased risk for nonchronic lymphocytic leukemias decades after the initial radiation exposures. This study examined more than 270,000 radiologists and radiologic technologists from various countries. The most reliable finding was increased mortality as a result of leukemia in workers who were employed before 1950.

Another study on mortality rates in interventional radiographers revealed no difference between radiographers performing other studies and radiographers performing interventional radiology studies. The study followed 88,766 U.S. radiologic technologists over the course of approximately 8 years. The authors collected information on work experience, types of procedures, protective measures, medical and family history, as well as lifestyle choices. Over the course of the study, there were 3,581 deaths. Of this number, 1,209 were from malignancies and 979 were from circulatory system diseases. However, the authors did not find a significantly increased mortality risk in radiologic technologists who reported performing a high number of interventional radiography procedures. Nevertheless, they stated the findings should be interpreted “cautiously” because of the short follow-up period. A 2006 study of breast cancer incidence in U.S. radiographers found no direct relevance of the effects of long-term, low-level exposure on breast cancer.

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

Radiation-Induced Cataracts

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

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

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

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

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. 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. 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.  

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. Radiation exposure levels from the same procedure and with similar patient conditions can differ dramatically between institutions. 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.

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

- 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. 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.

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 the:

- 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.

### Box 2

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


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

Cardiologists prescribe the majority of medical imaging examinations, but their radiation protection awareness is low.34 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.18

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
received instruction and demonstrated competency on all newly installed equipment and upgrades that affect dose.¹

Cardiac interventionalists are prominent among practitioners who might not have received radiological instruction as part of their medical education.³⁹,⁴¹ 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.³⁹,⁴¹ 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.⁴¹

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.⁴⁶ 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.⁴⁶

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.¹ 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:¹⁴:

- 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.⁶ 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.⁶

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.⁶,³³ 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.¹⁴

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

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

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

Registered Radiologist Assistants

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

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

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

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

Lack of compliance with established radiation safety practices could lead a radiographer to contribute to increases in radiation dose.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{18,50}

Improving radiation safety begins with a personal evaluation of radiographers’ own routine practices.\textsuperscript{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.\textsuperscript{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.\textsuperscript{54}

Radiographers have some control over the greatest source of unnecessary patient dose, which is repeated or unnecessary examinations.\textsuperscript{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.\textsuperscript{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.\textsuperscript{6,55}

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.\textsuperscript{18} The assumption should be that certified radiographers have received instruction in the recommended topics, including the following\textsuperscript{6,56}:

- 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.\textsuperscript{6}

The major focus of radiographers’ education should be specific to their job and roles.\textsuperscript{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.\textsuperscript{5} The ARRT offers secondary certification in interventional radiography and cardiology that requires this type of advanced knowledge.\textsuperscript{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
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).64 A general understanding of radiation and the potential exposure from fluoroscopy examinations and procedures can help patients better participate in their care and decision making. Information for the public and patients should be balanced and reflect scientific literature and findings.43

In particular, parents of children who undergo these types of procedures must understand fluoroscopy exposure because of children’s potential life spans and future additional imaging examinations. Parents also should learn more about complex interventional fluoroscopy procedures so they and their child can cooperate to the best of their ability.60

Fluoroscopy Education Methods

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

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

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

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

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.53-56 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.65 In addition, pediatric dose decreased after residents were instructed about pulsed fluoroscopy and how to obtain the best video frame-captured images using the lowest fluoroscopy pulse.67 Online training, virtual education, and competency evaluation in the form of a check-off list also have proven useful in decreasing dose.66,68 Requiring the use of dose-feedback systems has helped to decrease patient dose as well.66-68 Finally, coaching is useful to decrease dose and increase awareness of exposure.65

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

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.69,70

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.

Reprint requests may be mailed to the American Society of Radiologic Technologists, Communications Department, at 15000 Central Ave SE, Albuquerque, NM 87123-3909, or e-mailed to communications@asrt.org.

© 2015 American Society of Radiologic Technologists

References

7. Vaño E, Fernandez M, Sanchez RM, et al. Patient radiation dose management in the follow-up of potential skin injuries in


Radiation Protection Education in Fluoroscopy

To earn continuing education credit:
- Take this Directed Reading quiz online at www.asrt.org/drquiz.
- Or, transfer your responses to the answer sheet on Page 534 and mail to ASRT, PO Box 51870, Albuquerque, NM 87181-1870.

New and rejoining members are ineligible to take DRs from journal issues published prior to their most recent join date unless they have purchased access to the quiz from the ASRT. To purchase access to other quizzes, go to www.asrt.org/store.

*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. 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.

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

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

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

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

a. true
b. false

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Expires: June 30, 2017
Approved for 2.0 Category A CE credits

-- A passing score is 75% or better.
-- Take the quiz online at www.asrt.org/drquiz for immediate results and your CE certificate.
-- Or, mail the original answer sheet to ASRT, PO Box 51870, Albuquerque, NM 87181-1870.
-- ASRT must receive this answer sheet before the quiz expires and before the end of the CE biennium for which you want credit.
-- New or rejoining members are ineligible to take DR quizzes from journals published prior to their most recent join date unless they purchase access to the DR quiz.

Identification Section
We need your Social Security number to track your CE credits. Please fill in your SSN in the boxes on top, then fill in the circle corresponding to each number under the box. The circles must be filled in accurately.

Member Information Section
To ensure proper credit please PRINT the following information.

Name ____________________________
Address __________________________
City ______________________________
State ___________ ZIP _____________
Work Phone _________________________
Home Phone _________________________

CE Answers Section
USE A BLUE OR BLACK INK PEN. Completely fill in the circles.

Get immediate Directed Reading quiz results and CE credit when you take your test online at www.asrt.org/drquiz.

Note: For true/false questions, A=true, B=false.

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

No Photocopies Accepted
Breast Intervention and Breast Cancer Treatment Options

Olive Peart, MS, R.T.(R)(M)

Breast cancer is the second leading cause of death among women in the United States. Although controversy has emerged in recent years regarding the diagnosis and treatment of this disease, it remains important to detect and treat breast cancer before it has metastasized. This article provides an overview of breast biopsy techniques, biopsy specimen imaging, and treatment options for breast cancer patients, including surgery, radiation therapy, chemotherapy, and molecular treatments. Finally, breast reconstruction options are presented.

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

- Differentiate between cytologic and histologic sampling.
- Explain the advantages and disadvantages of biopsy methods.
- Describe the staging process for breast cancer.
- Discuss treatment options for breast cancer and their risks and indications.

Imaging techniques are used to diagnose lesions, calcifications, or architectural distortion of the breast parenchyma that could be considered suspicious. However, regardless of the imaging method, cancer cannot be diagnosed without a biopsy. With a positive biopsy, the health care provider’s action plan becomes critical in preserving and enhancing the patient’s quality of life.

Overview of Breast Imaging Techniques

Mammography is the preferred method of detecting breast cancer. Although other modalities can enhance the diagnostic information obtained, they cannot replace the mammogram, which can be analog, digital, or tomosynthesis imaging. Mammography can detect lesions that are irregularly shaped, lobulated, partially obscured, obstructed, or spiculated. Definite areas of architectural distortion and calcification also can be identified easily on mammograms.

After identifying an area of concern, the next step is to obtain supplemental projections or use adjunct imaging modalities to define the area of suspicion or verify the presence of an abnormality. Supplemental mammography imaging includes the use of any projection or technique that provides further information concerning the area of suspicion. Useful projections are spot compression or magnification images to assess calcifications or lesion margins, tangential projections to rule out skin lesions or calcifications, 90° lateromedial or mediolateral projections or the exaggerated craniocaudal projection to localize the lesion, and rolled positions to remove areas of overlap.

If mammography cannot provide additional information, adjunctive modalities become critical. Ultrasound imaging can be used to evaluate the content of circular or oval lesions, image dense breasts, and assess implants to detect leaks without radiation or biological risks. However, ultrasonography is operator dependent, and it cannot be used to image microcalcifications.

Magnetic resonance (MR) imaging can be used as an adjunct screening
tool for patients with a lifetime breast cancer risk of at least 20%, patients who received chest wall radiation between the ages of 10 and 30 years, and patients with the \textit{BRCA1} and \textit{BRCA2} genetic mutations. MR imaging is becoming the preferred method for evaluating implants and dense breasts, and it is invaluable for assessing nonpalpable lesions not identified on mammography. MR also can help in mapping the tumor extent and detect multifocal or multicentric disease. After a diagnosis, MR can be used:

- In the staging process to determine the feasibility of breast-conserving surgery vs mastectomy.
- To assess the spread of cancer to the lymph nodes.
- To evaluate the effectiveness of treatment.
- To evaluate margins for residual cancer.

Most of the risks of MR imaging are associated with its magnetic properties. Patients must be screened for implanted or embedded metallic objects before entering the MR suite because injury can occur if an object is moved or dislodged by the magnet. MR imaging cannot be used to evaluate microcalcifications, and it poorly visualizes the axillary nodes. The financial cost of MR imaging and its lower specificity results in a high false-positive rate, which limits this technology as a screening tool.

MR imaging of the breast has a sensitivity of 100% and a specificity of 91.7% for detecting breast cancer, compared with a sensitivity of 80.7% for mammography. The positive predictive value of MR imaging vs mammography is 40% vs 8.7%, and the overall accuracy of MR imaging is 92.2% vs 78.3%.

Molecular breast imaging technologies can detect defects at the cellular level by looking at biological activity using radiopharmaceuticals with a relatively short half-life. Positron emission tomography and positron emission mammography use fluorodeoxyglucose as contrast media. This radiopharmaceutical helps determine sites where there is a high rate of glucose metabolism. This nuclear medicine technology can be used to evaluate ambiguous mammograms and can provide useful information on metastasis to bone or soft-tissue areas. Positron emission tomography or positron emission mammography also are specific in detecting fibrotic scar tissue and necrosis, and they can assess the potential aggressiveness of breast cancer. However, the technology is affected by inflammation, infection, and the patient’s blood glucose levels. In addition, nuclear medicine scans are not accurate in detecting tumors smaller than 1 cm.

Breast-specific gamma imaging uses the radiopharmaceutical technetium Tc99m sestamibi, which has an affinity for cancer cells and accumulates in malignant lesions, which have a higher metabolic rate than benign tissue. The technology can be used to assess axillary node involvement, map lesions to optimize surgical planning, image dense breasts and implants, and evaluate scarring due to radiation or surgery. Although breast specific gamma imaging is less expensive than MR imaging, the high radiation dose limits its use.

Lymphoscintigraphy, or sentinel lymph node mapping, is used to track the spread of cancer from the breast. It is indicated for patients considering axillary node dissection to reduce the number of nodes removed. A radiopharmaceutical is injected directly into the tumor bed, after which the patient is taken for surgery. A Geiger counter is used to locate the first few lymph nodes on the chain that drains the breast so they can be removed.

### Histologic vs Cytologic Analysis

If a lesion is found on a mammogram, it should be evaluated properly to rule out malignancy, using multiple modalities if necessary. However, if malignancy cannot be ruled out, or if the finding has a high probability of malignancy, only a histologic or cytologic analysis can be used to confirm that the finding is malignant. Histologic or cytologic analysis results from interventional procedures for which the patient must be informed and fully prepared. The type of intervention performed depends on several factors, such as how suspicious a lesion is and its size, shape, and location as well as the number of lesions present. Other factors that determine the type of biopsy performed include the patient’s medical history, patient’s preference, training of the radiologist or surgeon, and type of facility where the biopsy is being performed.

Radiologists often use the Breast Imaging-Reporting and Data System (BI-RADS) to guide the choice of interventional procedure. The BI-RADS categorizes lesions according to their suspiciousness and recommends
a fine-needle aspiration, fine-needle biopsy, or a core biopsy on category 4 lesions. Occasionally a category 3 lesion will be recommended for biopsy, although the routine procedure is short-term follow-up. Because category 5 lesions are highly suggestive of malignancy, the minimal biopsy should be performed only if the protocol is to confirm a malignancy using a frozen section and then to perform a one-stage therapeutic operation. Otherwise, performing a minimal biopsy only adds an unnecessary surgical step in a patient’s treatment plan. If the minimal invasive biopsy leads to inconclusive results, a surgical biopsy is suggested. A surgical biopsy also is recommended if the cytologic or histologic findings are inconsistent with the imaging.

A cytologic analysis is performed after the removal of cell samples from the site with a 22- to 25-gauge needle. The cells are smeared on glass slides, air dried, and then stained. Routine cytology reports can be obtained within 24 to 48 hours.

A histologic analysis is performed on macroscopic tissue samples. The tissue specimen is obtained using core biopsy or open surgical techniques and preserved by fixing in a 10% formaldehyde solution. To harden the specimen, it is dehydrated, defatted, and embedded in warm paraffin. After cooling, the embedded tissue can be sliced as thin as paper, stained, and protected before being viewed under a microscope by a pathologist. Accurate results can be obtained in 3 to 5 days. However, preliminary results can be given in approximately 10 minutes. This is particularly useful during an open surgical biopsy when the surgeon removes a specimen while the patient is under anesthesia. The section is frozen, sliced, stained, and viewed under a microscope. If a malignancy is found, the information can be immediately conveyed to the surgeon.

Breast Interventional Procedures

Cyst Aspiration

An aspiration can be indicated to confirm suspicion of a cyst or relieve pain associated with a cyst by aspirating its contents. Aspirations can be performed free hand on palpable lesions or using ultrasound guidance and typically are performed using an 18-gauge needle.

One advantage of ultrasound-guided aspiration is that the patient can lie comfortably on the table during the procedure. Another advantage is that real-time imaging allows the radiologist to manipulate both the needle and the transducer as needed to obtain material from different parts of the lesion. If the lesion is found to be a simple cyst, the general recommendation is for routine follow-up. Lesions filled with nonbloody fluid and lesions that collapse during aspiration generally are considered normal. Lesions that are considered suspect might be solid, have cystic and solid components, or be indeterminate complex masses. Lesions with low-level internal echoes and those with fluid debris or sponge-like clusters of cysts with thickened walls need further study. In general, normal aspirates can include secretory, inflammatory, benign epithelium, or apocrine cells. If bloody fluid is aspirated, the lesion must be further evaluated by cytologic examination or biopsied.

Stereotactic Localization

If a lesion is nonpalpable, yet visualized on imaging, stereotactic imaging can be used to locate the exact coordinates of the lesion before a biopsy is performed. Stereotactic localization can be used on calcifications as well as circular, oval, or lobulated lesions. The technique is performed using either a dedicated prone table or a standard mammography unit with an add-on attachment.

The add-on unit images the patient in the upright position. These units are relatively inexpensive compared with dedicated prone units and do not require a dedicated biopsy room. Add-on units can image the posterior breast and axillary area better than the older prone units, but staff has less space in which to work. In addition, because the patient is upright and can see the insertion of the needle, there is a greater risk of a vasovagal reaction. Patient motion also can compromise the image with add-on units.

The prone units are dedicated procedure units where the breast of interest extends through a hole near the middle of the table. Some units allow both the ipsilateral arm and the breast of interest to extend though the hole, thus allowing access to far posterior lesions and allowing 360° tube rotation around the breast. The mammography unit and needle guidance device are located under the table. The table can be raised or lowered to suit the radiologist’s preference, and both the
The radiologist and technologist can remain seated during the procedure. The prone unit is more expensive, but there is less chance of a patient having a vasovagal reaction. In addition, these units essentially have only one use and might leave a room idle. Manufacturers have created a blended technology where a regular mammography unit can be converted to a prone biopsy unit as needed.\(^1,2\)

Whatever the equipment used for stereotactic imaging, angled images are obtained to triangulate the depth of a lesion within the breast and calculate its position in 3 dimensions. The horizontal (x-axis) and vertical (y-axis) dimensions are calculated with the nonangled radiograph. The tube is then angled 15° to the left and right along the x-axis to obtain 2 scout images that are used to calculate the lesion’s depth (z-axis). The stereotactic unit moves automatically for imaging and generates coordinates used to position a biopsy probe within the breast.\(^2\)

During the stereotactic procedure, appropriate placement of the needle is confirmed with prefire images. After confirmation of needle placement or adjustment, postfire images confirm that the biopsy needle traversed the area of interest. The breast must be compressed during the procedure because minimizing patient motion is critical. Any patient movement after prefire imaging will result in failure to obtain adequate samples of the lesion.\(^2\) After removal, the sample can be sent for cytologic or histologic analysis, depending on the type of sample removed. A radiopaque marker often is placed in the original site after sampling to identify the site of the microcalcifications or lesion.

Stereotactic localization is not recommended if the breast is compressed to less than 2.5 cm to 3 cm because a long-throw needle (ie, the distance the needle travels in the breast > 2 cm) will hit the detector plate of the stereotactic unit or penetrate the skin on the other side of the breast.\(^2\)

**Preoperative Needle Localization**

If stereotactic technology is not available, a preoperative needle localization technique can be used to locate any nonpalpable lesion or calcification within the breast. This procedure is done prior to a surgical incisional or excisional biopsy. The localization wire is placed in the breast using either mammographic or sonographic guidance. Typically, the patient is positioned with the area of interest under an open field or alphanumeric grid in the compression plate (see Figure 1).

After the skin is cleaned, the localization needle tip is inserted directly over the lesion. Care is taken not to penetrate to the opposite side of the breast. With the needle in place, the technologist takes an image. Compression is released without disturbing the needle and the second image is taken 90° to the first. (If the first image is in the craniocaudal projection, the second is taken in the mediolateral and vice versa.) These 2 images are used to triangulate the lesion’s location and position the needle accurately. The needle should be

---

**Figure 1.** A. Grid-type biopsy compression plate. B. Radiograph showing the breast compressed using the grid-type compression plate. C. An open field compression plate. Images courtesy of the author.
placed directly in the lesion with at least 5 mm of the wire within the lesion. Additional images can be taken as needed to confirm any re-placement of the needle. Once the final position of the needle is resolved, a guidewire is inserted through the needle. Most localization wires have a hook or curved end, which should be placed approximately 1 cm beyond the lesion (see Figure 2). The approach to the lesion should be parallel to the chest wall to minimize complications and, in general, the shortest approach should be used to reduce the risk of missing the lesion. After the needle localization procedure, the patient is sent to surgery for removal of the guidewire and the lesion.1,2

**Fine-Needle Aspiration or Biopsy**

Different fine-needle techniques can be used to obtain cellular material for cytologic analysis. Fine-needle aspiration removes the liquid content of a cyst. The technique can be performed solely to relieve pain and the aspirate discarded. The terms fine-needle biopsy (FNB) and fine-needle aspiration biopsy (FNAB) often are used interchangeably. When an FNAB is performed, the aspirate and any cellular material are sent for cytologic analysis. This technique can be used to diagnose both cystic and solid lesions such as fibroadenomas. If the lesion is not palpable, the needle can be guided to it under ultrasound guidance or mammographically using stereotactic breast localization. Fine-needle biopsy can reduce the need for surgical breast biopsy, but the accuracy of FNAB is dependent on the individual performing the procedure—the radiologist or surgeon—and the skill of the cytologist. Better specimens are obtained for cytologic assessment using smaller-gauge needles (eg, 22-, 23-, or 25-gauge). The needle length used depends on the depth of the lesion in the breast.1,2

FNAB requires aseptic but not sterile technique. The skin is cleaned with alcohol or Betadine, and a local anesthesia such as lidocaine is administered along the course of the proposed needle tract. FNAB collects cellular material that is then transferred to a glass slide where it is smeared, fixed, and stained. The slide is examined by a cytopathologist or cytotechnologist for diagnosis. In most cases, the cytopathologist or cytotechnologist is present during the FNAB procedure to verify adequate specimen collection. Care also must be taken in preparing the FNAB slides. The aspirated material must be spread evenly on the slides. Slides heavily stained by blood or other fluid are difficult to interpret, and if there is a delay in fixing the smear, it will become air-dried and impossible to interpret. FNAB provides cytologic rather than histologic specimens, and without a skilled cytopathologist or cytotechnologist, there is a higher probability of false-negative readings and a higher rate of insufficient specimen sample. Postprocedure patient care after FNAB is minimal. The skin is cleaned with alcohol, and bandages can be applied. Postbiopsy imaging of the site should be performed within 6 months to check for a missed lesion.1,2

**Core Biopsy Methods**

The core biopsy method is the most commonly performed, minimal invasive technique. It is inexpensive, easy to perform, and highly accurate for many lesions. Core biopsy removes tissue vs cells as with FNAB, and the tissue samples are obtained using an 11-gauge or larger needle. To yield adequate specimens, at least 5 core samples are needed to assess a lesion, and at least...
10 are needed to assess calcifications. Core biopsy is an outpatient procedure.1,3

The core samples can be obtained using a gun-needle combination or a vacuum-assisted device (see Figure 3). Gun-needle combinations are available as disposable and nondisposable, as well as long throw and short throw (ie, the distance traveled by the needle is < 2 cm). The length of the throw selection is determined by the breast’s size and the lesion’s location. Because of the larger needle size, core biopsy requires a 1- to 1.5-inch incision and sometimes requires stitches after the procedure.1,3

In the vacuum-assisted procedure, after numbing the skin, a quarter-inch incision is made to allow the insertion of the device’s hollow probe. The probe is guided into place using mammography, ultrasonography, or MR imaging. Once in place, a cylinder of tissue is suctioned through a hole in the side of the probe. A rotating knife inside the probe cuts the tissue sample from the breast. Several samples can be taken from the same incision. No stitches are needed, and there is minimal scarring. This method usually removes more tissue than a regular gun-needle core biopsy.1,3

The core biopsy also can be performed using an automatic or mechanical core “gun.” The gun-needle combination is designed to move a cutting needle rapidly through the breast. It has an inner needle with a trough extending within it. One end is covered by a sheath and attached to a spring-loaded mechanism. When the mechanism is activated, the needle moves forward, filling the trough with breast tissue. The outer sheath instantly moves forward to cut the tissue and keep it in the trough. It takes only a fraction of a second to obtain a sample, but the needle must be withdrawn to collect the tissue for each sample. Because each reinsertion results in additional destruction of breast tissue and hemorrhage into the area of biopsy, a small lesion can withstand only a limited number of insertions.1,3

Tissue samples from the core biopsy are sent for histologic analysis. In addition, most radiologists recommend radiographing the specimen using magnification technique. After the core biopsy, compression should be maintained at the incision site for 5 minutes to achieve hemostasis and to minimize hematoma formation. An ice pack can be applied to minimize swelling. The skin at the incision site should be closed with closure strips to minimize scarring. After a core biopsy, patients should be instructed to keep the wound dry and to leave the dressing on for at least 3 days. They should avoid strenuous activity for at least 1 to 2 days after the procedure.1,3

Ultrasound Guidance

Core biopsy can be performed using either ultrasound or MR imaging guidance. Ultrasonography is a highly accurate way to evaluate suspicious masses in the breast. If the lesion can be localized using ultrasonography, it can be biopsied with ultrasound guidance, which is a faster method and uses no ionizing radiation. Many radiologists prefer to do free-hand positioning of the needle within the breast, although there are needle-guidance systems available. Whatever the method used, the same person must control both the transducer and the needle. The procedure can take less than 1 hour and most patients are able to resume their usual activities later the same day, although athletic activities should be avoided on the day of the biopsy. The patient should be positioned either supine or turned slightly to the side. The patient’s ipsilateral arm should be raised, with the hand underneath her head. The ultrasound probe then is used to locate the lesion. If the lesion is in the lateral aspect of the breast, the patient should be in the oblique position for the examination. If the lesion is in the medial aspect of the breast, the patient should be supine.1,3

Advantages of the free-hand system include the ability to approach the lesion with the needle parallel to the chest wall, thereby avoiding puncturing the chest as well as eliminating the
expense of added equipment. Depending on the probe configuration, the geometry of the acoustic beam, and the route of the needle entry, a small portion of the needle might be visible as an echogenic dot or, if the needle entry is aligned with the acoustic beam and is nearly perpendicular, the entire shaft including the needle tip might be visible. Because of the throw of most core biopsy needles, the skin entrance site should be farther from the lesion and the transducer than in the case of FNAB, and the needle tip should always run parallel to the chest wall to avoid puncturing the pleura.1,3

Local anesthetic is injected to be sure that the patient feels no discomfort during the procedure. Ultrasonography can be used to guide the injection of anesthetic along the route to and around the lesion. Typically, a 4-mm or shorter incision is made in the skin at the site where the biopsy needle is to be inserted. The radiologist then guides a hollow core biopsy needle or the vacuum-assisted needle directly into the mass and obtains specimens using ultrasound guidance. Usually a minimum of 5 to 10 samples are taken using the core biopsy method, or at least 12 when using the vacuum device. The needles are angled differently for each core to obtain core samples from different parts of the lesion.1,3

Pre- and postfire images are always obtained to document the position of the needle relative to the lesion. It is not usually necessary to close the tiny skin incision with sutures, but a small compression dressing can be applied.

Ultrasonography-guided biopsy cannot be used if the lesion cannot be visualized with ultrasonography. Also, calcifications within a cancerous nodule are not shown as clearly with this modality compared with radiography. Another drawback of ultrasonography is that it cannot easily be used for deep lesions or large breasts because the 12 to 16 MHz transducers required for the necessary resolution in breast ultrasonography do not penetrate well beyond 3 cm to 4 cm.1,3

Magnetic Resonance Guidance

If a suspicious area is detected only on MR imaging or is not seen clearly on ultrasonography or mammography, the radiologist might recommend an MR-guided breast biopsy. As with ultrasonography- or mammography-guided minimally invasive biopsies, the MR biopsy is less costly than surgical biopsy and leaves little to no scarring.

MR breast biopsy can be performed using an open breast coil, which allows easy access to the breast. MR biopsy also is possible with full-field (ie, closed) magnets by immobilizing the breast within a guidance device, obtaining the MR images, then placing the needle according to coordinates generated using the MR images. Guided by MR imaging, the radiologist generally places an introducer, a biopsy needle within a vacuum-powered instrument, into the suspicious area and removes a sample. Generally, a 9-gauge stainless steel core needle is used to remove a small, cylindrical tissue sample, which is sent to a laboratory for analysis. The needle used must be MR-compatible and there are now new MR pulse sequences that significantly reduce artifacts from the needle. Many of the newer biopsy systems employ stereotactic guidance with a biopsy grid that precisely maps the location of the lesion. Many also use plastic localizing markers to allow pinpoint accuracy in identifying, localizing, and confirming the lesion’s position.1,3

Open Surgical Biopsy

An open surgical breast biopsy, sometimes called a partial mastectomy, is needed if the results of an FNAB or core biopsy are inconclusive, the lesion is located very close to the chest wall or immediately behind the nipple, or if the lesion or lesions are so hard that the radiologist cannot obtain an adequate sample. In addition, the open surgical biopsy is the next step after the wire localization.1,3

The surgical biopsy requires full sterile techniques. The procedure is generally performed as a same-day surgery with the patient given a general anesthetic. There are few complications, and most patients report pain at the site for only 1 to 2 days. Generally, aftercare treatment includes taking pain medication and using a cold pack.

There are 2 types of surgical biopsies. In an incisional biopsy, a sample of the lesion is removed for histologic testing while the patient is still under anesthetic. If the lesion is malignant, an excisional biopsy can be performed in which the entire lesion is removed, leaving clean margins.
Comparison of Breast Biopsy Techniques

Complications and the severity of biopsy adverse effects depend on the method used. In the case of needle localization, inaccurate placement or displacement of the wire can occur. With any breast biopsy, patients can develop an unexpected allergic reaction to local anesthetic, and there is a risk of bleeding, hematoma, or infection whenever the skin is penetrated. Infection requiring antibiotic therapy is rare. To avoid excessive bleeding, patients on aspirin or blood thinners are advised to stop their medication 5 days prior to the procedure.\(^1,2\)

The open surgical biopsy has the lowest false-negative rates (0.5%) but is the most invasive. Between 20% and 30% of breast cancers in the United States are still diagnosed surgically. The reported false-negative rate for malignancy with core biopsy is in the range of 2% to 6.7%, with a mean rate of 4.4%. False-negative findings are more likely to occur with microcalcifications. Stereotactic core-needle biopsy using a 14-gauge needle has a 90.5% sensitivity rate and a 98.3% specificity in diagnosing breast masses, compared with 62.4% and 86.9%, respectively, for fine-needle aspiration.\(^3,18,19\) A common error in core biopsy is understating the multifocality of the cancer. For example, a ductal carcinoma in situ could be diagnosed with a core biopsy, but invasive cancer might be found with excisional biopsy. The best core samples are obtained using a long-throw gun and taken with a 14-gauge needle. Insufficient sampling is reduced if at least 5 samples are taken when biopsying masses. The 14-gauge automatic needle has 2 main limitations: If multiple specimens are obtained, the later samples are contaminated with blood, and retrieval of calcifications is difficult if the calcifications are not along the line of fire of the needle or are located in small lesions.\(^18-20\)

FNAB is less expensive, less invasive, and faster than core biopsy, although it is more likely to lead to error due to insufficient sampling. The false-negative rate for the FNAB can range from 5% to 20% and is lower for experienced operators. The false-negative rate can be further reduced by using smaller-gauge needles and by increasing the number of aspirates obtained. The most substantial limitation for FNAB is the high rate of insufficient sampling. Rate of insufficient samples for FNAB under stereotactic guidance is higher and can reach 39.9% when compared to ultrasound guidance (8.5%). Rates are also higher for calcifications (46.1%) vs masses (26.6%). The rates for all types of lesion (masses and calcifications) are higher if there is no on-site cytopathologist (31.2% vs 14.5% with an on-site cytopathologist).\(^2,18,19\)

Ultrasound-guided biopsy performed using any of the biopsy methods is faster and less expensive than stereotactic biopsy. It also takes less time than surgical biopsy and causes less tissue damage. Ultrasonography offers real-time visualization of the needle, which means the motion of the biopsy needle can be tracked. It also delivers no ionizing radiation. Ultrasonography enables better biopsy of the axillary and chest wall areas that are difficult to biopsy using radiographic guidance. Most palpable lesions are best biopsied with ultrasound guidance, whereas calcifications are best biopsied mammographically. The exception is a cluster of cysts, which is difficult to evaluate using ultrasonography. Palpable lesions, however, must be suspicious or indeterminate on ultrasonography to warrant an ultrasound biopsy.\(^1,4\)

Specimen Radiography

The specimen is the breast tissue removed during a surgical or core biopsy. A specimen radiograph should be performed after every biopsy to confirm that the lesion was removed and that the margins are clean (see Figure 4). When imaging the specimen after a surgical biopsy, speed and efficiency are important because the patient might be under general anesthesia. If possible, the mammographer should use compression, and magnification is recommended for calcifications. If microcalcifications are present in a specimen, they should be counted and noted. The radiologist should indicate where the pathology is located on the specimen, as this will help the pathologist evaluate the lesion. This is especially important in patients with an extensive area of suspicion. If the tumor is close to the margins of the specimen or if the margins are positive for cancer, additional tissue must be excised before the incision is closed.\(^1\)

Breast Cancer Treatment Options

Breast cancer is not a medical emergency and most women are advised to consult more than one doctor, thereby getting a second opinion, before proceeding...
Breast cancer can be treated with surgery, radiation, or drugs (chemotherapy and hormonal therapy). Many oncologists use one or more of these combinations, depending on the type and location of the cancer, whether the disease has spread, and the patient’s overall health status.

Before treatment begins, the cancer must be staged and its size and location determined. It is essential to conduct tests for estrogen or progesterone receptors and tests to determine whether the cancer overexpresses any protein genes such as ERBB2 (formerly HER2 or HER2/neu) before treatment starts. Staging and treatment involve a multidisciplinary approach and the team of professionals must carefully coordinate communication to ensure quality patient care. The professional team can include a radiologist, surgeon, oncologist, dosimetrist, radiation therapist, radiation physicist, pathologist, reconstructive or plastic surgeon, gynecologist, and an oncology social worker.

Once treatment begins, the patient should follow a strict schedule and complete all treatment. Studies have shown that once radiation treatment begins, delayed or incomplete treatment often leads to worse outcomes and higher recurrence rates. As many as 20% of older women experience delayed or incomplete radiation treatment after breast-conserving surgery, and this can adversely affect disease-free survival. Delaying treatment by 8 weeks or more significantly increased the odds for recurrence or new breast malignancies in patients with early breast cancer. Patients whose radiation therapy was delayed 12 or more weeks after surgery, or 8 or more weeks after chemotherapy, were more than 4 times more likely to experience a subsequent breast cancer event, regardless of stage. For all patients, not completing radiation therapy was not associated with an increased risk for recurrence or relapse, but among those with stage I disease, an incomplete radiation therapy regimen was associated with worse overall survival.

Even after the cancer has been removed and treatment completed, the patient will continue with follow-up visits to an oncologist. Some patients will also be placed on long-term tamoxifen treatment and will be monitored carefully. Pregnancy after breast cancer treatment is no longer ruled out, and studies have confirmed that pregnancy does not increase the risks for recurrence of breast cancer. With better detection and treatment options, the 5-year survival rate after breast cancer diagnosis has been steadily improving (see Table 1).

Table 1

<table>
<thead>
<tr>
<th>Breast Cancer Survival Rates by Stage</th>
<th>5-year Survival Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>I</td>
<td>100</td>
</tr>
<tr>
<td>II</td>
<td>93</td>
</tr>
<tr>
<td>III</td>
<td>72</td>
</tr>
<tr>
<td>IV</td>
<td>22</td>
</tr>
</tbody>
</table>
Staging Breast Cancer

Breast cancer is classified in stages 0 to IV. A patient’s stage depends on the extent of the primary tumor, the spread of the cancer to regional lymph nodes, and whether distant metastasis has occurred. In staging, lower numbers represent less spread of the cancer. In the TNM staging system, the tumor, represented by the letter $T$, describes the size of the lesion. The lymph node involvement, represented by $N$, indicates the number of nodes involved.26

After a tumor is removed from the breast, the specimen is further examined for antibodies, enzymes, and proteins. This provides information on the prognosis and guides the choice of therapeutic options. Cancer cells might contain estrogen or progesterone receptors. Breast cancers that have estrogen receptors often are referred to as ER-positive (or ER+) cancers, while those containing progesterone receptors are called PR-positive (or PR+) cancers. About 2 out of 3 breast cancers have at least one of these receptors. One widely known marker is the growth-promoting protein called human epidermal growth factor 2 (HER2). Cancers with this marker can be treated with the drug trastuzumab (Herceptin). About 1 out of 5 breast cancers have too much of this protein. The ERBB2 gene instructs cells to make this protein, and tumors with increased levels of HER2 are referred to as HER2-positive.10,20,25

Mastectomy

Mastectomy is a surgical procedure in which the entire breast is removed. During the procedure an incision is made along the perimeter of the breast close to the tumor, and the underlying tissue is cut free and removed. There are different types of mastectomies.

In the radical mastectomy, the entire breast, lymph nodes, and chest wall muscles under the breast are removed. It is a very disfiguring, deforming, and debilitating procedure and is not commonly performed.26,27

The modified radical mastectomy removes the entire breast, including the nipple and areolar region and some of the underarm lymph nodes. This is the most common mastectomy procedure performed today. The modified radical mastectomy generally requires a hospital stay of 3 to 8 days depending on the body’s rate of healing. This surgical procedure can take 2 to 3 hours. The incision is closed with stitches or clips, which are removed within a week of the surgery. After the surgery, a draining tube often is placed in the breast to remove blood and lymph fluids, which accumulate during the healing process. Drainage tubes are removed after 2 weeks.25

In a skin-sparing mastectomy, the nipple and areola complex, existing surgical or biopsy scar, and all of the breast parenchyma are removed. By retaining most of the skin, skin-sparing mastectomy simplifies the reconstruction process and improves the cosmetic appearance of the breast. Preserving the areola is possible in selected cases. This process is contraindicated for some patients, however.21,26

Another procedure, the quadrantectomy or partial mastectomy, is an option for some women. This surgery removes a quarter of the breast, including the tumor, with clear margins of up to 2 to 3 centimeters of breast tissue, skin, and some chest wall muscle. As in a mastectomy, the lymph nodes in the axilla will be removed to check for cancer spread.21,26

The mastectomy generally proceeds normally for most patients; however, complications can occur, including hematoma or microhematoma, which appear on a mammogram as mixed-density oval or circular calcifications. Patients also can develop an infection that requires treatment. In addition, clear fluid (seroma) can become trapped in the wound.26

Lumpectomy

Lumpectomy is the most breast-conserving surgery available. Lumpectomy is the removal of the breast cancer tumor and the surrounding margins of normal breast tissue. A lumpectomy can be followed by 6 weeks of radiation therapy to ensure that all the cancer cells in the remaining breast have been destroyed. Radiation treatment usually begins one month after surgery, giving the breast time to heal. Other options included with the lumpectomy are chemotherapy to control the systemic spread of breast cancer or a 5-year or longer treatment with the drug tamoxifen.21,26

A number of factors determine whether a patient should have a modified radical mastectomy vs a...
lumpectomy. Some of these factors include tumor size, tumor type, and cancer stage. Other patients might not have clear choices or might choose the modified radical mastectomy on the basis of anecdotal evidence rather than on survival statistics. Breast conservation should be performed only if the treatment provides a cure rate equal to that obtained from a mastectomy. Indications for lumpectomy can include stage I or II ductal carcinoma in situ in which the cancer is still confined to the ducts. Poor candidates for lumpectomy include patients with 2 or more areas of cancer in the same breast (ie, multicentric disease), especially if the cancerous areas are widely separated. Women who have already undergone radiation in the breast or chest area cannot have another lumpectomy with radiation because repeated radiation treatment to the same area is contraindicated. Women whose previous lumpectomy did not completely remove the cancer cannot repeat the procedure. Radiation is not recommended in the early stages of pregnancy; therefore, if radiation is to follow a lumpectomy, women who are pregnant at the time of the lumpectomy will need an alternative procedure or might need to reconsider the pregnancy. The tumor size in relation to breast size is important because this can rule out breast conservation treatment. In some patients, the cosmetic result will not be acceptable and could result in breast deformity. Also, women with large cancers in small breasts or a cancer more than 5 cm in diameter typically have poor cosmetic results after a lumpectomy.1,2,6

Patients considering breast conservation surgery who need radiation treatment must remember that the radiation treatments last several weeks. If the patient cannot travel to a radiation treatment facility or undergo the full treatment, she cannot have breast conservation surgery. After the lumpectomy, the pathologist must check the tumor margins to make sure the surgeon removed the entire cancerous tumor. There should be no cancer present in the outermost edges of the specimen sample. Preliminary checks are usually made while the patient is still in the operating room, but the final result might not be available until days later. If the final results reveal positive margins, then additional surgery is necessary.1,3,6

Lumpectomy can be performed using a local anesthetic and sedation, or general anesthesia depending on the extent of the surgery needed. The surgeon makes a small incision over or near the site of the lesion, then excises the lesion plus a margin of at least 1 cm of normal surrounding breast tissue. In addition to a lumpectomy, a sampling of the axillary nodes or an axillary lymph node dissection is necessary to determine whether the cancer has spread outside the breast.1,3

Seroma usually fills the surgical site after the operation and helps to naturally remold the breast shape. Gradually, the seroma is absorbed and the body replaces it with scar tissue over a period of months. Patients usually require a 1- to 2-day hospital stay and most can resume normal activity in 2 weeks. The extent of breast soreness depends on the amount and location of tissue removed during surgery and the type of axillary dissection done. In rare instances, the seroma will recur after the lumpectomy, but this is easily aspirated on an outpatient basis.

Applying compression can reduce the risk of repeated seroma, or an injection of ethanol or an autologous fibrin clot can be used to fill and harden the space. A newer technique is an injection of a fibrin sealant during the lumpectomy to reduce accumulation of serous fluid. The fibrin sealant, fibrogen, is a protein from the blood that forms a clot when combined with thrombin, another blood-clotting protein.1,3

**Lymph Node Biopsy**

Lymph node biopsy or axillary lymph node dissection is a surgical procedure in which some or all of the lymph nodes are removed for testing. The procedure, called a lymphadenectomy, usually follows a lumpectomy or mastectomy to determine whether the cancer has spread to areas outside the breast. Complications of lymph node biopsy include infection, abnormal sensations, fluid collection in the axilla, and lymphedema.1,3,28

Researchers have concluded that the lymph node biopsy is unnecessary and the minimally invasive procedure called sentinel node biopsy, in which only 1 to 4 axillary nodes in the chain draining from the breast are removed, should be the treatment of choice. The sentinel node biopsy generally results in fewer complications than lymph node biopsy. To identify the sentinel node, the oncologist gives the patient an injection of a radioisotope, which sometimes is used with a blue dye.
A sentinel node biopsy plus radiation, chemotherapy, or both is an appropriate treatment for patients with early breast cancer (stage I or II) who have no palpable adenopathy and 1 to 2 sentinel lymph nodes containing metastases. The rationale is that chemotherapy and radiation therapy are both designed to kill cancer cells exiting the breast through the lymph system.1,23-25,28

**Overview of Radiation Therapy for Breast Cancer**

Radiation therapy has been used to treat cancer since shortly after the discovery of x-rays in 1895. As technology advanced, it provided the ability to produce a consistently high-energy beam, and in the 1950s the use of the linear accelerator (LINAC) became the mainstay for treatment delivery.21 Radiation therapy is practiced by exposing a specific body area, in this case the breast and torso, to high-energy radiation to destroy cancer cells, while at the same time limiting other parts of the patient’s body from radiation exposure. Radiation therapy can be administered either externally or internally. External-beam radiation therapy (EBRT) usually is given once a day for 6 to 7 weeks, while internal radiation, or brachytherapy, usually is given for 1 to 5 days. Some oncologists suggest that following a lumpectomy, giving a boost—a short, localized course of radiation—can be beneficial, especially for younger women (ie, aged younger than 40 years) with early stage breast cancer.21-23

Radiation therapy can be used to treat breast cancer in 2 ways: primary or adjuvant. Primary radiation is the use of radiation alone to treat breast cancer. Adjuvant radiation therapy uses radiation with surgery, chemotherapy or both to treat possible residual cancer. If the patient is receiving chemotherapy, the chemotherapy is usually given before the radiation treatment starts.27,29

**External-Beam Radiation Therapy**

Therapeutic radiation uses photons, made up of x-rays or gamma rays, or particulate radiation, such as electrons or neutrons. All of these are ionizing forms of electromagnetic radiation. High-energy photons are created from radioactive sources such as cobalt, cesium, or LINACs. The energy of the photons is expressed in electron volts and typically is used in megavolt energy ranges, whereas diagnostic imaging is in the kilovolt range.21-29

After performing a physical examination and reviewing the patient’s medical history and other pertinent data, the radiation oncologist discusses the available treatment options with the patient before treatment begins. The oncologist also might request further diagnostic testing.27,29

EBRT usually is delivered with a LINAC, which focuses and directs the radiation beam to the area designated for treatment. For breast cancer, LINAC-based EBRT is the most common type of radiation treatment administered. It involves the use of high-energy rays to destroy cancer cells in and around the breast tissue, including the chest wall, axilla, and lymph nodes. Higher energy photon beams penetrate deeper into the tissue. The oncologist determines the total dose of radiation to be given and the medical dosimetrist plans how that dose should be administered while limiting the dose to healthy tissue.21,29

Most of the biologic effects of ionizing radiation are thought to be caused by the improper repair of damage to DNA in the cells. DNA stores genetic information on cell growth, division, and function. Radiation destroys cancer cells in the treatment volume by damaging the cells’ DNA. There also is damage to the DNA of normal cells, although normal cells usually can repair themselves between treatments.

Pretesting identifies the specific area of the body to be treated, limiting the amount of radiation to healthy tissue. The treatment planning team, including the radiation oncologist, medical dosimetrist, medical physicist, radiation therapist, or a combination of these professionals, constructs a treatment plan around the information gathered from the pretreatment simulation. This information, usually in the form of volumetric imaging scans, is used to develop the treatment angles, dose distribution, and optimal field shape design. Computed tomography scans of the area can be taken and digitally reconstructed radiographs are created. The digitally reconstructed radiograph is a static 2-D image using reconstructed 3-D image scan information.

The digitally reconstructed radiograph is used to verify and document that the patient setup matches the treatment plan and the patient is being treated correctly.21,29 Beam-shaping blocks and multileaf collimators
often are used to protect normal tissues outside of the area of interest from receiving radiation. In addition, no one is permitted to be in the treatment room while a treatment is being delivered, so the radiation therapist monitors the patient via closed-circuit television and with a 2-way intercom.

EBRT usually begins 4 to 6 weeks following surgery to allow the patient to heal. EBRT takes only a few minutes to administer after the patient is in the correct position. Treatment usually is given 5 times per week for a total of 25 to 28 days to the entire breast, with 4 to 8 treatments given to the tumor bed only. Generally, these treatments are given with the same LINAC but using an electron beam instead of a photon beam. The electron beam penetrates only superficially.

Although the patient does not feel anything while the radiation beam is on, adverse effects can develop. Some of these include damage to the skin and tissue. Because this damage is unpredictable, some surgeons prefer that women delay reconstruction until after radiation therapy is completed. This minimizes the risks of unfavorable cosmetic outcomes such as the formation of scar tissue around the implant, a condition known as capsular contracture that can lead to hard and painful breasts. However, this practice is controversial and other surgeons maintain that if reconstruction is performed immediately, women fare better emotionally than if reconstruction is delayed.

Adverse effects of radiation can present early or late. The early effects usually occur 3 to 4 weeks into treatment and often resolve completely 4 to 6 weeks after treatment is complete. Later effects can take months or years to develop and are often permanent. Interruptions to radiation therapy are limited as much as possible to avoid altering the outcome of the treatment. Adverse effects might include:

- Fatigue.
- Swelling.
- Heaviness in the breast.
- Sunburned appearance.

During the treatment period, patients are advised to:

- Wear loose-fitting clothing.
- Wear a bra that is not too constricting.
- Wear material that breathes.
- Avoid exposing the treatment area to sunlight.
- Avoid extreme temperatures to the treatment area (eg, hot water, heating pads, warm compress, and ice packs).
- Avoid using lotions or powders on the treated area. The patient should ask the oncologist specific questions about items to avoid and which products might be soothing to the treated area.

Intensity-Modulated Radiation Therapy

Of the EBRT options available, intensity-modulated radiation therapy (IMRT) is increasingly used. It can minimize the dose to a patient’s pleura, lungs, and even the sternum more than ever before, delivering a more precise dose to the target area.

With reduced doses to normal tissue, IMRT can provide higher treatment doses to the target volume while limiting adverse effects. However, different parameters factor into the way a treatment is administered, such as the size, location, and type of cancer; the patient’s general health; and other medical therapy the patient is receiving. In general, women who received IMRT have reported fewer adverse effects compared with those undergoing traditional EBRT, including less swelling and skin color changes. Research shows that 41% of women who received IMRT had reddened or itchy skin compared with 85% of women receiving conventional radiation. Also, only 1% of women receiving IMRT have breast swelling, compared with 28% of women receiving conventional treatment. Changes in skin color were reported in 5% of the women undergoing IMRT, compared with 50% of those who had conventional treatment.

Internal Radiation or Partial Radiation

Internal radiation, called brachytherapy, also has been used in the treatment of breast cancer. Instead of using an external radiation beam, a radioactive source is placed internally. Brachytherapy can be used to deliver high doses of radiation to small areas. However, the patient must meet specific criteria to be eligible to receive brachytherapy to the breast.
Brachytherapy generally is used to give treatments over 3 to 5 days, instead of 6 to 7 weeks as with EBRT. The idea is to apply a more intense dose of radiation to the tumor bed, rather than to the entire breast. This is called accelerated partial breast irradiation, and it can be delivered using a few different methods. \(^{30,32}\) For example, a balloon is inserted into the tumor bed and inflated to fill the cavity following a lumpectomy procedure. Treatments are usually done on an outpatient basis, given twice a day for 5 days, with 4 to 6 hours between treatments. Each day the patient usually receives a scan, often a computed tomography scan, to evaluate changes to the tumor bed regarding air in the cavity, the balloon placement and volume, and correct distance from the edge of the device to the skin surface and chest wall. Small corrective actions can be made to ensure dose accuracy and homogeneity. \(^{21,31,33,34}\) The device or balloon remains in place for the entire course of treatment.

During each treatment, a tiny radioactive seed that is attached to a guidewire is inserted into the balloon via a catheter. The radioactive seed is maneuvered to various points within the balloon, delivering radiation in a prearranged pattern to shape the overall treatment. After the course of treatment is complete, the balloon is deflated and removed from the patient’s breast. The use of this method means the radiation is in the breast only during the short treatment sessions, and the patient is not considered radioactive as with other radiation used internally for medical purposes. Several devices currently on the market can be used to perform accelerated partial breast irradiation, offering optimal conformity of treatment delivery. \(^{21,31,33-35}\)

**Chemotherapy**

Chemotherapy uses a variety of drugs and can be used to stop the spread of cancer to other parts of the body, slow the growth of cancer, kill cancer cells that might have spread beyond the breast, or relieve symptoms of cancer. Chemotherapy can be given before or after cancer surgery, with or without other treatments, and is often a combination of drugs. Neoadjuvant chemotherapy is given before surgery to help shrink the cancerous tumor. Adjuvant chemotherapy is chemotherapy given in addition to another breast cancer treatment (eg, mastectomy). \(^{22}\)

More than 90 chemotherapy drugs are available. Alkylating agents work directly on the DNA to prevent cancer cells from reproducing. These drugs work on all phases of the cell cycle. Nitrosoureas act similar to alkylating agents. They interfere with enzymes that help repair DNA. Antimetabolites are drugs that work during the synthesis (S) phase of the cell cycle and interfere with DNA and ribonucleic acid growth. Antitumor antibiotics interfere with DNA by stopping enzymes and mitosis or by altering the membranes that surround cells. They are not the same as the antibiotics used to treat infection and work in all phases of the cell cycle. Mitotic inhibitors stop mitosis or keep enzymes from making proteins needed for cell reproduction. They are plant alkaloids or compounds derived from natural products and work during the mitosis (M) phase of the cell cycle. Corticosteroid hormones are steroids and natural hormone-like drugs used to kill cancer cells or slow their growth. Many are used with other drugs to increase their effectiveness. Sex hormones are drugs that alter the action or production of the female or male hormones and are used to slow the growth of cancer cells that are hormone-receptor positive. \(^{21,23}\)

Most physicians prefer a combination of lower doses of multiple drugs vs a high dose of one powerful drug. Low-dose drugs are associated with fewer adverse effects. Chemotherapy is considered a systemic form of cancer treatment because the drug is distributed throughout the entire body via the bloodstream. Chemotherapy drugs therefore affect all tissues and organs in the body. These drugs tend to attack cells that are quickly dividing, whether cancerous or not. \(^{21,23}\)

Generally, chemotherapy regimens are tailored for the individual patient and can vary tremendously. The type of treatment will depend on the patient’s age, overall health, cancer stage and grade, past or future treatments, and other health problems. Some patients receive chemotherapy as the only form of treatment because chemotherapy can be used to cure their type of cancer by totally destroying the cancerous cells in the body. However, chemotherapy also can be used to control the cancer and extend the patient’s life by stopping the cancer from growing and spreading, or as a palliative treatment to relieve symptoms caused
by the cancer. If chemotherapy is a part of a combined treatment, it is given first, before radiation or hormonal treatment.21,23

Some chemotherapy drugs are given orally as tablets or liquids or applied to the skin as a cream or lotion. Chemotherapy also can be given as an intramuscular injection or injected directly into the cancerous area. Chemotherapy courses can be given daily, weekly, monthly, or using other scheduling options, depending on the patient’s response to the drug. Generally, the treatment lasts 3 to 6 months, but most chemotherapy sessions include built-in rest cycles to give the healthy cells recovery time.21,23

Most chemotherapy for breast cancer is given intravenously through a semipermanent catheter or vascular access device implanted into a large vein in the arm, hand, or subclavian vein. A vascular access device is useful for giving several drugs at once, for long-term therapy, and for continuous infusion chemotherapy. The peripherally inserted central catheter and the implantable venous access port (eg, Port-A-Cath, Smith Medical) are examples of vascular access devices. The peripherally inserted central catheter is placed in the arm and threaded through the vein near the heart. No surgery is needed for this type of placement. The Port-A-Cath requires surgery to implant a catheter under the skin to provide continuous access to a large central vein.

Chemotherapy causes the most damage to bone marrow and blood cells, cells of the hair follicles, and cells in the reproductive and digestive tracts. Adverse effects from chemotherapy vary depending on the strength of drugs used, the dosage, and the duration of treatment. Some patients experience few adverse effects, whereas others experience many common adverse effects. The closer a woman is to menopause when she undergoes chemotherapy, the more likely she is to experience premature menopause. Symptoms include hot flashes, vaginal dryness, and irregular menstrual cycles. Some chemotherapy drugs also can cause birth defects; therefore, a woman should not be pregnant while on chemotherapy treatment.21,23

The main adverse effects from chemotherapy are nausea and vomiting, which often are caused by irritation to the lining of the stomach and duodenum, which in turn triggers the vomiting center in the brain. Patients also can experience mouth sores, taste changes, and decreased appetite. Diarrhea occurs because the rapidly dividing cells in the digestive tract are damaged, and constipation is due to loss of motility, poor diet, and certain medications. Other adverse effects can include hair loss (alopecia), which is generally temporary and occurs because hair follicles are weakened by the chemotherapy drugs, causing hair to fall out at a much faster rate than normal hair growth. Hair loss can occur 2 to 3 weeks after treatment begins, but grows back at the end of treatment, sometimes with a change in texture. Some patients also report tingling or burning sensations, numbness in the hands and/or feet, and skin irritations including redness, itching, peeling, or acne, and dark, brittle, or cracked fingernails, toenails, or both.21,23

Chemotherapy affects the bone marrow that makes blood cells, including red blood cells, white blood cells, and platelets (see Table 2). A low white cell count, called leukopenia, makes the body more susceptible to infections. Patients undergoing chemotherapy need careful monitoring of their immune system because white cells are an essential component of the body’s immune system. Red blood cells bring oxygen to the tissue. A reduction in red blood cells causes anemia, which is associated with fatigue, dizziness, headache, irritability, and increased heart rate or breathing. Platelets help to prevent unnaturally long bleeding. Low platelet count is referred to as thrombocytopenia.21,23

Table 2
Blood Cell Characteristics

<table>
<thead>
<tr>
<th>Type</th>
<th>Normal Count (mm$^3$)</th>
<th>Abnormally Low Count</th>
<th>Average Normal Life Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>4000-10 000</td>
<td>Leukopenia</td>
<td>6 hours</td>
</tr>
<tr>
<td>Red</td>
<td>4 million-6 million</td>
<td>Anemia</td>
<td>120 days</td>
</tr>
<tr>
<td>Platelets</td>
<td>150 000-450 000</td>
<td>Thrombocytopenia</td>
<td>10 days</td>
</tr>
</tbody>
</table>
Symptoms include the tendency to bruise easily or develop large and small bruises. Patients also can bleed longer than usual after cuts or have nosebleeds or bleeding gums. Severe cases of thrombocytopenia can cause internal bleeding.

Several drugs are available to counter the adverse effects of chemotherapy. For example, patients with low blood cell counts during chemotherapy can be given medication to help raise their blood cell or platelet counts, or they can be given a transfusion. Vasomotor symptoms can be managed with steroids or antidepressant drugs. A less-invasive treatment for some of the adverse effects of chemotherapy is acupuncture, which can be used to manage hot flashes, night sweats, and other vasomotor or related symptoms.21,23

**Hormone Treatment**

The idea of molecular treatment is to determine the exact genetic profile of the altered cancer cells and design a treatment plan based on the nature of these cells or subcells. This involves addressing each patient’s unique biology and disease structure, leading to a higher level of treatment efficiency and more successful outcomes.21,37-39

The earliest attempt at molecular treatment in cancer therapy was the drug tamoxifen. Tamoxifen has been used since the 1970s to treat patients with estrogen-receptor positive breast cancer. It is an antiestrogen drug called a selective estrogen receptor modulator. These modulators are drugs that block estrogen and can lower the risk of breast cancer recurrence in postmenopausal women after surgery. Tamoxifen prevents estrogen from latching onto tumor cell receptors and directing them to multiply. This slows or stops the growth of cancer cells in the body.40

Tamoxifen can be used after surgery and when cancer recurs after treatment because it helps to prevent new cancers from developing in women who have already been treated for breast cancer. Tamoxifen also is used to shrink large tumors so that they can be removed. Although tamoxifen does not prevent recurrence of estrogen-receptor negative breast cancer, it could make these cancers more detectable. In one study, ER—cancers were detected 77.4% of the time in a placebo group compared with 94.7% of the time in a group receiving tamoxifen.21,40-42

A study by the National Cancer Institute found that compared with the women on placebo, those taking tamoxifen had almost 50% fewer cases of invasive breast cancer. However, the benefits of tamoxifen were found to be negligible after 5 years.40,41

Tamoxifen is recommended for women at high risk for breast cancer, including women aged older than 60 years or women aged 35 to 59 years who have increased risk factors for breast cancer. Because of the adverse effects of tamoxifen, the breast cancer risks should be higher than average before a woman should consider taking tamoxifen. Increased risk factors can include a BRCA gene alteration, a previous history of breast cancer, family history of breast cancer, an atypical breast biopsy, not having had any children, having a first child at age 30 or older, starting menstrual periods before age 12, or going through menopause after age 50. Tamoxifen can cause depression, fatigue, and dizziness. Some patients experience vaginal dryness, itching, or bleeding and menstrual irregularities. Other adverse effects include loss of appetite, nausea and/or vomiting, weight gain, mild allergic reactions (eg, skin rashes), temporary thinning of the hair, headache (with some people affected by migraines reporting a change in the pattern of their headaches), and visual problems such as blurred or reduced vision.21,39

Tamoxifen has some weak estrogen-like properties and increases a woman’s risk for certain cancers. The drug does not cause a woman to begin menopause, although it can cause some symptoms of menopause such as hot flashes, night sweats, mood swings, and vaginal dryness. In most premenopausal women taking tamoxifen, the ovaries continue to act normally. The drug does not reduce menopausal symptoms and might actually make them worse. The more serious effects of tamoxifen have been linked to increased risks for endometrial cancer, pulmonary embolism, stroke and deep vein thrombosis, blood clots in the lungs, and uterine sarcoma (cancer of the connective tissue of the uterus). In general, blood clots occur more often in people with high blood pressure and diabetes, smokers, and those who are obese. Women who have had a hysterectomy do not have an increased risk for endometrial cancer. Tamoxifen is not recommended for women who have had blood clots or who are prone to developing blood clots; women taking blood thinners;
women with a history of high blood pressure, smoking, obesity, or diabetes; women who are pregnant or planning to become pregnant; women who are breastfeeding; women younger than age 35 years or less than 60 years who are not at increased risks for breast cancer; and women on hormone replacement therapy or raloxifene. Tamoxifen can cause birth defects if taken at the time of conception or during pregnancy, and might affect fertility. Other organs such as bone and the uterine lining also have estrogen receptors and tamoxifen reacts with these, leading to increased bone density and higher risks of uterine cancer. Physicians clearly must weigh the benefits vs the risks of tamoxifen. For example, an older patient might benefit from tamoxifen, but because of a prior history of stroke, tamoxifen would not be recommended. 40,41

The benefits of tamoxifen, however, are thought to outweigh the risks in some patients. The prophylactic effects of tamoxifen have been shown to last up to 5 years after treatment ends. Tamoxifen slightly reduces the risk of bone fracture of the hip, wrist, and spine in women who are past menopause, but it does not protect against heart attacks. Despite its benefits, some studies have found that tamoxifen is considered effective only within a 5-year period. However, more recent studies suggest that the benefits of tamoxifen can extend beyond 5 years. Some women have been known to develop a resistance to tamoxifen that might be associated with the function of another gene, PAX2. However, the exact nature of this resistance is still under investigation. 40,41

Recently, a number of drugs with effects similar to tamoxifen have appeared on the market. Many of these drugs do not have the dangerous adverse effects of tamoxifen; however, many are not as effective as tamoxifen. Researchers are also measuring how patients are responding to selective estrogen receptor modulators by monitoring a molecule, Ki-67. If Ki-67 diminishes or disappears, the treatment is effective. If Ki-67 remains high during treatment, there is a greater chance of cancer recurrence. 21,38

Raloxifene

Raloxifene (Evista) is another selective estrogen receptor modulator considered as a replacement for tamoxifen. Studies by the National Cancer Institute have confirmed that raloxifene has fewer adverse effects while offering similar benefits as tamoxifen. Raloxifene was originally marketed to treat osteoporosis in postmenopausal women and has been approved by the U.S. Food and Drug Administration as a treatment for invasive breast cancer in postmenopausal women since September 2007. Like tamoxifen, raloxifene decreases the risk of developing breast cancer by blocking the effects of estrogen, thereby stopping the growth of the cancer. 21,40,41

Raloxifene can result in similar adverse effects as tamoxifen; however, they are not as severe. More common adverse effects of raloxifene are hot flashes, especially within the first 6 months of raloxifene therapy; swollen hands, feet, ankles or lower legs; leg cramps; and joint pain. 21,40,42

Exemestane

Exemestane (Aromasin) is an oral steroidal aromatase inhibitor that offers better protection against tumor development and is associated with fewer adverse effects than tamoxifen. Exemestane lowers the blood levels of estrogen. It works by attaching to the aromatase enzyme and permanently deactivating it. Exemestane is used to treat early breast cancer in postmenopausal women. This drug can cause hot flashes, hair loss, bone or joint pain, fatigue, unusual sweating, nausea, diarrhea, dizziness, and bone loss. Bone loss is of concern for patients with osteoporosis. Some studies recommend giving 2 years of tamoxifen followed by 2 to 3 years of exemestane. 42

Anastrozole

Anastrozole (Arimidex) also can be used to reduce the recurrence of breast cancer. Trials with anastrozole show that women with hormone receptor-positive breast cancer were 65% less likely to have a relapse or a new tumor than women on tamoxifen.

In a study of more than 500 patients, approximately half were assigned tamoxifen and half took anastrozole. Fourteen percent of the patients on tamoxifen had a recurrence of their breast cancer within 3 years vs 5.4% of the patients taking anastrozole. Adverse effects of anastrozole include a higher rate of vaginal dryness, painful intercourse, and loss of interest in sex. It also causes a higher degree of bone demineralization, with possible risks of osteoporosis and osteoporotic fractures. 21,38,43
Trastuzumab and Lapatinib

More than 75% of breast cancers in the United States are ER+ cancers. However, another class of breast cancers also overexpress ERBB2. About 25% of the population have this overactive gene and do not respond to treatment with tamoxifen or other antiestrogen drugs. Trastuzumab (Herceptin) has been found to be effective therapy for these aggressive cancers. Minor adverse effects of trastuzumab are fever, chills, weakness, nausea, vomiting, cough, diarrhea, and headache. A major adverse effect of trastuzumab is possible damage to the heart muscle.

Another drug, lapatinib (Tykerb), also has been found to be effective in the treatment of HER2 aggressive cancers and cancers that are both HER2 and ER+. Lapatinib is in a class of medications called kinase inhibitors. It is effective in interrupting the HER2 growth receptor pathway. HER2 is essential for early development and later growth of the muscles of the heart. Trastuzumab, by blocking HER2, can increase risks for heart abnormalities. Heart abnormalities have been detected in 2% to 7% of patients taking trastuzumab, and this drug should not be given to patients with heart conditions. Conversely, lapatinib might cause liver damage, which can be severe or life threatening. Although lapatinib results in less damage to the heart than does trastuzumab, it can cause liver damage as soon as several days or as late as several months after the start of treatment. Lapatinib is an effective treatment for patients who do not respond to trastuzumab.21,41

Gene Therapy

Scientists believe that faulty genes are inherited and can become defective during one’s lifetime, especially if the gene is exposed to dangerous chemicals or radiation. Gene therapy involves inserting specific genes into cells to restore a missing function or to give the cells a new function. The theory here is that missing or damaged genes cause certain diseases. Gene therapy is currently under clinical trial.21,43,44

Examples of gene therapy include replacing the tumor suppressor genes that could help prevent cancer from developing, or stopping oncogenes or other genes important to cancer from functioning. Oncogenes are mutated forms of normal genes that cause cells to divide out of control, leading to cancer. Other genes allow cancer cells to metastasize. Stopping these genes or the proteins they make might prevent cancers from growing or spreading. In addition, genes can be added to make cancer cells more vulnerable to chemotherapy or radiation; other genes can prevent cancer cells from becoming resistant to chemotherapy drugs. However, some patients develop a resistance to the drug, and in others there is no response.21,43,44

Prophylactic Surgery

Prophylactic surgery is used to remove the entire breast when a woman has a very high risk factor for breast cancer. For example, women with mutations in the breast cancer genes BRCA1 or BRCA2 will sometimes consider a prophylactic mastectomy. If surgery is indicated for medical purposes, it is not considered cosmetic intervention. The procedure can take place in an outpatient surgical facility or in a hospital.21

Any woman considering breast mammoplasty must first have an initial consultation with a plastic surgeon. The surgeon should be certified by the American Society of Plastic Surgeons and this information should be verified as part of the initial evaluation. In general, implants and reconstruction are not recommended for women before 22 years of age because women’s breasts are not fully developed before that age. Breast augmentations or reductions are contraindicated for anyone aged younger than 18 years because, in addition to having immature breasts, the patient might not be mature enough to make an informed decision. Consultation plus mammography to rule out breast diseases is recommended prior to the surgery. The surgeon then determines which surgical technique is best for the woman.21

Surgical Reconstruction Using Implants

After a mastectomy, patients might consider augmentation mammoplasty. The technique of augmented mammoplasty has been in use since the 1950s. This surgical procedure restores the appearance of the breast for women who have had a breast removed because of breast cancer or high risk of breast cancer. Initially, liquid silicone was injected directly into the breast, but these procedures led to severe complications and the procedure was soon discontinued.21,26 Silicone gel-filled implants were first used in 1962. The technique was to fill a silicone elastomer bag
with silicone gel. In 1992, the U.S. Food and Drug Administration removed silicone from the public market because of complications such as leakage and rupture and its association with connective tissue disorders and immune disorders. The ban was finally lifted in 2006.

Today, implants often are saline-filled or silicone-filled and come in various shapes and sizes. There are 2 types of shells: textured shells and smooth shells. There also is a thicker silicone implant called a form-stabilizing, or “gummy bear,” implant.\(^\text{18,26}\)

Both the saline-filled and the silicone-filled implants have an outer shell composed of silicone elastomer. Some implant shells are double lumen, giving an extra protective layer to reduce the risk of ruptures. The saline-filled implants use sterile saline and can be round or anatomically shaped. Generally, during the implant surgery the empty saline sac is implanted. The surgeon later fills it to the desired size. The silicone-filled implant uses a silicone gel, which is less likely to leak in cases of rupture.\(^\text{21,26}\) Implants can be placed in front of the pectoral muscle (subglandular or retromammary implants) or behind the pectoral muscle (subpectoral or retropectoral implants).

In general, silicone implants have a more natural feel. They are softer and smoother and less likely to wrinkle or ripple than saline implants. The biggest disadvantage of the saline implant is wrinkles, which can sometimes be seen or felt, especially on thinner women. The smooth-textured saline implants are less likely to ripple. One suggested advantage of textured implants was the lower risks of capsular contracture. However, implants placed behind the pectoralis major muscle are less likely to ripple.

In case of rupture, the saline-filled implant deflates and the breast will become noticeably enlarged as the tissue fills with saline. Surgery is needed to remove the silicone shell. The ruptured silicone is often harder to palpate and might not even be noticeable. The U.S. Food and Drug Administration recommends imaging of the breast every 2 years to monitor silicone-filled implants. Saline and silicone implant procedures have similar risks, which can include poor reaction to anesthesia, excessive bleeding, hematoma, breast pain, permanent changes in nipple or breast sensation, infection, scar tissue formation or capsular contracture, and implant leakage or rupture.\(^\text{21,26}\)

Breast reconstruction generally is performed by a plastic surgeon after a mastectomy; reconstruction usually is not necessary after a lumpectomy. The surgeon rebuilds the breast contour and can even include a nipple and areola. The goal of breast reconstruction is to provide symmetry to the breasts and to permanently regain the breast contour so that patients will not need an external prosthesis. Breast reconstruction also can involve reduction, enlargement, or reshaping the remaining breast to match the reconstructed breast.\(^\text{21,26}\)

Some patients request a nipple and areola to make the new breast look more realistic. Tissue for the nipple and areola is taken either from the removed breast, from the opposite nipple, or from the ear. Tissue for reforming the areola also can be taken from the upper inner thigh. Tattooing is used to darken the areola to match the color of the opposite breast. Saving the nipple from the breast with cancer is often contraindicated because cancer cells can be present in the nipple.\(^\text{21,26}\)

**Implant Procedures**

Decisions about reconstruction can depend on the patient’s overall health, the stage of the breast cancer, the size of the natural breast, the amount of tissue available (eg, thin women might not have the excess body tissue to make a flap possible), the patient’s insurance coverage, the type of procedure, and the size of the implant or reconstructed breast. Many women elect to have breast reconstruction during the mastectomy to avoid an additional surgery. Occasionally, women choose to forgo surgical reconstruction and instead choose an external prosthesis; some patients do not want to have an implant in their body, or they do not want an additional surgery to further damage their body.\(^\text{21,26}\)

Breast reconstruction can be immediate or delayed. Some women want their breast restored as quickly as possible to avoid returning for another surgery; others do not mind waiting until their cancer treatment is completed. In the one-stage immediate breast reconstruction after mastectomy, the surgeon places the implant where the breast tissue was removed to form the breast contour. Delayed reconstruction, done some time after...
surgery, might be necessary if radiation immediately follows a mastectomy. Delayed reconstruction also could be necessary if the skin is tight and flat. In such cases, a tissue expander is placed under the skin and chest muscle. The tissue expander involves placing a balloon under the skin then injecting a saline solution at regular intervals to fill the expander over time. After the skin is expanded enough, the expander is removed and a permanent silicone or saline implant is put in place. Some saline expanders are left in place as the final implant.

Reconstruction will not affect the recurrence of breast cancer. There are complications with reconstructive healing that interfere with chemotherapy or radiation treatment or both. However, the advantages of immediate reconstruction are that the chest tissues are undamaged by radiation therapy and there is one less surgery needed. After radiation, the first step in implant surgery is stretching the skin with a tissue expander, but this process would be difficult if the skin is damaged by radiation. This leads to a higher rate of complications such as poor healing, skin breaks, and implants that protrude or stiffen.\(^1\,^2\,^6\)

Implants can rupture, or scar tissue can form around the implant (capsular contracture). Capsular contracture occurs when the scar or capsule around the implant begins to tighten and squeeze the implant, making the breast feel hard. Capsular contracture can require surgery to remove the scar tissue, or the implant might be removed or replaced.

If the implant is inserted before radiation, the scar tissue around the implant can contract because of the radiation, leading to distortion of the implant. Some surgeons mold a slightly larger breast, knowing that the radiation will tend to shrink the breast tissue. The other option for patients is the use of muscle, skin, and tissue from their own body to create a breast mound. This reconstruction can be performed at the time of the mastectomy, as it will not be reshaped by radiation. This technique is called autologous flap reconstruction.\(^1\,^2\,^6\)

**Autologous Reconstruction Surgery**

In autologous tissue reconstruction surgery, skin, fat, and muscle from the abdomen, back, or buttocks are taken to form a new breast. This surgery can be performed at the time of a mastectomy. It can complicate the surgical procedure and extend the length of surgery from 2 hours to up to 6 hours.\(^1\)

Transverse rectus abdominis muscle (TRAM) procedures can be either pedicle flap or free flap. Pedicle flap surgery involves leaving the flap of tissue attached to its original blood supply. The tissue is tunneled under the skin to the breast area. The free-flap technique removes the flap—including the skin, fat, blood vessels, and muscle—from its original location then attaches the flap to blood vessels in the breast area. This procedure involves the use of microsurgery to reconnect the tiny blood vessels, and requires longer surgery times. Some surgeons recommend the technique because it gives a more natural result.

Flap techniques cannot be offered to patients with diabetes, disease of the connective tissue, or vascular disease, or to those who smoke. In addition, thin women are not ideal candidates for tissue flaps because they do not have sufficient skin and tissue to donate for the reconstructed breast.\(^1\,^2\,^6\,^45\)

TRAM flap is a technique used to create a breast mound by removing skin, fat, and blood vessels from the abdomen area plus at least one of the abdominal muscles. It is named for the muscle in the area, the rectus abdominis muscle. The procedure results in a tightening of the lower abdomen or a “tummy tuck.” The removed flap, along with the superior epigastric artery, is tunneled under the skin to the breast area.\(^1\,^2\,^6\,^45\) In a muscle-sparing TRAM flap technique, very little of the abdominal muscle is taken. The result is less possibility of the loss of muscle function. This is a free-flap technique, and microsurgery is needed to reconnect the blood supply.

Latissimus dorsi flap surgery involves removal of muscle, fat, blood vessels, and skin from the back, moving them to the chest to create a breast mound. Generally, the flap is tunneled under the skin to the breast. This procedure can occasionally result in weakness in the back, shoulder, or arm.

The deep inferior epigastric perforators flap technique is named for the main blood vessel that runs through the area being removed. This technique uses fat and skin from the abdomen but does not use the muscle to form the breast mound. The procedure is a free-flap one because the tissue is completely detached from the abdomen and moved to the breast. This
surgical technique is longer than the TRAM flap techniques. It can take 5 to 8 hours of surgery if both breasts are reconstructed. Deep inferior epigastric artery perforator flap also requires microscopic surgery to connect tiny blood vessels. However, with no muscle removal, the recovery time is shortened and the risk of losing abdominal muscle strength is lower. 

In the gluteal free-flap technique, the gluteal muscles from the buttocks are used to create a breast shape. This procedure is similar to the free TRAM flap and also requires microsurgery to attach tiny blood vessels.

Women usually find that there are changes in nipple and breast sensation. The reconstructed breast will not have nerve sensation because the nerves cannot be transferred. Although the flap technique does not restore normal sensation to the breast, some feeling might return. Some advantages of autologous tissue reconstruction are that radiation is much better tolerated than with implant reconstruction and patients are less likely to require follow-up surgical intervention. The autologous tissue reconstruction process carries a small risk of weakening the muscles at the site where tissue is removed; however, there are newer techniques such as muscle-sparing autologous tissue reconstruction. Recovery from autologous tissue reconstruction surgery can take up to 2 months. In any of the flap techniques, tissue necrosis of all or part of the flap can occur. In this case, the flap must be removed.

Complications from reconstructive surgery can include anesthesia complications (a risk with any surgery), infections that can result in undesirable cosmetic results, bleeding in patients with poor clotting time, fluid collection resulting in swelling and pain, and excessive scar tissue at the site that can take 1 to 2 years to fade and will never completely disappear. Both saline- and silicon-filled implants can cause a rare form of immune system cancer called anaplastic large-cell lymphoma. This lymphoma grows in the capsule of scar tissue that forms around an implant, causing lumps, pain, and asymmetry from the fluid buildup and swelling. In some cases, removing the implant and scar tissue is the only treatment needed. Other patients need chemotherapy and radiation.

After a breast surgery, many physicians do not order mammography of the reconstructed breast. Nevertheless, studies show that 8% to 10% of women will have a recurrence in the scar after a mastectomy during the first 5 years. In addition, before the mastectomy, the cancer could have already spread to other areas of the body. Most research suggests that patients should have either visual inspection of the site by an oncologist, or imaging should be done yearly within the first 5 years of the mastectomy. Women also should continue breast self-examination, checking both the natural breast and the reconstructed breast at the same time each month.

**Pain Medication and Pain Management**

Pain receptors are located throughout our bodies in nerve endings in the skin and mucous membranes. When pain receptors are triggered by mechanical, chemical, or thermal stimuli, the pain signal is transmitted through the nerves to the spinal cord and then to the brain. Cancer pain can result from a number of factors, including blocked blood vessels causing poor circulation, bone fractures, metastasis to the bone, cancer invading the neural structures, tumors exerting pressure on a nerve, infection, inflammation or adverse effects from treatments such as chemotherapy or other drugs, radiation therapy, and surgery.

Pain is commonly associated with advanced cancer; more than 30% of all cancer patients experience pain, and as many as 50% of patients are undertreated for cancer pain. Some studies estimate that 90% of cancer patients experience pain. Although analgesic use should be carefully monitored, there are still reports of reluctance to provide analgesics to cancer patients because of concerns about inappropriate use or dependence on opioids.

Cancer pain can be acute or chronic. Acute pain might last only a short time and can be the result of surgery or an immediately injury. Chronic pain continues for 6 months or more, and depending on the severity of the pain, patients can have life-altering implications such as diminished activities or dependence on basic functions.

Pain management depends on the cause of the pain. Nevertheless, all cancer pain, whether acute or chronic, needs to be addressed. Patients also can experience breakthrough pain in which the medication they are taking no longer controls the pain, possibly because of
changes in absorption, metabolism, or elimination of the drugs. In end-stage cancer, chemotherapy, radiation, or surgery can be used to reduce tumor size if the tumors are exerting pressure on a nerve.

Newer pain medications are even more potent than morphine. Patients can be given intrathecal anaesthetics, which are pain-killing drugs injected directly into the cerebrospinal fluid. Nerve blocks also can be used to kill or deaden the nerve associated with the pain. Acupuncture has been found to be effective for some patients, although studies suggest that the benefits from the technique are subject to patients’ expectations and beliefs.66,47

Conclusion

Cancer care cannot focus solely on eliminating the tumor. It also must assist with the patient’s psychological well-being. The patient’s psychological status can affect treatment options and even recovery time. A patient’s suffering can lead to depression, stress, and other mental and emotional conditions that should not be ignored. Good oncology care providers often are proactive in identifying patients’ needs and helping them find the resources and support they need.

At present, all breast cancer detection and treatment tools have advantages and disadvantages, and because of the wide variety patients must explore their options wisely. The good news is that researchers have been especially excited about the development in recent years of various targeted therapies. Ideally, targeted therapies could be tailored to whatever genetic mechanism is responsible for the patient’s tumor. These therapies show promise and could result in even more individualized treatments.

Detecting cancers early still offers the best treatment options and the highest survival rate. This fact is driving the need to perfect breast cancer detection tools. However, despite the numerous adjunctive detection tools available, mammography is still the most comprehensive tool in the fight against breast cancer.

References


Accessed April 9, 2015.


Breast Intervention and Breast Cancer Treatment Options

To earn continuing education credit:
- Take this Directed Reading quiz online at www.asrt.org/drquiz.
- Or, transfer your responses to the answer sheet on Page 564M and mail to ASRT, PO Box 51870, Albuquerque, NM 87181-1870.

New and rejoining members are ineligible to take DRs from journal issues published prior to their most recent join date unless they have purchased access to the quiz from the ASRT. To purchase access to other quizzes, go to www.asrt.org/store.

*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. The tangential projection is useful for assessing:
   a. calcifications and lesion margins.
   b. lesions deep within the breast.
   c. areas of overlapping tissue.
   d. skin lesions or calcifications.

2. Magnetic resonance (MR) imaging is useful as an adjunct screening tool for patients:
   a. who have a lifetime breast cancer risk of at least 10%.
   b. who received chest wall radiation between the ages of 10 and 30 years.
   c. without mutations of the **BCRA1** or **BRCA2** gene.
   d. with fatty breasts.

3. MR imaging’s use as a screening tool is limited because of:
   1. cost.
   2. lower specificity.
   3. high false-positive rate.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

4. Lymphoscintigraphy is indicated for patients:
   a. considering axillary node dissection.
   b. with cystic breast disease.
   c. trying to decide on a lumpectomy vs a mastectomy.
   d. considering lumpectomy only.
5. Using the Breast Imaging-Reporting and Data System (BI-RADS), a patient with a category 4 lesion would be recommended to have:
   a. aspiration or biopsy.
   b. short-term follow-up.
   c. long-term follow-up.
   d. mastectomy.

6. An advantage of ultrasound-guided aspiration is that:
   a. it can be performed using an 11-gauge needle.
   b. ultrasonography allows real-time imaging.
   c. the radiation dose with ultrasonography is relatively low.
   d. the patient is under anesthesia.

7. If a lesion is nonpalpable, yet visualized on imaging, which of the following can be used to pinpoint the exact location of the lesion before a biopsy?
   a. stereotactic localization
   b. cyst aspiration
   c. histologic analysis
   d. fine-needle aspiration biopsy (FNAB)

8. In the dedicated prone biopsy system, the mammography unit and the needle guidance device are located:
   a. right next to the patient.
   b. above the patient’s head.
   c. under the table.
   d. above the table.

9. According to the article, FNAB is used to diagnose cystic and solid lesions such as fibroadenomas.
   a. true
   b. false

10. In most cases a cytopathologist or cytotechnologist is present during an FNAB to:
    a. aspirate the material for the slides.
    b. ensure that there is enough blood to stain the slides.
    c. confirm that the lesion was removed.
    d. verify adequate specimen collection.

11. A vacuum-assisted biopsy device removes:
    a. cell samples using a suction mechanism.
    b. core samples similar to a gun-needle combination.
    c. core samples using a gun-needle combination.
    d. cell samples with a disposable system.

12. In the core biopsy procedure using the gun-needle combination, each reinsertion of the needle results in:
    1. destruction of breast tissue.
    2. damaged samples.
    3. hemorrhage.
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

13. Core biopsy can be performed using which of the following for image guidance?
    1. MR
    2. ultrasonography
    3. computed tomography
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3
14. An open surgical breast biopsy is needed when the:
   1. results of an FNAB are inconclusive.
   2. lesion is located very close to the chest wall.
   3. lesion is so hard the radiologist cannot obtain an adequate sample.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

15. In an excisional biopsy:
   a. the entire lesion is removed, leaving clean margins.
   b. a sample of the lesion is removed for histologic testing.
   c. the margins of the lesion are removed for testing.
   d. the lesion is sampled but not removed.

16. A common error in core biopsy is:
   a. insufficient sampling.
   b. understating the multifocality of the cancer.
   c. overstating the multifocality of the cancer.
   d. false-positive findings of microcalcifications.

17. Which of the following statements is false about FNAB when compared with core biopsy?
   a. FNAB is less expensive.
   b. FNAB is less invasive.
   c. FNAB is faster.
   d. FNAB is less likely to lead to error due to insufficient sampling.

18. The 5-year survival rate for stage II breast cancer is _______
   a. 54
   b. 72
   c. 93
   d. 98

19. Cancer cells that contain estrogen receptors often are referred to as:
   a. HER2.
   b. HER2/neu.
   c. ER-positive.
   d. PR-positive.

20. The modified radical mastectomy is the most common mastectomy procedure performed today.
   a. true
   b. false

21. Complications of mastectomy can include:
   a. hematoma.
   b. carcinoma.
   c. multicentric disease.
   d. enlarged axillary nodes.

22. A lumpectomy could be contraindicated for all of the following patients except those with:
   a. 2 or more areas of cancer in the same breast.
   b. a previous lumpectomy that did not completely remove the cancer.
   c. large tumors in a small breast.
   d. stage 1 or II ductal carcinoma in situ.

23. The sentinel node biopsy procedure:
   a. results in more complications than the lymph node biopsy.
   b. removes only 1 to 4 axillary nodes.
   c. requires that the patient also undergo a lymph node biopsy.
   d. is a highly invasive procedure.

24. In primary radiation therapy treatment, radiation:
   a. is delivered before chemotherapy.
   b. is delivered before surgery.
   c. is used in addition to a hormone treatment.
   d. alone is used to treat breast cancer.
Directed Reading Quiz

25. Adverse effects of external-beam radiation therapy (EBRT) might include all of the following except:
   a. fatigue.
   b. swelling.
   c. a sunburned appearance of the skin.
   d. dark, brittle, or cracked fingernails.

26. During radiation treatment for breast cancer, patients are advised to:
   a. wear clothing made of material that breathes.
   b. take hot showers and use heating pads.
   c. apply lotion or powder to the treatment area.
   d. wear a tight-fitting bra for support.

27. Compared with patients who receive traditional EBRT, women who undergo intensity-modulated radiation therapy are less likely to report:
   1. itchy skin.
   2. breast swelling.
   3. changes in skin color.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

28. Internal radiation, also known as brachytherapy:
   a. can be used to reduce treatment from 6 to 7 weeks to only 3 to 5 days.
   b. reduces radiation treatment to 10 minutes.
   c. often means a longer treatment that is less convenient for the patient.
   d. applies the radiation from the outside in.

29. Chemotherapy regimens:
   a. are fixed and do not vary from individual to individual.
   b. can be given only for a few days.
   c. are tailored for individual patients.
   d. are not affected by the patient’s age or sex.

30. Symptoms of low platelet count could include:
   a. anemia.
   b. fatigue.
   c. nosebleed.
   d. infections.

31. Tamoxifen is a(n):
   a. antiestrogen drug.
   b. antiprogesterone drug.
   c. chemotherapy drug.
   d. pain medication.

32. One factor that increases risk of breast cancer is starting menopause before 50 years of age.
   a. true
   b. false

33. If a saline-filled implant ruptures, the:
   a. implant will deflate and the breast will become enlarged.
   b. rupture will be imperceptible.
   c. implant will deflate and the breast will become smaller.
   d. tissue will fill with silicone.

34. The free-flap reconstructive technique:
   a. removes skin and fat, then tunnels it under the skin to create a breast mound.
   b. involves the use of microsurgery to reconnect tiny blood vessels.
   c. uses a saline-filled sac to create a breast mound.
   d. involves the use of a silicone shell.

35. Intrathecal anesthetics for cancer pain are injected directly into the:
   a. cerebrospinal fluid.
   b. affected organ or tissue.
   c. nerve root.
   d. a vein.
Thank you for taking the time to complete this evaluation. Your opinion helps us serve you better. Your comments will remain confidential and will not affect the scoring of your Directed Reading (DR) test. **Choose only ONE response for each question.** Use a blue or black ink pen. Do not use felt tip markers. Completely fill in the circles.

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

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

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

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

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

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

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

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

If you have comments or questions about this Directed Reading, please write them below or send them separately to Ellen Lipman, Director of Professional Development, ASRT, 15000 Central Ave SE, Albuquerque, NM 87123-3909 or elipman@asrt.org.
Breast Intervention and Breast Cancer Treatment Options

Expires: June 30, 2017
Approved for 2.5 Category A+ CE Credits

-- A passing score is 75% or better.
-- Take the quiz online at www.asrt.org/drquiz for immediate results and your CE certificate.
-- Or, mail the original answer sheet to ASRT, PO Box 51870, Albuquerque, NM 87181-1870.
-- ASRT must receive this answer sheet before the quiz expires and before the end of the CE biennium for which you want credit.
-- New or rejoining members are ineligible to take DR quizzes from journals published prior to their most recent join date unless they purchase access to the DR quiz.

Identification Section

We need your Social Security number to track your CE credits. Please fill in your SSN in the boxes on top, then fill in the circle corresponding to each number under the box. The circles must be filled in accurately.

Member Information Section

To ensure proper credit please PRINT the following information.

Name __________________________
Address _________________________
City _____________________________
State_____________ ZIP____________
Work Phone_______________________
Home Phone_______________________

CE Answers Section

USE A BLUE OR BLACK INK PEN. Completely fill in the circles.

Get immediate Directed Reading quiz results and CE credit when you take your test online at www.asrt.org/drquiz.

Note: For true/false questions, A=true, B=false.

1 O O O O O 11 O O O O O 21 O O O O O 31 O O O O O
2 O O O O O 12 O O O O O 22 O O O O O 32 O O O O O
3 O O O O O 13 O O O O O 23 O O O O O 33 O O O O O
4 O O O O O 14 O O O O O 24 O O O O O 34 O O O O O
5 O O O O O 15 O O O O O 25 O O O O O 35 O O O O O
6 O O O O O 16 O O O O O 26 O O O O O
7 O O O O O 17 O O O O O 27 O O O O O
8 O O O O O 18 O O O O O 28 O O O O O
9 O O O O O 19 O O O O O 29 O O O O O
10 O O O O O 20 O O O O O 30 O O O O O

No Photocopies Accepted
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

---

**Figure 1.** A. Brain activity attributed to phonological manipulation in normal readers was observed in the left occipitotemporal region, inferior parietal region, and inferior frontal cortex, consistent with previous studies. The thalamus and cerebellum also were bilaterally active (these deeper foci are not seen in the Figure). In the right hemisphere, the inferior and middle temporal cortex as well as middle frontal gyrus were identified. B. The dyslexic group showed activity related to phonological manipulation in the bilateral inferior parietal and inferior frontal regions, the middle temporal cortex, precuneus, and cerebellum. C. A between-group statistical comparison of the control and dyslexic groups revealed less activity in the dyslexic group in the left inferior parietal regions (supramarginal and angular gyri), superior parietal lobule, precuneus, and medial frontal gyrus. Dyslexic subjects also displayed less activation in several right hemisphere regions compared to controls: the occipitotemporal junction, as seen in the Figure, and medial structures, including precuneus, medial frontal, fusiform, and cingulate gyri (not seen in these lateral projections). This article was published in Neuron, Vol. 44. Eden EF, Jones KM, Cappell K, et al. Neural changes following remediation in adult developmental dyslexia. 413. Copyright: Cell Press 2004.
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.

References
12. Holman BL, Chandak PK, Garada BM; Brigham and Women’s Hospital Department of Radiology. Atlas of Brain Perfusion SPECT. Boston, MA: Division of Nuclear Medicine, Dept. of Radiology, Brigham & Women’s Hospital, Harvard Medical School: 1998. NLM ID 101133580.
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.1

Left ventricular aneurysms can occur as a complication following myocardial infarction.1 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).1,2 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.1 The majority of left ventricular true aneurysms are located apically and develop as a result of wall thinning.1,4 Left ventricular true aneurysms occur in 10% to 38% of patients following myocardial infarction, and they occur more often in women than in men.5,6

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).7 Although ventricular 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.

Mary Frances Sedlacek, R.T. (R)(M)(CT)(MR), has been a radiologic technologist for more than 30 years. She has worked for 11 years as a magnetic resonance technologist for the University of Colorado Hospital in Aurora, Colorado. She can be reached at maryfrances.sedlacek@uchealth.org.

**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.”

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] team working.” 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.14

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

---

**Table 1.**

<table>
<thead>
<tr>
<th>Variance Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implant/metallic device</strong></td>
</tr>
<tr>
<td><strong>Implant</strong></td>
</tr>
<tr>
<td><strong>Metallic device</strong></td>
</tr>
<tr>
<td><strong>Metallic implant</strong></td>
</tr>
<tr>
<td><strong>Medical device</strong></td>
</tr>
<tr>
<td><strong>Surgical device</strong></td>
</tr>
<tr>
<td><strong>Personal device</strong></td>
</tr>
<tr>
<td><strong>Personal implant</strong></td>
</tr>
<tr>
<td><strong>Personal metallic device</strong></td>
</tr>
<tr>
<td><strong>Personal metallic implant</strong></td>
</tr>
<tr>
<td><strong>Other</strong></td>
</tr>
</tbody>
</table>

---

**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.¹ 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.¹ 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.¹⁵

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

<table>
<thead>
<tr>
<th>Variance</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance not specified</td>
<td>1</td>
</tr>
<tr>
<td>Allergy</td>
<td>1</td>
</tr>
<tr>
<td>Implant/metabolic device</td>
<td>1</td>
</tr>
<tr>
<td>Peripheral IV or access port</td>
<td>6</td>
</tr>
<tr>
<td>Past medical/surgical history</td>
<td>6</td>
</tr>
<tr>
<td>No data</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22</strong></td>
</tr>
</tbody>
</table>

Abbreviation: IV, intravenous.

![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.

Zachary J Berry, BS, R.T.(R)(MR), is a magnetic resonance technologist for MRI Group, LLP, in Lancaster, Pennsylvania. He also is comanager of the Nepal program for RAD-AID International. Zachary is a graduate student at the Rutgers University School of Health Related Professions. Zachary B Barr, BS, R.T.(MR)(N), is a magnetic resonance technologist and quality coordinator for MRI Group, LLP, in Lancaster, Pennsylvania.

The authors would like to thank Emanuel Kanal, MD, FACR, FISMRM, AANG, for his guidance and support in the early stages of this project.

**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 Accessories**²

- 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 posterioranterior 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.](image-url)
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>
<thead>
<tr>
<th>More Distance</th>
<th>Less Intensity (Quantity of Radiation)</th>
</tr>
</thead>
<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>
</tr>
</tbody>
</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.

Tammara M Chaffee, MEd, R.T.(R)(M), is an assistant professor of radiologic technology at Doña Ana Community College in Las Cruces, New Mexico.

References
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

---

**Box 1**

**Ethical Principles Guiding Research Involving Human Subjects**

<table>
<thead>
<tr>
<th>Principle</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respect for Persons</td>
<td><em>Autonomy</em> — Individuals have the right to make their own decisions about participation in a research study, voluntarily, without coercion or fear of penalties.</td>
</tr>
<tr>
<td></td>
<td><em>Informed consent</em> — 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>
</tr>
<tr>
<td></td>
<td><em>Comprehension</em> — 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>
</tr>
<tr>
<td></td>
<td><em>Vulnerable subjects</em> — 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>
</tr>
<tr>
<td>Beneficence</td>
<td><em>Protection from harm</em> — The researcher has a duty to protect study participants from physical and psychological harm during and as a result of the research study.</td>
</tr>
<tr>
<td></td>
<td><em>Assessment of risks and benefits</em> — 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>
</tr>
<tr>
<td></td>
<td><em>Systematic assessment</em> — Assessment of risks and benefits should be thorough, systematic, and nonarbitrary.</td>
</tr>
<tr>
<td>Justice</td>
<td><em>Fair treatment</em> — Research study participants have the right to be treated fairly.</td>
</tr>
<tr>
<td></td>
<td><em>Equal treatment</em> — The researcher has a duty to treat people equally regarding the benefits and burdens of the research.</td>
</tr>
<tr>
<td></td>
<td><em>Selection of subjects</em> — 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>
</tr>
</tbody>
</table>
advances in biomedical research and health care, it’s imperative that we do so in a responsible manner.\textsuperscript{13}

**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.\textsuperscript{14} 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.\textsuperscript{15}

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,\textsuperscript{16} and some might be eligible for expedited review.\textsuperscript{17} 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\textsuperscript{16,a}**

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, 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

---

**Box 4**

**Summary of Research Activities Eligible for Expedited IRB Review**

Clinical studies of drugs and medical devices when (a) an investigational new drug application is not required, or (b) an investigational device exemption application is not required, or (c) the medical device is cleared/approved for marketing and is being used in accordance with its cleared/approved labeling.

Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture (a) from healthy, nonpregnant adults who weigh at least 110 lb, and no more than 550 ml blood is drawn in an 8-week period, not more than 2 times per week, or (b) from other adults and children, no more than 50 ml in an 8-week period, not more than 2 times per week.

Prospective collection of biological specimens for research purposes by noninvasive means (eg, hair and nail clippings, deciduous teeth, excreta and external secretions, saliva).

Collection of data through noninvasive procedures routinely employed in clinical practice, excluding procedures involving x-rays or microwaves (eg, electrocardiography, magnetic resonance, ultrasonography, Doppler blood flow, echocardiography).

Research involving materials that have been collected solely for non-research purposes (eg, data, documents, records, specimens).

Collection of data from voice, video, digital, or image recordings made for research purposes.

Research on individual or group characteristics or behavior (including research on perception, cognition, motivation, identity, language, communication, cultural beliefs/practices, social behavior) or research employing survey, interview, oral history, focus groups, program evaluation, human factors evaluation, or quality assurance methodologies.

Continuing review of research previously approved by the IRB, where (i) the research is permanently closed to the enrollment of new subjects, (ii) all subjects have completed all research-related interventions, (iii) the research remains active only for long-term follow-up of subjects, or (iv) the remaining research activities are limited to data analysis.

Continuing review of research, not conducted under an investigational new drug application or investigational device exemption and where the IRB has determined that the research involves no greater than minimal risk and no additional risks have been identified.

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.

**References**


---

Christina A Truluck, PhD, R.T.(N), CNMT, is an associate professor, program director, and clinical coordinator for the nuclear medicine and PET-CT programs at Thomas Jefferson University, Philadelphia, Pennsylvania. Truluck is an active member of the American Society of Radiologic Technologists (ASRT), serving on the Radiologic Technology Editorial Review Board, Practice Standards Council, and ASRT Foundation Scholarship Review Committee. She also received an ASRT Foundation International Speakers Exchange Award in 2011.

James Johnston, PhD, R.T.(R)(CV), FASRT, is a professor of radiologic sciences and dean of the Robert D and Carol Gunn College of Health Sciences and Human Services, Midwestern State University, in Wichita Falls, Texas. He received an ASRT Foundation International Speakers Exchange Award in 2008. Johnston is a former ASRT Scholarship Review Committee member and recently established the James and Stephanie Johnston Journey Scholarship to support higher education for medical imaging professionals. He is chairman of the ASRT Committee on Bylaws and the Radiologic Technology Editorial Review Board.
Cutting-edge, Cost-effective CE... ...Designed to Meet Your Goals!

- Choose from more than 150 titles—and 400 credits!
- MR and CT cross-training.
- MR and CT registry preparation.
- Best Money Back Guarantee in the industry!
- MQSA compliance in Digital Mammography.

Technologists and their managers agree: “MIC’s courses really work!”

### The CT Registry Review Program
- Covers every topic on the ARRT’s post-primary exam in CT.
- It’s guaranteed: Pass the ARRT exam in CT or your money back!
- 22 Credits & 8 StudyModules.

### The MRI Registry Review Program
- Covers every topic on the ARRT’s post-primary exam in MRI.
- It’s guaranteed: Pass the ARRT exam in MRI or your money back!
- 28 Credits & 12 StudyModules.

### The CT CrossTrainer™
- Covers all the essentials of CT.
- Requires no prior training in CT.
- Explains CT so you’ll understand it!
- 17 Credits & 6 StudyModules.

### The MR CrossTrainer™
- Covers all the essentials of MR.
- Requires no prior training in MR.
- Explains MR so you’ll understand it!
- 18 Credits & 6 StudyModules.

### Digital Mammography Essentials™
- Meets MQSA requirements for modality-specific training.
- Covers all the essentials of digital mammography & requires no prior training.
- 11 Credits & 4 StudyModules.

### Radiology Trends for Technologists™
- Choose from 75 hot topic review articles.
- StudyBuddy helps you focus on relevant info.
- CT, MR, Mammo, PET, SPECT, etc.
- 1.5 to 4 Cat A credits for each “Trends” title!

### Sectional Anatomy & Imaging Strategies™
- Learn all the essential concepts of sectional imaging...in a convenient self-study format!
- Explains sectional anatomy and tomographic imaging so you’ll really understand it!
- 18 Credits & 6 StudyModules.

Every MIC course is accredited for Category A CE credits which are fully recognized by the ARRT & NMTCB.

Call today for your
Free Info Kit
800-589-5685
or visit www.MICinfo.com

Technologists and their managers agree: “MIC’s courses really work!”

### MIC facts:
- Free UPS Ground Shipping (for orders over $99)
- Free Post-Test Retakes
- Free Certificate Replacement
- Free Postage For Post-Tests
- Fax or Mail Your Answers
- Toll-Free Customer Service
- Major Credit Cards Accepted
- Discounts for Former Students, Groups and Early Registration
- Boldest Money Back Guarantee in the Industry!
Topics in Mammography

SELF-DIRECTED Mammography Training Program:
- 40 Category A Credits - MQSA compliant
- Digital Mammo & 3D Breast Tomosynthesis
- NEW - Basic Positioning Video
- (2) ARRT Certification Exam Review Tools
- $450 TOTAL on USB drive

ARRT Mammo Certification Review Tools:
- Visit the website
- All Courses are Category A (ARRT)

Order at www.Radcomm.net Toll-Free: 888-497-2923

Radiologic Educational Services
PO Box 11820, Olympia, WA 98508

Bring a Friend
And you both could Win!
Recommend a colleague to join ASRT and you both get a chance to win a great prize.

To find out more please visit www.asrt.org/bringafriend.

New CE Courses!

My Membership
My Peace of Mind

I love the CE track and transfer service. I attend the OSRT conference each year in order to keep up with my CE credits. The ASRT does a great job of tracking them, accounting for them and sending them to ARRT for my registration. The turnaround time is great as I typically get them back much quicker than promised.

— Connie Pabst, R.T.(R), of Cincinnati, Ohio

Thank you for being an ASRT member!
Need assistance? Call us at 800-444-2778 or e-mail memberservices@asrt.org.
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.

You Might Have Missed…

People with depression exhibit shrinkage of the hippocampus, a brain region that regulates stress.

Turn to Page 565 for the full story.
Leadership Essentials • Online Education

Module 1 – Introduction to Supervision
Module 2 – Competent Communication
Module 3 – Employment Law
Module 4 – Performance Coaching
Module 5 – Quality Standards

Module 6 – Accreditation and Regulations
Module 7 – Budgeting and Finance
Module 8 – Project Management
Module 9 – Leadership Skills
Module 10 – Health Economics

Discover the leadership skills needed to take your career to the next level.

- Learn strategies for success.
- Develop the leader in you.
- Supervise with skill.

Earn up to 11 CE credits and receive a document recognizing your achievement once you successfully complete all 10 modules. We also offer individual credit modules and an institutional/educator series for classroom use or training.

www.asrt.org/leadership
**Serving imaging professionals 24 years!**

Gage Continuing Education has been serving imaging professionals worldwide since 1991. We were one of the first to offer continuing education to radiologic technologists, and we continue to be the leader in the field of home study continuing education.

Over 60 home study courses are available. Give our friendly staff a call, they look forward to assisting you.

All of our courses have been reviewed and approved by the ASRT and meet the ARRT requirement for Category A continuing education credits. We also have Category A+ continuing education credits for the Registered Radiologist Assistant (RRA). **New! We now have Certified Radiology Administrators (CRA) approved courses.**

You can count on Gage CE to be here when you need us.

Discounts available for group orders – call for details!

<table>
<thead>
<tr>
<th>COURSE NAME</th>
<th>CREDITS</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI in Practice</td>
<td>28 Category A Credits</td>
<td>$119.50</td>
</tr>
<tr>
<td>Molecular Diagnosis</td>
<td>6.5 Category A+ Credits</td>
<td>$54.50</td>
</tr>
<tr>
<td>Diseases of the Human Body</td>
<td>20 Category A Credits</td>
<td>$94.50</td>
</tr>
<tr>
<td>Stress Management</td>
<td>11 Category A Credits</td>
<td>$69.50</td>
</tr>
<tr>
<td>Parkinson’s Disease</td>
<td>7.5 Category A Credits</td>
<td>$59.50</td>
</tr>
<tr>
<td>The Lung</td>
<td>9.5 Category A Credits</td>
<td>$89.50</td>
</tr>
<tr>
<td>Pulmonary Medicine</td>
<td>36 Category A+ Credits</td>
<td>$119.50</td>
</tr>
<tr>
<td>Infectious Diseases</td>
<td>47 Category A Credits</td>
<td>$129.50</td>
</tr>
<tr>
<td>Anatomy for the Radiology Professional</td>
<td>15 Category A Credits</td>
<td>$74.50</td>
</tr>
<tr>
<td>Pathophysiology of Disease Part One</td>
<td>32.75 Category A+ Credits</td>
<td>$144.50</td>
</tr>
<tr>
<td>Pathophysiology of Disease Part Two</td>
<td>34.5 Category A+ Credits</td>
<td>$144.50</td>
</tr>
<tr>
<td>Diagnostic Sonography</td>
<td>18.0 Category A Credits</td>
<td>$119.50</td>
</tr>
<tr>
<td>The Central Nervous System</td>
<td>41.5 Category A Credits</td>
<td>$129.50</td>
</tr>
<tr>
<td>Rad Tech’s Guide to Radiation Protection</td>
<td>5 Category A Credits</td>
<td>$59.50</td>
</tr>
</tbody>
</table>

“...Another excellent course! I learned things I never learned in school...”

— L.S., Lexington, NC

We have a new website!
We are continually striving to make your CE ordering experience easier. Our new website will let you sort by state, credit hours and price so you can find the perfect course to fulfill your CE requirements. Remember, we will be here when you need us!

FREE same day certificate faxback service
FREE replacement of lost certificates
FREE retaking of exams if needed.
FREE gift book with every course ordered.

We have a new website!
We are continually striving to make your CE ordering experience easier. Our new website will let you sort by state, credit hours and price so you can find the perfect course to fulfill your CE requirements. Remember, we will be here when you need us!

“...Another excellent course! I learned things I never learned in school...”

— L.S., Lexington, NC

Discounts available for group orders – call for details!

www.GageCE.com | 1-800-383-4445 or 1-877-775-GAGE

2416 Merchant Ave. | Odessa, FL 33556-3460

Thank you! We appreciate your business!