DIRECTED READING ARTICLES

Abdominal Aortic Aneurysms
PAGE 145

Radiation Protection in Computed Tomography
PAGE 169CT

PEER-REVIEWED ARTICLES

Gonadal Shielding in Radiography: A Best Practice?
PAGE 127

A Multidiscipline Study of Education Program Accreditation Type and Certification Exam Performance
PAGE 135
• Stay up to date on current trends in radiology!
• CT and MR registry preparation.
• CT and MR cross-training.
• MQSA compliance in Digital Mammography and Digital Breast Tomosynthesis.
• Best Money Back Guarantee in the industry!
• Choose from more than 150 titles—and 400 credits!

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

WEIGHT BEARING X-RAYS FOR ATHLETES

POSITIONING HIM IS A SNAP!

Extra Wide 2-Step Platform

734-474-6537

Empower Your Professional Community

You Can Change an R.T.’s Life

100% of donations support scholarship, grant and fellowship opportunities for ASRT members. Make your gift today!

800-444-2778, Ext. 1912
foundation.asrt.org

©2016 ASRT Foundation. All rights reserved.
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. Periodical class postage paid at Albuquerque, NM 87123-3909, and at additional mailing offices. Printed in the United States. © 2016 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 email memberservices@asrt.org. ASRT members also can submit changes of address online at 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 publications@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 $7.97 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 asrt.org/publications.

Single issues, both current and back, exist in limited quantities and are offered for sale. For prices and availability, visit 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.

Errata

Page 521 of the “Radiation Safety Compliance” Directed Reading, which appeared in the May/June 2016 issue, erroneously stated that technologists working in fluoroscopy or interventional radiology are required to wear a wraparound apron with 0.5-mm lead equivalent. Wraparound aprons are recommended but not required. Page 521 also incorrectly stated that dosimeters should be worn outside of clothing, under the apron in the same location while performing radiographic or CT procedures. When wearing an apron during radiographic or CT procedures, dosimeters under the apron are not necessary. These errors did not affect the post-test.

The Directed Reading post-test for “Patient Care, Communication, and Safety in the Mammography Suite,” published in the targeted version of the September/October 2016 issue, contained 2 errors. Question 10 has 2 correct answers, and the answer to question 11 is not in the text. Because of these errors, these 2 questions will not be used in grading.

Thank you to the readers who called these items to our attention.
**Radiologic Technology Journal Staff**

**Julie Hinds**, scientific journal managing editor  
**Sherri Mostaghmi**, associate editor  
**Lisa Kiusner**, scientific publications manager  
**Kathi Schroeder**, director of publications and editing  
**Katherine Ott**, senior professional development editor  
**Ellen Lipman**, director of professional development  
**Taylor Henry**, graphic designer  
**Myron King**, graphic designer  
**Marge Montreuil**, graphic designer  
**Laura Reed**, graphic design manager

**ASRT Office**

15000 Central Ave SE  
Albuquerque, NM 87123-3909  
Phone: 800-444-2778; Fax: 505-298-5063  
asrt.org

For questions regarding subscriptions or missing issues, call Member Services at 800-444-2778 or email memberservices@asrt.org.

For advertising information, contact Robin Treaster at 800-444-2778 or email adsales@asrt.org.

For questions concerning editorial content, email publications@asrt.org.

**Submissions**

Submissions from radiologic science professionals and researchers are encouraged. Visit asrt.msubmit.net to upload a manuscript. Author guidelines are available at asrt.org/authorguide.
Certification Simplified

Online education that satisfies the ARRT 16-credit requirement for structured education.

Bone Densitometry
Cardiac Interventional
Breast Sonography
Computed Tomography
Mammography
Magnetic Resonance
Sonography
Vascular Intervventional

✓ Convenient Online Education
✓ Easy to Get Started
✓ Accepted by ARRT

www.asrt.org/structurededucation
Contents

Volume 88, Number 2 • November/December 2016

PEER-REVIEWED ARTICLES

Gonadal Shielding in Radiography: A Best Practice?
Terri L Fauber .......................................................... 127

A Multidiscipline Study of Education Program Accreditation Type and Certification Exam Performance
Ben Babcock .......................................................... 135

DIRECTED READING ARTICLES

Abdominal Aortic Aneurysms
Jeffrey S Legg, Lynn M Legg ........................................ 145

Radiation Protection in Computed Tomography
Scott L Cupp .......................................................... 169CT

COLUMNS

Research & Technology
Measuring the Effect of Breast Density Legislation on a State’s Patients .... 189CT

Special Report
Clinical Decision Support: What Should We Expect? .................. 193

Bookshelf
Imaging Resources .................................................. 195

JRCERT Update
JRCERT’s Strategic Planning Vision From a Radiology Management Perspective ........................................ 199

In the Clinic
Professional Interpretation Services in Health Care .................. 201

Management Toolbox
Job Application Tips ................................................. 205

Global Outlook
Bringing People Together ............................................. 210

Focus on Safety
The Need for Shielding Is Undeniable .............................. 214

Practice Fundamentals
Perfecting the L5-S1 Spot Projection ................................ 216

Patient Care
Identifying Domestic Violence in Patients .......................... 218

Teaching Techniques
Using Brochures to Teach Clinical Communication Skills ....... 222

Writing & Research
Qualitative Research: An Introduction .......................... 225

Guide for Authors
The ASRT Author Guide Is Online ................................ 232

My Perspective
Film-Screen Radiography in Bachelor’s Degree Program Curriculum .... 234

Open Forum
Statistical Significance ............................................. 237

Backscatter
What’s Inside? ....................................................... 240

This symbol indicates expanded content.

ON THE COVER

Inspired by the beautiful imagery produced in an arteriogram, Kaitlin Walsh used water color to depict an abdominal aneurysm in the painting, “The Weakening Aorta.” In her second of 6 journal covers, she aimed to highlight the allure of the radiograph, as well as capture the threatening nature of an aneurysm.
Surgery
Leak resistant container enables safe transport of tissue specimens and for inking of margins.

Radiology
Alphanumeric grid compresses and defines area of interest on the X-ray image.

Pathology
Grid localization identifies exact lesion location for sectioning and histologic analysis. Functions as a storage device.

PathProof™
Surgical Breast Specimen Container
Better • Safer • Saves Money

www.pathproof.org info@pathproof.org

As seen in RADIOLOGIC TECHNOLOGY, May/June 2016, “Surgical Breast Tissue Specimen Handling and Transportation in Radiology”, Container C

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!

“I just completed your CT course. I was extremely pleased at the super fast shipping and the ability to take the test online. Great company. Thank you again for a great option for completing CEUs! Love your company and will do business again!” (Jerry)

xrayce.com
X-RAY CE® P.O. Box 1303 Rockwall, Texas, 75087

20% off any course with coupon code “Scanner”

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!

Radiology 101 - NEW! 15.5 A CEUs $97.95
Fundamentals of Musculoskeletal Imaging 22.0 A CEUs $159.95
Manual of Radiology 20.0 A CEUs $129.95
Musculoskeletal Imaging 18.5 A CEUs $97.95
Gastrointestinal Imaging 18.0 A CEUs $97.95
Spine Imaging 14.0 A CEUs $89.95
Breast Imaging: Case Reviews 10.0 A CEUs $69.95
Radiologic Science for Technologists 28.0 A CEUs $159.95
Practical Digital Imaging and PACS 28.0 A CEUs $159.95
PACS 27.5 A CEUs $159.95
Breast Cancer Imaging 20.0 A CEUs $184.95
Sectional Anatomy 32.0 A CEUs $159.95
Radiographic Image Analysis 28.5 A CEUs $154.95
Special Radiographic Procedures 22.5 A CEUs $139.95
Comprehensive Radiographic Pathology 14.5 A CEUs $97.95
Computed Tomography 22.5 A CEUs $139.95
Radiation Protection 12.0 A CEUs $69.95
Interventional Radiology 12.5 A CEUs $89.95
Radiographic Imaging & Exposure 11.5 A CEUs $79.95
Patient Care in Radiography 10.75 A CEUs $79.95
Accident and Emergency Radiology 8.0 A CEUs $69.95
Pediatric Imaging Case Reviews 15.0 A CEUs $99.95
Mammographic Imaging 13.5 A CEUs $119.95
Emergency Radiology 13.0 A CEUs $97.95

All courses approved as Category A or A+ Credit for ARRT licensure renewal.
Gonadal Shielding in Radiography: A Best Practice?

Terri L Fauber, EdD, R.T.(R)(M)

**Purpose** To investigate radiation dose to phantom testes with and without shielding.

**Methods** A male anthropomorphic pelvis phantom was imaged with thermoluminescent dosimeters (TLDs) placed in the right and left detector holes corresponding to the testes. Ten exposures were made of the pelvis with and without shielding. The exposed TLDs were packaged securely and mailed to the University of Wisconsin Calibration Laboratory for reading and analysis.

**Results** A t test was calculated for the 2 exposure groups (no shield and shielded) and found to be significant, $F = 8.306$, $P < .006$. A 36.4% increase in exposure to the testes was calculated when no contact shield was used during pelvic imaging.

**Discussion** Using a flat contact shield during imaging of the adult male pelvis significantly reduces radiation dose to the testes.

**Conclusion** Regardless of the contradictions in the literature on gonadal shielding, the routine practice of shielding adult male gonads during radiographic imaging of the pelvis is a best practice.

**Keywords** gonadal shielding, pelvic imaging, radiation dose, best practice

Minimizing patient radiation exposure during routine diagnostic imaging is a fundamental practice of radiography. Patient shielding is an important step to reduce patient radiation exposure, yet the practice of shielding patients’ radiosensitive organs is inconsistent. In addition, research suggests that improper shielding could lead to repeat exposures, further increasing the patient’s radiation dose. Recently, the efficacy of shielding male and female gonads has been in question. The risk of low-dose medical radiation exposure continues to be debated in radiology. Stochastic effects, such as cancer and hereditary diseases (ie, genetic mutations), have been associated with low-dose radiation exposure; however, critics say that little evidence supports low-dose cancer risk. Regardless of this debate about low-dose radiation risk, it generally is recognized that medical radiation exposure should be minimized.

Minimizing radiation exposure to patients is emphasized throughout the radiologic technology profession’s practice standards, and gonadal shielding is considered a best practice. However, it is not routinely practiced and conflicting reports on its effectiveness have been published. These contradictions regarding the efficacy of gonadal shielding, the profession’s promotion of shielding, and the reality that shielding is not routinely practiced by radiographers prompted this investigation into the effectiveness of male gonadal shielding during pelvic radiography.

This study experimentally measured the radiation dose to the male gonads with and without shielding. Radiographers need to become more aware of gonadal shielding and its effect on patient dosimetry. Empowering radiographers, educators, and students with the knowledge of how gonadal shielding affects patient radiation dose will result in improved patient radiation safety practices.

**Purpose** To investigate radiation dose to phantom testes with and without shielding.

**Methods** A male anthropomorphic pelvis phantom was imaged with thermoluminescent dosimeters (TLDs) placed in the right and left detector holes corresponding to the testes. Ten exposures were made of the pelvis with and without shielding. The exposed TLDs were packaged securely and mailed to the University of Wisconsin Calibration Laboratory for reading and analysis.

**Results** A t test was calculated for the 2 exposure groups (no shield and shielded) and found to be significant, $F = 8.306$, $P < .006$. A 36.4% increase in exposure to the testes was calculated when no contact shield was used during pelvic imaging.

**Discussion** Using a flat contact shield during imaging of the adult male pelvis significantly reduces radiation dose to the testes.

**Conclusion** Regardless of the contradictions in the literature on gonadal shielding, the routine practice of shielding adult male gonads during radiographic imaging of the pelvis is a best practice.

**Keywords** gonadal shielding, pelvic imaging, radiation dose, best practice

A dramatic increase in radiographic imaging procedures during the past few decades has resulted in a “significant increase in the population’s cumulative
exposure to ionizing radiation. Concerns about low-dose radiation exposure and stochastic effects, such as cancer and hereditary diseases, continue to be investigated. The general consensus among regulatory agencies regarding radiation risk is to adhere to the linear nonthreshold dose response.21,22 This means that the greater the exposure to ionizing radiation, the greater the potential for biologic harm. Although some would argue there is a threshold of radiation dose before biologic harm, uncertainties about the risk of low-dose radiation exposure remain.13 Directly attributing cancer to low-dose radiation exposure has been problematic, and to date there is little evidence to support the low-dose cancer risk.23,24 Factors such as human variability in terms of lifestyle, age at exposure, sex, weight, time since exposure, type of tissue, and the similarity of low-dose medical radiation exposure to the levels of background radiation make it difficult to link low-dose radiation exposure directly to biologic harm.15

Estimates about risks of low-dose exposure are extrapolated from data obtained as a result of high-dose exposure, such as animal studies and studies of the Japanese survivors of the atomic bomb.11-13,22 Critics of the linear nonthreshold risk model believe extrapolating data from high-dose to low-dose exposures is problematic.11-13 For example, evidence suggests that humans have defense mechanisms against low-dose exposure and might exhibit adaptive responses, such as stimulation of defenses and DNA repair.12,14 In addition, translating data from animal studies to humans has limitations.13 Yet, supporters of the linear nonthreshold radiation risk model maintain that “the available data on biologic mechanisms do not provide general support for the idea of a low-dose threshold or hormesis [beneficial effects].”11

Draper believed that “human germ-cell mutations do occur” and the lack of sensitive laboratory techniques might be the obstacle to detect mutations.25 In its most recent publication, the International Commission on Radiological Protection verified the uncertainties about risk by acknowledging that genomic instability and bystander effects might result from low-dose radiation exposure.26 According to Ojima et al, radiation-induced bystander effects happen when damage occurs in cells that did not directly absorb the radiation, such as double-strand breaks.27 Kadhim and Hill suggested that these biological effects are “a consequence of cellular communication with irradiated cells.”28 Double-strand breaks are considered a significant and deleterious effect on cellular response to low doses of radiation exposure.27 If double-strand breaks are not repaired or misrepaired, genetic changes might result.27 In addition, genomic instability can result in heritable changes in the “progeny [offspring] of irradiated cells,” thereby extending the risk of low-dose radiation exposure.29 These heritable changes, such as “delayed gene mutations and chromosomal damage can occur many generations after the original exposure and might play a role in radiation induced cancer.”28 Because the stochastic effects of radiation exposure are cumulative, repeated low-dose radiation exposure from routine imaging has the potential for health risks.30,31

Research regarding risk to offspring as a result of paternal and maternal preconception radiation exposure has demonstrated contradictory results. Studies focusing on radiation exposures to patients, health care workers, nuclear workers, cancer survivors, and atomic bomb survivors have found limited evidence to support health effects to their offspring.34,35,36 However, compelling evidence regarding spontaneous abortions, infertility, and increased risk of infant leukemia have been found in the literature and should not be discounted.32-34

The tissue-weighting factor (WT) is a means to specify the relative radiosensitivity of organs. The gonads have a tissue-weighting factor of 0.08, which is higher than that of organs such as the bladder, liver, and thyroid (0.04).10,26 Because the testes are sensitive to ionizing radiation and paternal preconception radiation exposures could cause reproductive or offspring health effects, epidemiological research on animals is warranted. Giovannetti et al found long-lasting and increasing DNA damage in mice following a single exposure at 0.1 Gy (100 mGy).35 In addition, Gong et al showed that low-dose-rate radiation exposures significantly damaged the testes and sperm.36 Damage to the testes included a decrease in their weight, “increase in the proportion of abnormal tubules,” and a decrease in the sperm count following exposure to 3.49 mGy per hour over a period of days, totaling a dose of 2 Gy.36 Epidemiological studies involving animals provide important information regarding low-dose exposure...
to the testes; however, finding direct evidence of reproductive harm in humans remains challenging. Although research on low-dose radiation exposure in humans is inconclusive, limiting radiation exposure to the gonads is an important radiation safety practice and is endorsed by the American Society of Radiologic Technologist as a practice standard.

For lumbar and pelvic radiographic imaging, the greatest percentage of exposure to the gonads is from scattered radiation within the irradiated tissues; however, exposure does occur from the primary beam when the gonads are in close proximity and to some extent from x-ray tube leakage and off-focus radiation. Gonadal shielding is a standard practice in radiography when radiosensitive organs lie within 4 cm to 5 cm of the primary x-ray beam. Two types of shields commonly used in pelvic imaging are contact shields (flat and shaped) and shadow shields, which are placed below the collimator. Both types of shields require careful positioning to eliminate interference with the anatomy of interest. Professional standards of practice and regulatory guidelines continue to recommend gonadal shielding as one method of reducing radiation exposure to radiosensitive germ cells. Although recommended as a best practice, evidence suggests that the use of routine gonadal shielding is inconsistent.

International studies on pediatric and adult male gonadal shielding during pelvic imaging have confirmed that a high percentage of patients are not shielded. Kenny and Hill investigated pediatric patients who had received a diagnosis of slipped capital femoral epiphysis and who had multiple radiographic imaging examinations. The authors found a lack of consistency in the use of gonadal shielding. Subsequent studies also found problems with gonadal shielding in boys and girls. Frantzen et al reviewed 500 pelvic images in children and found that the shielding placement was incorrect on radiographs for girls in 91% of cases and in 66% of cases for boys. The authors concluded that the risks of radiographic repeats due to incorrect gonadal shielding outweigh the benefits of shielding. In addition, Warlow et al found inadequate gonadal shield placement in 41% of the pediatric male pelvic radiographs. Although male gonadal shielding was found to be inadequate, the authors continued to recommend shielding male patients during pelvic imaging.

In addition to research on the lack of consistent or proper gonadal shielding, some studies have questioned whether shielding actually reduces the dose to the gonads because “surface shields can only protect against external scatter and leakage radiation.” Daniels and Furey investigated the effectiveness of surface shielding by measuring the gonadal air kerma exposure with and without shielding for a variety of kV values (60, 80, 100, and 120) and at varying distances (0-20 cm) between the gonads and the inferior edge of the primary beam. According to their findings, the radiation air kerma decreased significantly as the distance between the inferior edge of the primary field and the gonads increased, yet the authors found no difference in gonadal exposure with and without shielding. For the male gonads in the anteroposterior (AP) projection, the authors estimated that 85% of the exposure was from internal scatter and a much smaller percentage was due to external radiation. Therefore, they contended that gonadal shielding had minimal effect and other dose minimizing techniques should be used, such as higher kVp and collimation. Interpretation of the findings is limited because the authors reported the data as averages for the 4 kV groups (60-120); however, the greatest amount of exposure occurred when the gonads were located at the collimated edge of the x-ray beam.

Similar findings by Mekis et al suggested no difference in the radiation dose to the testes when using a contact shield for the AP projection of the sacroiliac joints, and they recommended imaging them in the posteroanterior (PA) projection. However, a study by Clancy et al investigated the effectiveness of gonadal shielding and found that the testes received a significantly lower exposure (42%) when shielded during AP lumbar spine imaging. Clancy et al measured organ radiation exposures with thermoluminescent dosimeters (TLDs) placed in the detector holes corresponding to the phantom’s testes.

Contradictions regarding the effectiveness of gonadal shielding in the literature only add to the confusion regarding the need for consistent and proper shielding as a best practice in radiography. Therefore, it is important to further investigate whether shielding actually reduces radiation exposure to the gonads. An experimental study investigating the effect of gonadal shielding...
Gonadal Shielding in Radiography: A Best Practice?

Methods

This study used an experimental design to investigate male phantom gonadal dose with and without shielding. TLDs were placed in the 2 detector holes corresponding to the area of the testes on a male anthropomorphic phantom and the pelvis was radiographed. A flat contact shield was used for shielding the phantom’s testes. This type of shield was selected because it is more typically found in diagnostic x-ray rooms. The independent variable was gonadal shielding and the dependent variable was the radiation dose to the testes. Ten exposures of the AP pelvis were taken without gonadal shielding and 10 exposures with gonadal shielding. Organ radiation dose was investigated by measuring the TLDs exposure to the phantom’s testes.

Equipment

An Axiom Multix M radiographic unit (Siemens Healthcare) was used to image an adult male anthropomorphic phantom. The radiographic unit allows imaging with film-screen, computed radiography, and flat panel detector image receptor technology. The flat panel detector is a mobile direct radiography (DR) image receptor that can be positioned in the table or upright Bucky units. The mobile detector is a 14-bit amorphous silicon DR image receptor sized 43 cm × 35 cm.

The anthropomorphic adult male phantom is a tissue-equivalent patient used in medical imaging and radiation therapy (Computerized Imaging Reference Systems Inc). The phantom is “manufactured to provide tissue equivalent substitutes with tolerances better than 1% for bone and soft tissue and 3% for lung tissue at photon energies from 30 keV to 20 MeV.”

The phantom is designed with sectional slabs manufactured with holes for TLD placement in specific organs. The male phantom’s pelvis was radiographically exposed with TLDs placed in the 2 detector holes corresponding to the area of the testes (see Figure 1). The testicular detector holes are located at a depth of 5 mm from the top surface of the phantom.

A flat contact shield was placed over the area of the phantom’s testes. The 0.5-mm lead equivalent shield was tested for its ability to absorb ionizing radiation. Two exposures were made with and without the flat contact shield and the milliroentgen measured with a calibrated dosimeter (Radcal). The milliroentgen reading with the flat contact shield was reduced by 98%.

Before initiating the study, a variety of quality control tests were performed on the radiographic system, including a DR system calibration and self-test (all tests were passed), exposure reproducibility (variance < 0.05) and linearity (variance < 0.10), kilovoltage accuracy (within ± 5%), exposure timer verification (within ± 5%), and measurement of tube filtration (3.6 mm). All tests indicated the imaging system was functioning properly with adequate tube filtration.

Figure 1. Location of thermoluminescent dosimeters 1 and 2 shown within the anthropomorphic phantom. This illustration is not drawn to scale. Image courtesy of the author.
Experiment Procedure
A DR image was produced using 81 kVp with 22 mAs to replicate a typical technique used for an AP pelvic image without gonadal shielding. The automatic exposure control device was used to determine the appropriate mAs without shielding and yielded a mAs of 22, which was used for each of the exposures for shielding and no shielding. A 40-inch (100-cm) source-to-image distance was used with a small focal spot, and the x-ray light field was collimated to 12 inch × 15.5 inch (30 cm × 38 cm) to include the pelvic anatomy. The testes were located 2 cm below the bottom edge of the collimated x-ray field light.

Ten exposures were made of the pelvis with and without shielding to provide sufficient data for statistical analysis. The flat contact shield was placed consistently at the bottom edge of the collimated x-ray field light for each of the exposures. The TLDs were placed in the right and left detector holes of the testes, exposed, and replaced for each of the 20 exposures, totaling 40 exposed TLDs. In addition, one TLD was placed on the anterior surface of the pelvis at the central ray location for each of the 10 exposures for shielding and no shielding (totaling 20 exposed TLDs) to measure air kerma at the central ray. The precise location of the central ray was marked on the phantom so the centering point was consistent. The experimental parameters were reproduced consistently for each of the 10 exposures for shielding and no shielding.

Data Analysis
The exposed TLDs were packaged securely and mailed to the University of Wisconsin Calibration Laboratory for reading and analysis. The report generated by the laboratory provided the TLD readings in milliroentgen radiation units. The central ray exposure milliroentgen values were converted to air kerma in milligray units using the 0.881 correction factor, and the gonadal exposure readings were converted to microgray radiation units using the 0.90 F-factor conversion.

Data were entered into SPSS 22 software (IBM) for statistical analysis. Descriptive statistics were performed to determine the mean and standard deviation of the data collected. A t test was calculated to determine any differences in the air kerma exposures at the central ray location for both exposure groups. In addition, the t test for independent means statistic was performed to determine whether significant differences existed in the gonadal dose for no shielding and shielding. The t test statistic was used because there were 2 groups with interval type data for both analyses.

Results
Figure 2 shows the air kerma exposures in milligray at the central ray location for the 2 groups, no shield and shielded. A t test was calculated and found not to be significant, F = 1.144, P = .299 (see Table 1). This indicates that the exposure to the pelvis for both groups was consistent. Figure 3 shows the gonadal exposure (µGy) for the groups. A t test was calculated for the 2 exposure groups and found to be significant, F = 8.306, P < .006 (see Table 2). The average exposure to the gonads for the no shield group was 254.1 µGy (222.8-270.5) and 186.4 µGy (178.7-198.9) for the shielded group, resulting in a 36.4% increase in exposure to the testes when no contact shield was used during pelvic imaging. Therefore, the null hypothesis stating no difference is seen in radiation dose to the testes with shielding and without shielding was rejected.

Discussion
This study demonstrated that the organ radiation dose to the testes during radiographic pelvic imaging was reduced with statistical significance when using a flat contact shield. These findings conflict with the studies by Daniels and Furey and Mekis et al who believed that radiation exposure to the testes is not significantly reduced by the use of a flat contact shield. However, the findings support the study by Clancy et al, which showed that radiation exposure to the testes can be reduced significantly when using a flat contact shield.

It is important to note that the radiation exposure during pelvic imaging in this study was in the microgray range (100 µGy = 10 mrad). Although this is in the lower range of radiation exposure, little evidence of a threshold for stochastic effects following testicular radiation exposure exists. The linear nonthreshold dose response remains the profession’s accepted theory and, as a result, even very low radiation doses have the potential for biologic harm. Until undisputed evidence reveals that low-dose exposure has no harmful effects on the radiosensitive
accurately. In addition, the decrease in absorbed dose to the phantom’s testes with a flat contact shield can differ at varying kV levels. Future research investigating gonadal shielding by varying the kV/mAs levels, in addition to using a cup-type shield, could demonstrate a greater decrease in absorbed dose to the testes.

testes or male reproductive health, shielding the testes during pelvic imaging should remain a best practice.

It is important to consider the findings of this study in light of its limitations. The contour and location of the testes in the phantom are fixed and might not represent the contour and location in an adult patient

### Table 1

<table>
<thead>
<tr>
<th>Exposure Groups</th>
<th>No Shielding</th>
<th>Shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>345.9</td>
<td>334.3</td>
</tr>
<tr>
<td>2</td>
<td>334.3</td>
<td>321.7</td>
</tr>
<tr>
<td>3</td>
<td>336.7</td>
<td>323.2</td>
</tr>
<tr>
<td>4</td>
<td>335.7</td>
<td>323.4</td>
</tr>
<tr>
<td>5</td>
<td>333.2</td>
<td>338.9</td>
</tr>
<tr>
<td>6</td>
<td>324.0</td>
<td>331.8</td>
</tr>
<tr>
<td>7</td>
<td>314.9</td>
<td>327.2</td>
</tr>
<tr>
<td>8</td>
<td>327.9</td>
<td>337.4</td>
</tr>
<tr>
<td>9</td>
<td>326.3</td>
<td>340.3</td>
</tr>
<tr>
<td>10</td>
<td>320.7</td>
<td>337.3</td>
</tr>
<tr>
<td>Mean</td>
<td>330.0</td>
<td>332.5</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>8.946</td>
<td>6.469</td>
</tr>
<tr>
<td>t test</td>
<td>F = 1.144</td>
<td>Significance = .299*</td>
</tr>
</tbody>
</table>

* > .05 and not significant.

### Table 2

<table>
<thead>
<tr>
<th>Exposure Groups</th>
<th>No Shielding</th>
<th>Shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>264.6</td>
<td>185.4</td>
</tr>
<tr>
<td>2</td>
<td>253.4</td>
<td>180.0</td>
</tr>
<tr>
<td>3</td>
<td>303.3</td>
<td>186.3</td>
</tr>
<tr>
<td>4</td>
<td>258.3</td>
<td>198.9</td>
</tr>
<tr>
<td>5</td>
<td>252.0</td>
<td>180.0</td>
</tr>
<tr>
<td>6</td>
<td>241.7</td>
<td>178.7</td>
</tr>
<tr>
<td>7</td>
<td>270.5</td>
<td>192.6</td>
</tr>
<tr>
<td>8</td>
<td>230.4</td>
<td>193.1</td>
</tr>
<tr>
<td>9</td>
<td>243.9</td>
<td>186.3</td>
</tr>
<tr>
<td>10</td>
<td>222.8</td>
<td>183.2</td>
</tr>
<tr>
<td>Mean</td>
<td>254.1</td>
<td>186.4</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>22.60</td>
<td>7.52</td>
</tr>
<tr>
<td>t test</td>
<td>F = 8.306</td>
<td>Significance = .006*</td>
</tr>
</tbody>
</table>

* < .05 and significant.

---

**Figure 2.** Air kerma in milligray at the central ray location for no shielding and shielding groups.

**Figure 3.** Gonadal exposure in microgray for no shielding and shielding groups.
Although it is not practical to insert TLDs into a live patient, measuring gonadal dose during pelvic and lumbar imaging of cadavers would yield more realistic data.

Few studies exist regarding the attitudes of radiologic technologists about the importance of gonadal shielding and self-reported practices. MacKay et al found differences in attitudes about shielding and practices among Western Australian radiographers for age, sex, education level, and type of employment facility. A large study in the United States on self-reported knowledge about the efficacy of gonadal shielding and its routine practice would provide important information on shielding as a radiation safety practice. Investigating the effectiveness of staff training on the practice of correctly shielding the gonads also would provide valuable information to encourage radiographers to use gonadal shielding routinely.

Conclusion

Using a flat contact shield during imaging of the adult male pelvis demonstrated statistically significant reduction of radiation dose to the testes. Regardless of the contradictions in the literature about the stochastic effects of low-dose radiation exposure and the efficacy of gonadal shielding, the routine practice of shielding the adult male gonads during radiographic imaging of the pelvis is a best practice. Radiographers should make considerable effort to shield the male gonads during radiography of the male pelvis.

References
14. Tubiana M, Feinendegen LE, Yang C, Kamiński JM. The linear no-threshold relationship is inconsistent with radiation...
134

Gonadal Shielding in Radiography: A Best Practice?


A Multidiscipline Study of Education Program Accreditation Type and Certification Exam Performance

Ben Babcock, PhD

**Purpose** To examine the relationship between radiologic technologists’ performance on 3 medical certification exams and the type of accredited education program they attended.

**Methods** Data came from 3 certification exam programs administered by the American Registry of Radiologic Technologists (ARRT). The author used simple means and mixed-effect models to analyze 13 years of data.

**Results** The difference in performance between programs with and without programmatic accreditation, as modeled with linear mixed-effect models, amounted to approximately 2 exam questions out of 200 for radiography, no difference for nuclear medicine technology, and approximately 4 questions out of 200 for radiation therapy.

**Discussion** Exam performance differences among the accreditation types were not large, if they indeed existed, for ARRT certification exam data.

**Keywords** accreditation, certification, education, exam performance, radiologic technology certification
contrast, is a mechanism wherein an independent body evaluates an entire university, college, or other educational entity, of which a given field’s education program is a part. For example, the Higher Learning Commission evaluates universities that have radiography programs.⁶ A given radiography program would have a type of accreditation through the larger institution if the Higher Learning Commission deemed the entire institution was worthy of accreditation.

The difference in scope of these accreditation types has led to cost–benefit questions about accreditation types for educational programs geared to specific professions, particularly in medicine. Proponents of programmatic accreditation argue that only programmatic accreditation can ensure that educational programs geared to a profession maintain the highest standards of educational quality.⁶ They also argue that the more specific standards demanded by programmatic accrediting bodies relating to particular professions lead to educational experiences that are guaranteed to be aligned with practice.⁷ Programs with only institutional accreditation might not be able to guarantee such an alignment based on accreditation status alone.⁴ The implication is that the educational experiences from programmatically accredited programs will lead to students graduating with superior clinical knowledge, skills, and abilities compared with students graduating from programs that do not meet the standards of programmatic accreditation. Superior graduates would, by this logic, lead to better patient care.

Some education programs do not agree with this line of logic. Proponents of institutional accreditation alone being sufficient often argue that the education program relating to a given professional discipline generally is scrutinized through the larger institutional accreditation process. The institution has a vested interest in making sure the specific program in question is a quality program. If an institutional accrediting body determines that a program is not of sufficient quality, then the entire institution risks losing its overall institutional accreditation. The additional cost in money and faculty time might not, in some proponents’ opinions, be worth the programmatically accredited distinction to that institution’s program.⁸⁹

Decisions by certifiers to accept programmatic accreditation mechanisms generally have been noncontroversial. In contrast, decisions by certifiers to accept programs with only institutional accreditation have been somewhat contentious, particularly in medical and allied health professions. Despite an ongoing debate, little published research exists that attempts to measure the effect of accreditation on students’ knowledge, skills, and abilities.⁹⁰ In particular, scant peer-reviewed research has been conducted on whether and how much education programs with different accreditation types differ in student performance on widely administered, objectively measured outcomes of student knowledge. This study analyzes data from 3 main national certifications administered by the American Registry of Radiologic Technologists (ARRT), 2 relating to medical imaging and 1 relating to radiation therapy, to determine any differences in certification exam outcomes for students graduating from programs accredited only programmatically, only institutionally, or both.

Context

Candidates applying for ARRT primary certifications must graduate from education programs accredited by a mechanism acceptable to ARRT. Primary certifications include radiography, nuclear medicine technology, radiation therapy, sonography, and magnetic resonance imaging. This study examines radiography, nuclear medicine technology, and radiation therapy, as these certification programs have a longer, established history than do sonography and magnetic resonance imaging. These 3 certifications also have more education programs recognized by ARRT, which yields more statistically sound comparisons. In addition, the number of candidates taking the sonography and magnetic resonance imaging primary certifications is too low (generally < 200 total first-time examinees per year) to include in this study. ARRT has adopted the policy that programmatic and institutional accreditation mechanisms are acceptable, recognizing a variety of accreditation bodies within these categories.¹¹

The effect of accreditation type on ARRT exam scores is complicated for a variety of reasons. Logistically, programs might make a choice to change accreditation type or status. Although most education programs maintain the same status for years, some programs drop or add an accreditation, thus
changing the program’s accreditation type for this sort of analysis. In addition, ARRT recognizes only 1 programmatic accreditor for radiography and radiation therapy (JRCERT), as well as only 1 for nuclear medicine technology (Joint Review Committee on Educational Programs in Nuclear Medicine Technology [JRCNMT]). However, ARRT recognizes numerous institutional accreditors. Because only one acceptable organization manages programmatic accreditation in each of those disciplines, the accreditation process as applied by the programmatic accreditors varies less across different education programs than does the institutional accreditation process.

Statistical score challenges related to dependencies within education programs complicate the comparison of accreditation types, too. Students in the same program take similar classes with similar instructors. Scores coming out of a program are correlated; ignoring this correlation by averaging across all students can bias statistical analyses. In addition, many programs have few students taking the certification exam in a given year. If a program has only 2 students, for example, 1 student passing vs not passing causes a significant change in the passing rate. ARRT exams have different forms across time. Although ARRT controls the difficulty of the exams using statistical equating, the distribution of scores on different forms can vary over time, causing characteristics of very high and very low scores to differ. Finally, the percentage of students graduating from programs with only programmatic accreditation has decreased in recent years. This trend is due, in part, to ARRT’s policy decision requiring certification candidates to have at least an associate degree. Many hospital-based programs that had only programmatic accreditation became associated with a community college, which gave those programs institutional accreditation. This yielded smaller sample sizes for the programmatically accredited only category in recent years. Smaller sample sizes could yield less stable or reproducible results.

With these issues in mind, this study contains a variety of analyses to compare the performance of education programs with programmatic accreditation only, institutional accreditation only, or both. These analyses use performance on ARRT radiography, radiation therapy, and nuclear medicine technology certification exams as the metrics of interest. It is possible that schools with different accreditation types could differ on metrics other than performance on ARRT exams, but exam performance is a critical outcome measure given the importance of certification to employability. This study is a follow-up to a previous, nonpeer-reviewed study conducted by the ARRT and includes additional data and updated statistical methods.

Methods

Data for this study were from 3 ARRT certifications: radiography, nuclear medicine technology, and radiation therapy. ARRT attained National Commission for Certifying Agencies accreditation for all 3 of these programs, indicating that the programs adhere to modern standards of practice for the certification industry. Each exam also conforms to psychometric best practices as outlined in the Standards for Educational and Psychological Testing.

Each certification mandates that candidates comply with ARRT’s Standards of Ethics, complete a formal education program accredited by a mechanism acceptable to ARRT in the chosen discipline, and pass an exam that measures the knowledge and cognitive skills underlying the intelligent performance of the tasks typically required for practice within the discipline.

The data for this study’s analyses were exam candidates’ education program graduation dates, the programs they attended, years in which they took the exam, exam scores, and passing or failing statuses. ARRT gathers the first 2 pieces of information as a part of its process to determine whether candidates are eligible to take the given certification exam. ARRT gathers the rest of the information from its exam administration vendor during the course of the exam administration process. Additional data about the education programs included the relevant start and ending dates (if applicable) for each program’s programmatic and institutional accreditations. ARRT gave authorization for the author to use these data from its regularly updated exam records database for the purposes of conducting this study.
Candidates may take ARRT exams year-round via computer at various testing centers across the United States. After candidates take the exams, the testing facility transmits the results to ARRT. The exams in this study consisted of 200 scored questions each, with candidates receiving an overall scaled score, not a percentage correct, as the most important performance metric. Exam scaled scores were on a scale of 1 to 99, with a scaled score of 75 representing a passing score. This study used first exam attempt data from candidates who took the radiography, nuclear medicine technology, or radiation therapy exams from 2001 through 2013 and graduated from one of the 3 types of accredited programs. This represents a total of 168,929 exam records, with 150,905 coming from radiography, 6,819 coming from nuclear medicine technology, and 11,205 coming from radiation therapy.

These totals exclude graduates of military-based education programs, as these graduates often have an atypical exam experience. For example, some candidates have a substantial time gap between graduation and the exam because of deployment. Other candidates might be able to schedule an exam during deployment but must arrange for travel to a different country (possibly back to the United States) to take the exam.

There were 3 accreditation categories: programmatic only, institutionally accredited only, and both. Each student’s exam record corresponded to a status category based on the relevant educational program’s status at the time the student graduated from the program. The technique allowed programs with changing accreditation types over time to still enter into the analyses. A graduation date was not available for certain students in the earlier years of this analysis, so the exam date served as the closest possible substitute for graduation date. The data supplied by ARRT indicated that the vast majority of students took certification exams within 2 months of graduation, so the exam date served as a suitable proxy for graduation date when needed. Each individual’s graduation date and education program ID could be used to determine what the education program’s accreditation category was on the date the person graduated.

Analyses

Two types of analyses were used. The first was analyzing mean results by year, separated by the categories of programmatically accredited only, institutionally accredited only, or both. Although a simple analysis of means in this context might experience the statistical challenges for drawing conclusions noted earlier, patterns in these results could shed light on accreditation type and how it relates to exam performance in a descriptive sense.

The second type of analysis was multilevel mixed-effects modeling, sometimes called hierarchical linear modeling, to analyze the data. These models nested students within education programs, statistically accounting for correlated results within programs and for varying program size. Two types of mixed-effects models were used to match the key types of data involved: linear models for modeling exam scaled scores and log-linear models for modeling pass/fail exam results. These models accounted for yearly overall exam performance differences as well as program accreditation type. Although students’ classification into accreditation type related to graduation date, these analyses modeled time effects based on exam date to control for the differences in overall student exam performance over time. At least 5 students had to take the exam in a given year from a given program for that program’s cohort for that year to enter into this type of analysis, as smaller numbers of students resulted in statistically nonidentifiable models.

The coefficients of the log-linear models are more difficult to interpret, as they are in a log-odds metric. The size of the coefficients affect the modeled probability (or percentage) passing in a nonlinear fashion.

The choice to use this statistical modeling was to account for statistical dependencies that occur as a result of certain students graduating from the same program. Simpler models, such as one-way analysis of variance or chi-square tests of independence, do not account for these dependencies, thus violating the statistical assumptions of these models. This violation would call into question the resulting P-values for hypothesis testing. The models also statistically accounted for yearly variations in exam performance, thus eliminating these differences as potentially confounding variables from the analysis. These models simultaneously take into account exam year effects and clusters of students within education programs before evaluating the effect of accreditation status.
Results

Table 1 contains the sample sizes by program accreditation type in radiography, nuclear medicine technology, and radiation therapy from 2001 through 2013, as well as the percentages graduating from the different types by year. Several important trends are pertinent to interpreting this study’s results. First, the raw sample sizes for radiography are larger than for nuclear medicine technology and radiation therapy. This means that the results for individual years for radiography tend to be more stable than the results for nuclear medicine technology and radiation therapy. Radiation therapy has the next largest sample sizes, and nuclear medicine technology has the smallest sample sizes. In addition, the nuclear medicine technology programmatic only and institutional only conditions have several years where the total number of candidates is fewer than 100. This small sample size makes the conclusions for any one year less stable, so results should be interpreted with caution.

Second, for all disciplines, the percentage of graduates in the institutional only category is increasing. The percentages generally decrease in the programmatic only category. This makes interpreting programmatic only results for individual years difficult for nuclear medicine technology and radiation therapy because sample sizes already are small. The percentages in the both programmatic and institutional categories vary depending on the year.

<table>
<thead>
<tr>
<th>Sample Sizes and Percentages of Graduates by Education Program Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample Size</strong></td>
</tr>
<tr>
<td><strong>RAD</strong></td>
</tr>
<tr>
<td>P</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>P+I</td>
</tr>
<tr>
<td><strong>NMT</strong></td>
</tr>
<tr>
<td>P</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>P+I</td>
</tr>
<tr>
<td><strong>THR</strong></td>
</tr>
<tr>
<td>P</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>P+I</td>
</tr>
</tbody>
</table>

*Columns might not add to 100% because of rounding.

Abbreviations: I, institutional only; NMT, nuclear medicine technology; P, programmatic only; P+I, programmatic and institutional; RAD, radiography; THR, radiation therapy.
A Multidiscipline Study of Education Program Accreditation Type and Certification Exam Performance

Peer Review

Figure 1 is a graph of the mean scaled scores and the mean passing percentages over time for radiography. The limits of the vertical axis are the typical range of individual scaled scores that ARRT has observed. Several trends can be observed from this graph. First, the mean scaled score for the 3 accreditation types over time is similar. Occasional differences in terms of pass rates were seen, but there were numerous years in which the mean pass rates for institutional only and programmatic only were within a single percentage point. Pass rates for all years were high, and all mean scaled scores were well above the scaled score of 75 required for passing the exam.

Figure 2 contains mean scaled scores and mean passing percentages over time for nuclear medicine technology. Again, the mean scaled scores for the 3 types were similar and overlapped for much of the time period. Performance for the programmatic only programs increased in later years, but the sample sizes were small for those years, making the results for recent years less stable. The passing rates between years were more variable than for radiography. The accreditation status with the highest passing rate varied throughout the years of this study, so it was difficult to find a strong trend based simply on examining these averages without additional statistical modeling.

Figure 3 contains mean scaled scores and mean passing percentages over time for radiation therapy. In contrast to radiography and nuclear medicine technology, a clear trend in the radiation therapy exam performance ordering is seen. For both mean exam scores and mean passing rates, programmatic accreditation only programs appear to have the highest performance, followed by programs with programmatic and institutional accreditation, followed by the institutional accreditation only programs. The institutional only and the programmatic and institutional programs seemed to have performed better in the last few years displayed, but the time period was too brief to make any solid conclusions.

Hierarchical Models

Table 2 contains the fixed-effect coefficients from the hierarchical linear models for scaled score. For all conditions, programmatic accreditation only in 2001 was the base (intercept) condition. All other coefficients represent the mean difference between a condition and the intercept. For example, the mean radiography scaled score in 2004 was, on average, 1.11 scaled score points higher than in 2001. This study included year effects to control for varying examinee performance and sample size across time. The focus of these models rests in the...
coefficients for institutional only and programmatic and institutional factors.

For radiography, a statistically significant difference exists between the candidates from the institutional accreditation only programs compared with the programmatic only programs. Institutional accreditation only programs performed approximately 0.66 scaled score points lower than the programmatic only programs. This translates to approximately 2 exam questions out of 200. No significant difference was seen between mean scaled scores for programs with both programmatic and institutional accreditation when compared with the programmatic only programs. For nuclear medicine technology, programs with only institutional accreditation performed the same as the programmatic only programs, with no significant difference. In addition, no significant difference was seen between programs with both programmatic and institutional accreditation and the programmatic only programs. For radiation therapy, no statistically significant differences in mean exam score by accreditation category were demonstrated.

Table 3 contains the fixed-effect coefficients from the hierarchical log-linear model predicting passing rate. For radiography, a statistically significant difference was seen in log odds of passing between the programmatic only and the institutional only programs, with institutional only programs having 0.26 log odds poorer chance of passing. Given the other coefficients of the model, this translates to a 1% to 2% difference in passing rate. The programs with both programmatic and institutional accreditation performed identically to the programmatic only programs. For nuclear medicine technology, no statistically significant differences for passing rate among the accreditation types were demonstrated. For radiation therapy, a statistically significant difference in log odds of passing between the programmatic only and the institutional only programs was seen, with institutional only programs having 0.70 log odds lower passing rate. Given the other coefficients of the model, this translates to a 5% to 10% difference in passing rate. No significant difference between the

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>RAD</th>
<th>NMT</th>
<th>THR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>83.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>83.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>80.52&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2002</td>
<td>−.16</td>
<td>−.28</td>
<td>.55</td>
</tr>
<tr>
<td>2003</td>
<td>−.01</td>
<td>.37</td>
<td>.22</td>
</tr>
<tr>
<td>2004</td>
<td>1.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.83</td>
<td>.82</td>
</tr>
<tr>
<td>2005</td>
<td>2.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.33&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.18&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2006</td>
<td>2.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.74&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.09&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2007</td>
<td>2.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.91&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2008</td>
<td>1.98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.83&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.87&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2009</td>
<td>2.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.77&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2010</td>
<td>2.28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.87</td>
<td>1.57&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2011</td>
<td>2.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.00</td>
<td>2.64&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2012</td>
<td>2.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.70</td>
<td>2.85&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2013</td>
<td>1.29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.00</td>
<td>2.37&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Institutional only</td>
<td>−.66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>−.04</td>
<td>−1.33</td>
</tr>
<tr>
<td>Both programmatic and institutional</td>
<td>.03</td>
<td>−1.10</td>
<td>.06</td>
</tr>
</tbody>
</table>

<sup>a</sup>Coefficients are in scaled score points. The intercept condition represents the modeled mean score for the year 2001 for programs with only programmatic accreditation.

<sup>b</sup>Statistically significant, P < .01.
Discussion

This research compared education programs with different accreditation types in terms of performance on 3 national certification exams. These programs were programmatically accredited, institutionally accredited, or both. Results showed that differences in performance among the accreditation types varied for the 3 certifications involved. For radiography, programs with only institutional accreditation performed lower than programs with programmatic accreditation, although the differences were small. The difference in total score was about 2 questions out of 200, and the difference in passing rate was approximately 1% to 2%. The performance of the institutional only programs and the both programmatically and institutionally accredited programs for more recent years appears to be nearly identical. These small differences are statistically, but not practically, significant. For nuclear medicine technology, no significant differences in mean score or pass rate among the accreditation categories existed. For radiation therapy, a somewhat larger nonsignificant difference in total exam scores was seen, but the difference still amounted to approximately 4 questions out of 200. This difference was close but not significant at the .01 level, possibly because the small sample sizes and small number of programs in radiation therapy yielded insufficient statistical power. The largest effect of the study was the difference in passing rate for institutionally accredited only radiation therapy programs, which was 5% to 10% lower than programmatically only accredited programs.

Based on these results, education programs with differing accreditation types did not have large differences in exam performance. Only in radiation therapy did the effect for passing rate approach a level where the difference might be meaningful. Even then, the observed differences were smaller than or comparable to the differences in exam performance between the baseline and final years of this study. That is not to say that accreditation type causes, or does not cause, differences in certification exam performance. The current research is observational. The groups of education programs self-selected into categories of accreditation type. To make a stronger causal inference, programs would need to be assigned to accreditation type randomly, and such a study is impossible to implement in practice.

Certification exam scores are not the only metric by which researchers could measure the effectiveness of education programs. A variety of variables could be used to evaluate student performance from programs dealing with everyday practice, the quality of care, patient outcomes, and, in the context of medical imaging and related disciplines, the quality of the images produced. However, it is unclear whether another type of data would yield results as reliable or as comprehensive across numerous education programs as certification exam results. Future research could gather different types of data to evaluate the achievement or effectiveness of students graduating from programs with various accreditation types.

Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>RAD</th>
<th>NMT</th>
<th>THR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.23</td>
<td>.37</td>
<td>.20</td>
</tr>
<tr>
<td>2002</td>
<td>.05</td>
<td>.66</td>
<td>.11</td>
</tr>
<tr>
<td>2003</td>
<td>.13</td>
<td>.04</td>
<td>.18</td>
</tr>
<tr>
<td>2004</td>
<td>.26</td>
<td>.43</td>
<td>.22</td>
</tr>
<tr>
<td>2005</td>
<td>.35</td>
<td>.05</td>
<td>.20</td>
</tr>
<tr>
<td>2006</td>
<td>.57</td>
<td>.26</td>
<td>.56</td>
</tr>
<tr>
<td>2007</td>
<td>.63</td>
<td>.35</td>
<td>.22</td>
</tr>
<tr>
<td>2008</td>
<td>.65</td>
<td>.71</td>
<td>.38</td>
</tr>
<tr>
<td>2009</td>
<td>.70</td>
<td>.74</td>
<td>.41</td>
</tr>
<tr>
<td>2010</td>
<td>.83</td>
<td>.03</td>
<td>.16</td>
</tr>
<tr>
<td>2011</td>
<td>.84</td>
<td>.06</td>
<td>.61</td>
</tr>
<tr>
<td>2012</td>
<td>.90</td>
<td>.17</td>
<td>.69</td>
</tr>
<tr>
<td>2013</td>
<td>.33</td>
<td>.58</td>
<td>.69</td>
</tr>
<tr>
<td>Institutional only</td>
<td>.26</td>
<td>.10</td>
<td>.70</td>
</tr>
<tr>
<td>Both programmatic and institutional</td>
<td>.00</td>
<td>.64</td>
<td>.19</td>
</tr>
</tbody>
</table>

*Coefficients are in the log-linear (logit) metric. The intercept condition represents the modeled log odds of passing the exam for the year 2001 for programs with only programmatic accreditation.

Statistically significant, \( P < .01 \).
This research dealt only with radiography, nuclear medicine technology, and radiation therapy. It might be possible to observe different patterns of results based on accreditation type in other contexts. Future research should attempt to use methods similar to those used in this research to study other professions in which accreditation types could affect outcomes.

Finally, institutional policies affected the relative sample sizes observed in this study. The percentages of students graduating from programmatically accredited only schools decreased over time. The decrease might have been the result of a variety of factors. One important contributing factor was the ARRT policy that took effect in 2015 requiring new primary certification candidates to have at least an associate degree.

**Conclusion**

This study analyzed exam performance among education programs with varying accreditation types. Accreditation is important to ensure that education programs meet quality learning standards. This study will help build the literature as part of a larger context for the discussion of accreditation types, which will advance high standards in a variety of professions.

---

Ben Babcock, PhD, is supervising senior psychometrician for the American Registry of Radiologic Technologists (ARRT) in St Paul, Minnesota. He can be reached at ben.babcock@arrt.org.

The author would like to thank Dan Anderson, MA; Adam Wyse, PhD; and Jerry Reid, PhD, for their editing suggestions for this work, as well as Tina Sorenson for contributing her knowledge of ARRT’s database of education programs. The viewpoints and discussions found in this article do not necessarily represent the official position of ARRT.

Received November 20, 2015; accepted after revision March 17, 2016.

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

© 2016 American Society of Radiologic Technologists

---

**References**


Abdominal Aortic Aneurysms

Jeffrey S Legg, PhD, R.T.(R)(CT)(QM), FASRT
Lynn M Legg, MBA, R.T.(R)(M)

After completing this article, the reader should be able to:
- Describe aortic anatomy.
- State the preventive screening recommendations for abdominal aortic aneurysm (AAA).
- Identify the most common locations of AAA occurrence.
- Recall the preferred imaging modalities for AAA and their specific applications.
- Discuss treatments for AAA.

Abdominal aortic aneurysm (AAA) is a significant disease affecting the circulatory system. Risk factors include smoking, hypertension, sex, and a possible hereditary predisposition. AAAs remain asymptomatic for years, and various imaging methods are used in their detection, diagnosis, and treatment. This article reviews the anatomy and physiology of the aorta as well as the signs and symptoms, pathophysiology, epidemiology, and risk factors for the development of AAA. The use of ultrasonography and other imaging modalities for pre- and post-treatment is discussed, as is endovascular aortic repair.

The aorta is the largest artery in the human body. Originating from the left ventricle, it extends into the chest and down into the abdomen. The vessel is the main conduit for distributing oxygenated blood from the heart to the body. Abdominal aortic aneurysm (AAA) is a localized enlargement within the abdominal cavity.

Anatomy and Physiology
The aorta is the major artery of the body carrying oxygenated blood from the heart through the thoracic and abdominal cavities of the body (see Figure 1). The aorta attaches superiorly to the left ventricle. Blood is pumped through the aorta with every left ventricular contraction. A 3-leaflet valve at the junction of the left ventricle and aorta (aortic valve) prevents retrograde flow of blood into the ventricle.

The aorta is divided into 4 sections: ascending aorta, aortic arch, thoracic aorta, and abdominal aorta. The ascending aorta, which rises superiorly from the left ventricle, is approximately 3 cm in diameter but can vary depending on patient sex, age, and size. At the root of the ascending aorta are 3 anatomical dilatations called the aortic sinuses. From the left and right aortic sinuses arise the left and right coronary arteries, respectively. The coronary arteries vascularize the heart (see Figure 2). The posterior sinus has no coronary artery.
As the aorta rises superiorly from the heart, it makes a downward curve, which is known as the aortic arch. The aortic arch often is visible on chest radiographs; from it arises arteries supplying blood to the head, neck, and upper limbs—the brachiocephalic artery (which bifurcates to form the right subclavian artery and right common carotid artery), left common carotid artery, and left subclavian artery. The aortic arch also has function in homeostasis, containing baroreceptors and chemoreceptors that send information about carbon dioxide levels and blood pH to the medulla oblongata.2,3

Beyond the aortic arch, the aorta descends caudally, which is called the descending aorta. The descending aorta is divided into 2 parts based on location. The initial section of the aorta that passes through the mediastinum and chest is called the thoracic aorta. Many branches originate from the thoracic descending aorta, including intercostal and subcostal arteries, bronchial arteries, and branches that supply blood to the esophagus, mediastinum, pericardium, and diaphragm.2

The aorta enters the abdominal cavity through the diaphragm and then divides into 2 major vessels: common iliac arteries and the median sacral artery. Important branches of the abdominal aorta are the lumbar and musculophrenic arteries, renal and suprarenal arteries, and arteries that vascularize the abdominal viscera, such as the celiac trunk and the superior and inferior mesenteric arteries.2

Generally, all arteries have 3 layers. The layers of the aorta are composed of smooth muscle, nerves, intimal cells, and extracellular matrix. The aortic wall is divided into 3 layers (from external to lumen): tunica externa (or tunica adventitia), tunica media, and tunica intima (see Figure 3). The vascular supply to the tunica externa and tunica media is provided by an extensive network of small blood vessels known as the vasa vasora.2

Blood flows through the aorta in pulses due to contraction of the left ventricle. The elasticity of the aorta allows it to expand and contract as the heart pumps blood through it. The tunica media contains collagen and elastin filaments that allow it to stretch and contract in response to the pulsatile flow of blood, assisting in the propulsion of blood through the circulatory system.
Prevalence

AAAs are the most common arterial aneurysm, with approximately 80% occurring below the renal arteries at the area of aortic bifurcation. Studies of adults 50 years and older indicate an AAA prevalence of 3.9% to 7.2% in men and 1.0% to 1.3% in women. Worldwide, the prevalence is higher in western countries than in Asiatic countries, and higher in Australia than in the United States and Europe. If diagnosed before becoming symptomatic, an AAA can be treated and cured. However, a ruptured AAA is considered a medical emergency, with a 59% to 90% mortality rate if it occurs outside a hospital environment. The operative mortality for AAA, defined as death regardless of cause occurring within 30 days after surgery, is approximately 40%. Mortality rates for elective (ie, nonemergency) AAA repair are significantly lower, ranging from 0.6% to 5.3%. Therefore, careful screening to detect AAAs and followup when diagnosed are necessary, specifically with at-risk patients.

The diameter of the aneurysm influences the potential for rupture. For AAAs 3.0 cm to 3.9 cm in diameter, the annual risk for rupture is negligible. The risk is 1% for aneurysms that are between 4.0 cm and 4.9 cm, and
undetected for years. Similarly, the rate of AAA expansion is difficult to predict. The most common presentation of a nonruptured AAA is vague, yet persistent and deep, back and abdominal pain that might extend to the flanks and groin. A pulsatile pain might be felt around the umbilicus; however, this pain often is noticeable only on examination.

The symptoms of a ruptured AAA are more significant, yet still ambiguous. These include pain in the abdomen or back and can be confused with renal calculus, diverticulitis, or herniation. This severe pain might appear suddenly, be constant, or spread to the groin, buttocks, legs, or scrotum. Tachycardia and dizziness on standing also is common. Other symptoms include syncope, loss of consciousness, sweaty/clammy skin, nausea, and vomiting. Internal bleeding from a ruptured AAA can result in hypovolemic shock with symptoms such as hypotension, cyanosis, skin mottling, and altered mental status. These symptoms are serious considering that nearly 65% of patients with a ruptured AAA die of sudden cardiovascular collapse.

Medical imaging plays an important role in the diagnosis, surveillance, treatment, and follow up for AAA. Because the majority of AAAs are asymptomatic, their initial diagnosis might be an incidental finding during imaging.

**Screening and Surveillance**

The U.S. Preventive Services Task Force (USPSTF) is an independent panel of experts in primary care and prevention that systematically reviews the evidence of effectiveness and develops recommendations for clinical preventive services. The USPSTF offers separate AAA screening recommendations for men and women. For a man aged 65 to 75 years who has smoked 100 or more cigarettes in his lifetime, the Task Force recommends one-time screening. For this group, it also recommends clinicians be selective when counseling those in the same age cohort who have never smoked because the benefit for screening is small. For male nonsmokers, the individual and his physician(s) should base their decision on the individual’s medical and family history, other risk factors, and personal values. The USPSTF does not recommend routine AAA screening for female nonsmokers, regardless of age, because the evidence about its benefit is insufficient.

**Risk Factors**

The etiology of AAA is unknown; however, several risk factors are associated with an increased incidence. One significant risk factor is smoking. Singh et al posited that an individual’s number of years smoking is the critical risk factor. Occasional, past, short-term tobacco use also was found to increase the risk of AAA, although this risk decreased over time after cessation of smoking. Many studies include high blood pressure and chronic hypertension (systolic $\geq$ 160 mm Hg; diastolic $\geq$ 95 mm Hg) as risk factors. However, conflicting evidence exists over whether the risk of AAA from hypertension is gender specific. Analysis by Forsdahl et al, for example, indicated that the risk exists only in women. In addition, the prevalence of AAA among men older than 50 years of age is 4 to 6 times greater than that of women of the same age. Interestingly, AAAs appear to develop 10 to 15 years later in women than in men. The peak prevalence of AAA in men is 5.9% at ages 80 to 85 years. However, among women the peak prevalence is 4.5% at 90 years or older. A hereditary link for the development of AAAs has been hypothesized, prompting studies into the effects of genetics on AAA development among twins and other close relatives. Results from the Swedish Twin Registry, which contains data on twins in Sweden since 1886, indicated that monozygotic twins (ie, 2 offspring developed from a single fertilized ovum) had a 24% probability of having an AAA if the other twin had one. Another study indicated that a positive family history of AAA in a first-degree relative increases the risk of aortic aneurysm by up to a factor of 10. Research continues in an attempt to determine the specific genes associated with AAA development.

**Signs and Symptoms**

Because AAAs are asymptomatic until they expand enough to press on local organs or rupture, they can go
However, recommendations differ. The American College of Cardiology and the American Heart Association, for example, suggest screening for men 60 years and older who have a first-degree relative with AAA. The American Society for Vascular Surgery and the European Society for Vascular Surgery advocate for screening for all men 65 years and older, regardless of smoking history. Both vascular surgery societies also recommend screening for women who are considered high risk based on smoking or family history.

Color duplex ultrasonography is the recommended tool for AAA screening. Advantages include high sensitivity and specificity for AAA, low cost, availability, short examination time, patient acceptance, and no radiation exposure. Recommendations for screening ultrasonography for the abdominal aorta are promoted in a joint resolution by the American College of Radiology (ACR), the American Institute of Ultrasound in Medicine, and the Society of Radiologists in Ultrasound. These organizations formed a consensus group that advocates use of real-time scanners using transducers that allow for appropriate penetration and resolution. Suggested parameters include longitudinal (along the long axis of the aorta) and transverse images (perpendicular to the long axis of the aorta) that include the proximal (inferior to diaphragm, near the celiac artery), mid (near the level of the renal arteries), and distal (above the iliac bifurcation) sections of the aorta (see Figure 5).

The Society for Vascular Ultrasound recommends use of duplex instrumentation that displays 2-D structures and motion in real-time and Doppler. Recommendations for spectral analysis and color Doppler imaging include:

- Proper sample volume size and positioning.
- An angle of 60° or less with respect to the vessel wall and direction of blood flow.
- Measurement of spectral velocities.
- Imaging carrier frequency between 2.25 MHz and 4.0 MHz as needed for penetration.
- Doppler carrier frequency of 2.5 MHz to 4.0 MHz as needed for penetration.

AAAs should be measured in the anteroposterior dimension, and the greatest dimension should be reported.

Aortic diameters smaller than 3.0 cm are considered normal, and they require no further screening or surveillance. According to Lederle et al, small to medium-sized AAAs (3.0-5.4 cm) should undergo surveillance and follow up. Aneurysms in the 3.0-cm to 3.9-cm range require a conservative management approach that seeks to slow the growth of the AAA. Aneurysms in this range are at risk for enlarging and should be monitored every 2 to 3 years. Medium-sized aneurysms (4.0-5.4 cm) should be monitored every 6 months. AAAs 5.5 cm or larger require treatment.

Regardless of surveillance frequency, life-long control of risk factors, such as smoking, hypertension, hyperlipidemia, and diabetes, is necessary. Pharmacotherapy might be required. The role of beta blockers, used to control hypertension, in reducing AAA growth and improving health outcomes is questionable.

Figure 5. Ultrasound images of AAA in transverse (A) and longitudinal (B) views. Calipers size the AAA at 60.3 mm and 51.9 mm in the transverse and longitudinal views, respectively. Reprinted with permission from Brekken R, Dahl T, Hernes TA. Ultrasound in abdominal aortic aneurysm. In: Grundmann R, ed. Diagnosis, Screening and Treatment of Abdominal, Thoracoabdominal and Thoracic Aortic Aneurysms. Rijeka, Croatia: InTech; 2011:103-124.
Abdominal Aortic Aneurysms

Pretreatment Planning

Computed tomography angiography (CTA) is considered the preferred imaging surveillance method for pre- and post-endovascular aneurysm repair (EVAR) as well as for postopen surgical repair. Chaer recommends obtaining 2.5 mm or smaller slices of the abdomen and pelvis using 3-D reconstruction. This method allows for accurate measurements perpendicular to the true axis of the aorta. Three-dimensional aortic measurements are more accurate than 2-D measurements and aid sizing of the graft (see Figure 7).

Anatomic considerations from preoperative imaging include aneurysm morphology and measurements. Examples of important aortic measurements for sizing an endograft include aortic neck:

- Diameter at the most caudal renal artery branch.
- Length, or distance from most caudal renal artery to the origin of the aneurysms.
- Angulation, or angle formed between points connecting the lowest renal artery, the origin of the aneurysm, and the aortic bifurcation.

Figure 8 illustrates several AAA measurements as described by Goshima et al. The various measurements allow for accurate sizing of the stent-graft and aids in placement.
from the base of the lungs to the symphysis pubis, timed to a bolus tracking at the celiac trunk of 150 HU over the baseline.

**Magnetic Resonance Angiography**

Magnetic resonance angiography (MRA) with gadolinium is an alternative for pre-EVAR planning in patients for whom iodinated contrast is contraindicated.\(^4\) However, because nephrogenic systemic fibrosis (a rare syndrome involving fibrosis to internal organs, skin, and joints) is linked to gadolinium-based contrast agents and anaphylactic reactions, evaluation of renal function prior to MRA contrast is recommended.\(^4\) MRA has a lower sensitivity (ie, ability to identify true positive cases) than does CTA to detect small blood vessels and renal arteries with diameters smaller than 2 mm. For pre-EVAR planning, the ACR recommends T1- and T2-weighted spin-echo image sequences for assessing aneurysm morphology and relevant vascular anatomy.\(^4\) The use of noncontrast MRA sequences are gaining acceptance but should be performed only in centers with expertise in the technique.\(^4\)

**Other Modalities**

Unlike CTA and MRA, neither digital subtraction angiography nor ultrasonography are recommended for pre-EVAR measurements. Specifically, digital subtraction angiography is limited by measurement errors arising from parallax and magnification, and it cannot evaluate the true aortic lumen diameter.\(^4\)

**Treatment**

Various options are available for treating AAAs, including endovascular and open surgery, and
important factors for any treatment are aneurysm size and risk of rupture (see Table 1). The enlargement rate of AAAs varies; some increase steadily, others increase rapidly, and about 20% remain the same size indefinitely. The typical expansion rate is 0.3 cm to 0.4 cm per year.

**Elective Treatment**

Two types of treatment for AAAs are available: open surgical repair and endovascular aneurysm repair (EVAR). Although physician clinical decision-making is outside the scope of this article, factors typically considered include mortality rates, complications, and balance of short- vs long-term benefits (eg, risk of reintervention with EVAR vs open repair).

Surgical repair of AAAs in the 4.0-cm to 5.4-cm range has not reduced mortality rates compared to periodic surveillance. However, for aneurysms larger than 5.5 cm, open surgical intervention is recommended if the perioperative and postoperative complications are lower than the estimated risk of rupture. Additional indications for elective surgery include increase in size by more than 0.5 cm within 6 months, regardless of size.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>AAA Size and Rupture Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (cm)</td>
<td>Rupture Risk (%/year)</td>
</tr>
<tr>
<td>&lt; 4</td>
<td>0</td>
</tr>
<tr>
<td>4-4.9</td>
<td>1</td>
</tr>
<tr>
<td>5-5.9</td>
<td>5-10</td>
</tr>
<tr>
<td>6-6.9</td>
<td>10-20</td>
</tr>
<tr>
<td>7-7.9</td>
<td>20-40</td>
</tr>
<tr>
<td>&gt; 8</td>
<td>30-50</td>
</tr>
</tbody>
</table>

* Elective surgical repair should be considered for aneurysms > 5 cm.

**Open Repair**

Open repair is the traditional approach for treating AAAs. Once open repair is decided upon, imaging is used to identify anatomical variants to guide treatment and prevent unexpected complications. Open repair is conducted under general anesthesia, and a large incision is made either transperitoneally or retroperitoneally to access the abdominal aorta. Research indicates no significant differences in outcome between the 2 approaches; thus, the choice of approach might be based on patient body habitus, patient preference, the surgeon’s experience and preference, or a combination of these factors.

The affected portion of the aorta is resected and replaced with a synthetic graft (see Figure 10). If the AAA involves the iliac arteries, the synthetic graft is extended to include those vessels. An aneurysm proximal to the renal arteries results in the arteries being reimplanted into the graft, or the creation of a bypass graft. Aortic replacement graft materials include polyester (eg, Dacron), polytetrafluoroethylene, and autogenous vein; woven polyester most commonly is used. Important qualities in graft material include ease in handling, durability, and appropriate porosity. The diameter of the selected graft should match the aortic diameter; the diameter of a graft usually is smaller than the diameter of an endograft used in the same location, if endovascular management is elected.

**Endovascular Aneurysm Repair**

EVAR is less invasive than open repair and consists of interventional radiology or surgical placement via the
from various manufacturers. Stents typically are made of nitinol, Elgiloy, or stainless steel (see Figure 11). Complications of EVAR include infection, thrombosis, incorrect placement of the graft (ie, kinking, angulation), graft migration, and endoleaks (ie, the flow of blood into the aneurysm sac after graft placement). EVAR requires more frequent imaging followup than does open repair.

**Ruptured AAA Repair**

A ruptured AAA is defined as a bleeding outside of the wall of the aneurysm that requires immediate treatment, as the condition nearly always is fatal; death usually occurs within hours. The mortality rate from ruptured AAAs during open repair is approximately 50%; EVAR has a lower mortality rate—between 20% and 30%. Although outcomes can improve with EVAR over open repair, the emergent nature of a ruptured AAA creates major challenges. For example, most medical institutions are not equipped to treat ruptured AAAs with EVAR. In addition, patients experience better outcomes undergoing a procedure at the institution to which they are first admitted; a 17% to 19% increase in mortality has been reported when patients are transferred to another facility for open repair.

Specific to AAA, additional imaging reconstruction techniques are used to obtain accurate measurements. Multiple vendors supply software that allow for semiautomated measurements of vessel diameter and length in relation to the proximal and distal margins of the aneurysm. Three-dimensional analysis includes volume rendering, maximum-intensity projection, and curved planar reformations. Benefits of reformatted and reconstructed images include more accurate pretreatment measurements. Three-dimensional volume rendering provides excellent depiction and precise measurement of any angulation in tortuous AAAs.

**Post-treatment Imaging**

Imaging after AAA treatment is routine to detect issues or complications with the graft, which can include endoleak and fistula formation, as well as to monitor aneurysm size. The timing of follow-up imaging varies with...
Iezzi et al recommend that a 90-ml to 130-ml bolus of contrast be administered at a rate of 3 ml/s to 4 ml/s during the arterial phase. Bolus-tracking software is used to delay the scan until a 100-HU change develops in the opacification of the aorta. Delayed phase images are acquired after the arterial phase, typically 60 to 120 seconds after the initial contrast material injection. Postprocessing includes maximum-intensity projection and volume rendering. Because of the frequency of CT scans for post-EVAR follow-up, radiation dose reduction methods should be employed.

Although MRA is an appropriate alternate to CTA, it is less accurate for assessing the metallic components of the endograft, which might induce artifacts.

Abdominal CTA techniques for post-EVAR patients vary between institutions, but imaging parameters can include:

- Single arterial phase.
- Biphasic (ie, noncontrast CT and either the arterial phase, or arterial and delayed phases).
- Triphasic (noncontrast CT, arterial phase, and delayed phases).

the type of treatment employed. For example, in patients who underwent open repair, a CT scan is recommended within 5 years to detect aneurysm degeneration involving the pararenal aorta, iliac arteries, endograft, or anastomotic sites. However, compared to open repair, EVAR requires more frequent imaging follow up. Post-EVAR contrast-enhanced CT is recommended at the 1-, 6-, and 12-month marks—as well as for lifelong annual surveillance—and is the ACR's suggested imaging modality of choice. The primary goal of post-EVAR is to evaluate the integrity of the stent-graft, including evaluation for migration, kinking, structural failure, and endoleak (see Figure 12). Decreasing aneurysm sac size is evidence of a well-functioning stent-graft. Volume analysis of the aneurysm sac is recommended by the ACR because it entails all dimensions of the AAA.

Abdominal CTA techniques for post-EVAR patients vary between institutions, but imaging parameters can include:

- Single arterial phase.
- Biphasic (ie, noncontrast CT and either the arterial phase, or arterial and delayed phases).
- Triphasic (noncontrast CT, arterial phase, and delayed phases).

Iezzi et al recommend that a 90-ml to 130-ml bolus of contrast be administered at a rate of 3 ml/s to 4 ml/s during the arterial phase. Bolus-tracking software is used to delay the scan until a 100-HU change develops in the opacification of the aorta. Delayed phase images are acquired after the arterial phase, typically 60 to 120 seconds after the initial contrast material injection. Postprocessing includes maximum-intensity projection and volume rendering. Because of the frequency of CT scans for post-EVAR follow-up, radiation dose reduction methods should be employed.

Although MRA is an appropriate alternate to CTA, it is less accurate for assessing the metallic components of the endograft, which might induce artifacts.

Abdominal Aortic Aneurysms

According to the ACR, the following imaging results have been found for the various endograft elements:

- Nitinol (nickel and titanium alloy) – causes relatively few MR artifacts and allows for visualization of the stent lumen and adjacent structures; considered the best candidates for MRA.
- Elgiloy (alloy of cobalt, chromium, and nickel) – might cause significant artifacts and compromise visualization of the stent-graft lumen while allowing visualization of the adjacent structures.
- Stainless steel – might cause significant artifacts similar to Elgiloy.

Despite potential artifact issues, MRA has been found highly sensitive to endoleaks. In addition, MR images can be reformatted for volume and diameter measurements.

Duplex ultrasonography also is used in post-EVAR follow up and is recommended as an adjunct to non-contrast CT. Sandford et al recommend the use of contrast enhancement to improve post-EVAR scanning. Angiography is, at best, “a second-line imaging modality in post-EVAR patients” because of its invasiveness and use of contrast. Digital subtraction angiography is less sensitive than CTA in detecting endoleaks, but its ability to assess the direction of blood flow makes it more accurate in classifying endoleaks.

**Dose Reduction**

Dose reduction during CT and CTA is important considering patients will undergo a lifetime of surveillance following EVAR. A variety of techniques and methods has been employed to reduce radiation dose, including automatic exposure control, change in technical parameters, iterative reconstruction, and dual-energy CT. Use of automatic tube current modulation (or automatic exposure control) can reduce radiation dose by up to 50%.

Similarly, decreasing tube voltage also reduces dose. A dose reduction of approximately 33% results from a decrease from 120 kV to 100 kV. However, Raman states that changing the kV is a rarely used option because of a potential increase in image noise and that technologists and radiologists must appraise a variety of factors individually to determine whether a lower kV is appropriate.

Increasing the pitch has been demonstrated to reduce radiation dose in a retrospective study of thoracolumbar

**Table 2**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>System Name(s)</th>
<th>Parameter Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>AutomA; SmartmA</td>
<td>Measure of image quality/noise level defined related to uniform water phantom</td>
</tr>
<tr>
<td>Philips</td>
<td>Dose Right</td>
<td>Image quality expressed in terms of noise level of an existing optimal clinical image</td>
</tr>
<tr>
<td>Siemens</td>
<td>CARE Dose 4D</td>
<td>mAs that would be used for an average-sized patient</td>
</tr>
<tr>
<td>Toshiba</td>
<td>SUREExposure 3D</td>
<td>Standard deviation of pixel values in an image (higher standard deviation = higher noise)</td>
</tr>
</tbody>
</table>

**Figure 12.** Transverse CT angiogram of abdomen and pelvis post-EVAR treatment. Note the metallic stent surrounding the aorta (arrow). Note: this is the same patient from Figure 9. The stent-graft is in the correct location and shows no sign of endoleaks. Reprinted with permission from Moole H, Emani VK, Ramashai S. Mycotic aneurysm in a turtle hunter: brief review and a case report. J Community Hosp Intern Med Perspect. 2015;5(3):27229. doi:10.3402/jchimp.v5.27229.
Larger dose reductions were reported by Buffa et al in their comparison of single-phase dual-energy CT to conventional CTA. Each patient underwent a single-energy nonenhanced scan, an arterial phase, and a delayed phase. The delayed phase began 30 seconds after the arterial phase using the dual-source mode. The researchers found that the effective dose from the dual-energy mode acquisition (delayed phase) was 40.3% less than the 2 scans in the single-energy mode (ie, nonenhanced and arterial phases). An estimated dose reduction of 61.7% was achieved when the dual-energy acquisition was compared to a single-source, triple-phase CTA (ie, noncontrast and 2 arterial phase scans).

Iterative reconstruction—or more accurately, statistical iterative reconstruction—is a data reconstruction method that improves on the commonly used filtered back-projection in CT. Iterative reconstruction allows for lower radiation dose via lower tube potentials and current levels without the increase in image noise common in filtered back-projection. In iterative reconstruction algorithms:

\[ \text{Projection data are predicted based on an assumption about the initial attenuation coefficients of all voxels. These predicted data are compared to measured projection data, and the voxel attenuation values are modified until an acceptable level of error between the predicted and measured data is achieved.} \]

**Prognosis**

The data are mixed regarding mortality differences in open repair compared to EVAR. Improved outcomes have been reported for EVAR over open repair, including decreased length of hospitalization and lower perioperative morbidity. However, the benefits of EVAR are accompanied by lifelong radiologic surveillance and possible radiation exposure because of the higher rate of complications compared to open repair. Complications include endoleak, stent-graft migration, kinking, and thrombosis. Nonetheless, EVAR is recommended for patients with multiple risk factors for a poor prognosis following open repair and who have anatomy suitable for stent-graft placement.

The incidence rate for endograft complications ranges from 11% to 30%. The most common complication of EVAR is endoleaks, which places the post-EVAR...
patient at continued risk for aneurysm sac enlargement or rupture. This persistent flow of blood into the sac post-EVAR represents a failure to exclude the aneurysm completely. Estimates for the prevalence of endoleaks ranges from 4% to 23%. Endoleaks are classified into 5 types, with each varying in severity, prevalence, reason for leakage, and risk of secondary rupture (see Figure 13).

Type I endoleaks result from an incompetent seal at the proximal or distal stent-graft attachment sites. These leaks consist of the flow of blood into the aneurysm sac proximal or distal to the stent graft. Type I endoleaks typically occur either immediately after insertion or soon thereafter. Treatment of type I endoleaks is recommended at the time of diagnosis because the aneurysm sac can grow and rupture from systemic pressure. Follow-up imaging, usually CT, demonstrates blood outside the stent-graft. This type of endoleak can be repaired through endovascular means; open surgical repair is a viable but secondary option for repair.

A type II endoleaks comprise between 10% and 45% of all endoleaks. These endoleaks entail retrograde blood flow from aortic branch vessels (eg, lumbar, internal iliac, accessory renal, middle sacral, and inferior mesenteric arteries). Risk factors for type II endoleak development include the number of patent lumbar arteries and the diameter of lumbar arteries, as larger arteries tend to be associated with persistent endoleak. Type II might not be visible on the arterial phase of a CT scan, resulting in the need for delayed imaging. Color duplex ultrasonography or arteriography also might be needed for diagnosis. According to Chaer, controversy exists regarding the significance and management of type II endoleaks. The majority of researchers believe that follow-up imaging for changes in aneurysm sac diameter and shape are most important because spontaneous resolution has occurred in approximately one-third of cases. However, evidence of increased diameter of the aneurysm sac necessitates repair, usually endovascularly. Repair consists of the embolization of the patent arteries involved.

Figure 13. Illustration of endoleak classification. Reasons for aneurysm sac filling, expansion, or both include: A. Type I, incomplete or ineffective seal. B. Type II, retrograde branch flow of blood. C. Type III, tear in graft fabric. D. Type IV, porous graft fabric. E. Type V, no clear evidence for filling. © ASRT 2015.
A type III endoleak is serious because it originates at the junctions of the endograft components, or from holes or tears in the endograft fabric. The resulting leak increases the pressure in the aneurysm sac, leading to the potential for aneurysm expansion and rupture.\textsuperscript{46,99} Typical repair of type III leaks consist of the deployment of additional stent-grafts to seal the hole or tear, or to bridge the disconnected endograft components\textsuperscript{46}

Type IV endoleaks occur when blood is leaking from either the graft wall fabric or suture holes; however, this type of endoleak has become less common because of improvements in graft technology and materials. Type IV endoleaks have not been associated with long-term adverse events and typically are self-resolving.\textsuperscript{46}

With a type V endoleak, also referred to as *endotension*, the aneurysm sac continues to expand without an identified or demonstrable source of leakage or flow via any imaging modality.\textsuperscript{103} Although poorly understood, type V endoleaks are believed to have been improved with a change in graft design.\textsuperscript{92,94}

Migration of a stent-graft entails the movement from its original location after EVAR, with a migration of 0.5 cm to 1 cm considered significant.\textsuperscript{44} The use of prior images is critical for comparing the original location of the stent-graft with the location from later images to detect and evaluate migration. The use of consistent anatomic landmarks from radiologic images, such as the renal and superior mesenteric arteries, can be used to detect migration. Factors related to stent-graft migration include device type, landing zone length, and neck diameter and configuration. Although preoperative planning is important, morphologic changes in the aneurysm (eg, neck enlargement) can lead to stent-graft migration.\textsuperscript{44}

Endograft kinking or occlusion is a complication more commonly seen in EVAR patients than those undergoing open repair (2.3% vs 0.2%, respectively).\textsuperscript{105} Results from a European study reveal post-EVAR endograft kinking in 1.7% to 3.7% of cases with a significant association with type I and III endoleaks.\textsuperscript{104,106} A final complication is arterial thrombosis, estimated to occur in approximately 3% of EVAR patients. A key to reducing the risk of thrombosis is identifying healthy catheter entrance vessels using a thorough preoperative evaluation. Evaluation of the entry vessels

is recommended to include the degree of calcification, artery diameter, and tortuosity.\textsuperscript{108} Although the complication rate of AAA treatment is small, the aforementioned complications might require intervention depending on their severity.

**Conclusion**

Aortic abdominal aneurysm is a focal, localized enlargement or dilatation of a section of the abdominal aorta and is the most common type of arterial aneurysm affecting older adults. Medical imaging, including CT, MR, ultrasonography, and angiography, plays an important role in the detection, diagnosis, treatment, and follow-up of AAAs. Various imaging modalities, including ultrasonography, are used as a screening tool to detect AAAs while they are small. Surgical and endovascular treatment options for AAA are available and improve patients’ survival. Post-treatment, radiologic imaging plays an important role in assessing the treatment and monitoring the patient.

Jeffrey S Legg, PhD, R.T.(R)(CT)(QM), FASRT, is associate professor and chair of the Department of Radiation Sciences for Virginia Commonwealth University (VCU). He is associate editor-Americas for *Radiography* and chairman of the ASRT Foundation Research Grants Advisory Panel.

Lynn M Legg, MBA, R.T.(R)(M), manages the radiology department and teaches radiographic imaging for the VCU School of Dentistry. She has published on topics such as mammography and dental radiography.

The authors thank Jaime Tisando, MD, FACP, FACC, FAHA, FSIR, FSAR, professor emeritus of radiology and surgery for VCU Medical Center, for his encouragement, excellent review and suggestions.

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

© 2016 American Society of Radiologic Technologists

**References**


Abdominal Aortic Aneurysms


Abdominal Aortic Aneurysms

To earn continuing education credit:

- Take this Directed Reading quiz online at asrt.org/drquiz.
- Or, transfer your responses to the answer sheet on Page 168 and mail to ASRT, PO Box 51870, Albuquerque, NM 87181-1870.

New and rejoining members are ineligible to take Directed Readings 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 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. An abdominal aortic aneurysm (AAA) is a focal, localized enlargement of a section of the abdominal aorta at least ______ cm, or when the diameter is ______ % larger than normal.
   a. 7; 30
   b. 3; 50
   c. 4; 75
   d. 6; 15

2. For a man aged 65 to 75 years who has smoked 100 or more cigarettes in his lifetime, the U.S. Preventive Services Task Force recommends screening:
   a. once.
   b. every 5 years.
   c. every 10 years.
   d. at various times based on other risk factors.

3. ______ is the recommended tool for AAA screening.
   a. Color duplex ultrasonography
   b. Magnetic resonance angiography (MRA)
   c. Computed tomography angiography (CTA)
   d. Endovascular aneurysm repair (EVAR)

4. Suggested parameters of ultrasound imaging for AAA include:
   1. coronal (back to front)
   2. longitudinal (along the long axis of the aorta).
   3. transverse (perpendicular to the long axis of the aorta).
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

continued on next page
5. ______ is considered the preferred method for pre- and post-EVAR as well as postopen surgical repair imaging surveillance.
   a. Color Doppler ultrasonography
   b. CTA
   c. MRA
   d. Radiography

6. Anatomic considerations from preoperative imaging include aneurysm morphology and measurements. Examples of important aortic measurements for sizing an endograft include all of the following except aortic neck:
   a. diameter.
   b. length.
   c. angulation.
   d. density.

7. ______ is an alternative for pre-EVAR planning in patients for whom iodinated contrast is contraindicated.
   a. Color Doppler ultrasonography
   b. MRA with gadolinium
   c. CT without contrast
   d. Plain film radiography

8. MRA has a lower sensitivity than ______ in detecting blood vessels and renal arteries with a diameter smaller than 2 mm.
   a. CTA
   b. digital subtraction angiography
   c. color Doppler ultrasonography
   d. CT without contrast

9. The mortality rate from ruptured AAAs during open repair is approximately ______ %; EVAR has a mortality rate between 20% and 30%.
   a. 30
   b. 50
   c. 65
   d. 75

10. Dose reduction techniques during CT and CTA, such as using ______ , are important because patients will undergo a lifetime of surveillance after EVAR.
    1. automatic exposure control
    2. dual-energy CT
    3. iterative reconstruction
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3
2017 ASRT Award for Advocacy

Nominate an individual or affiliate society!

The ASRT Award for Advocacy honors both an individual and an affiliate society for outstanding advocacy efforts on behalf of the radiologic science community.

Submit your nominations for the 2017 award by Dec. 1, 2016.

www.asrt.org/advocacyaward
Directed Reading Evaluation
Abdominal Aortic Aneurysm

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 eclipman@asrt.org.
Abdominal Aortic Aneurysm

| 1 | 6 | 8 | 0 | 6 | - | 0 | 1 |

Expires: December 31, 2019
Approved for 1.25 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.

<table>
<thead>
<tr>
<th>Identification Section</th>
<th>Member Information Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>To ensure proper credit please PRINT the following information.</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social Security number</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

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 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 |

No Photocopies Accepted
Radiation Protection in Computed Tomography

Scott L Cupp, MS, DABR

Computed tomography (CT) is a valuable diagnostic tool. Advances in CT technology have increased the modality’s speed and improved ease of use. In emergency departments, CT has become the preferred method for imaging most trauma patients, largely because CT can help physicians quickly diagnose hemorrhages. The proliferation of CT use has led to the modality contributing a significant portion of the average U.S. patient dose from ionizing radiation. In 1987, the National Council on Radiation Protection and Measurements (NCRP) published Report No. 93, which showed that medical imaging with ionizing radiation accounted for 11% of the average radiation dose in the United States. Nuclear medicine contributed 4%, with a total medical contribution of 15%. Other man-made sources, including consumer products and nuclear weapons testing fallout, contribute 3%. Natural background sources, including radon and cosmic and terrestrial radiation, contributed to 82% of radiation exposure to the U.S. population.

In 2006 the NCRP published Report No. 160, which updated the average radiation dose to individuals in the United States. According to the report, CT alone contributed 24% of the radiation exposure to U.S. citizens. Interventional fluoroscopy contributed 7%, radiography and fluoroscopy made up 5%, and nuclear medicine contributed 12%. All medical sources together totaled 48% of the average radiation exposure in the United States.

Recent media coverage has made the general public more aware of the perceived dangers associated with CT imaging. CT technologists should remain knowledgeable about radiation dose units, CT technology as it relates to exposure, radiation biology, current radiation dose risk estimates, and radiation protection practices and requirements.
Photons

X-ray photons constitute a form of electromagnetic radiation, which comprises oscillating electric and magnetic fields. Photons travel at the speed of light and do not possess mass. X-ray photons can bend around massive objects, such as the sun or a black hole, but on Earth they travel in straight lines. The energy of a photon ($E_{\text{photon}}$) can be calculated by multiplying its frequency ($f$) by the Planck constant ($h$), which is referred to as the Planck equation ($E_{\text{photon}} = hf$). The Planck constant also can be written as $h = 6.63 \times 10^{-34}$ J, but this would give the photon's energy in joules instead of electron volts (eV), which is the unit radiologic technologists are more familiar with. Electromagnetic radiation has a continuous spectrum of energies, from low-energy (low-frequency) radio waves to very high-energy (high-frequency) x-rays or cosmic rays. Low-frequency photons do not possess enough energy to remove electrons from atoms or molecules. X-ray photons possess enough energy to remove electrons, thus producing ions. This is why x-rays are referred to as ionizing radiation.

Photoelectric Absorption

Photoelectric absorption occurs when the incident photon is absorbed completely by an inner shell electron. During the absorption process, the inner shell electron is liberated from its orbital shell and becomes known as the photoelectron. The photoelectron then moves away with kinetic energy. The incident photon must have more energy than the binding energy of the electron for the incident photon to remove the orbital electron. If the energy of the incident photon is less than the binding energy of the orbital electron, the incident photon cannot remove the orbital electron from its shell. Electron-binding energy is dependent on the orbital shell and atomic number (the number of protons) of the atom. The inner K-shell has the highest electron-binding energy of the orbital shells; the electron-binding energy decreases further from the nucleus. As the number of protons in the nucleus increases, the electron-binding energy for all of an atom’s orbitals also increases. Materials with higher atomic numbers are more likely to photoelectrically absorb a photon than are materials with lower atomic numbers. Bone has an average atomic number of 13.8, and soft tissue has an average atomic number of 7.0.

Photon Interactions

Understanding how x-ray photons interact with matter is key to comprehending the effects of radiation. Three possible photon interactions in the diagnostic energy range are possible: coherent, Compton, and photoelectric. Only Compton and photoelectric interactions apply to the CT energy range.
number of 7.4; therefore, bone is more likely to absorb a photon photoelectrically. The relative probability of photoelectric absorption for 2 given substances is calculated as the cube of the ratio of the substances’ atomic numbers. For example, bone’s average atomic number is approximately twice that of soft tissue, which means that bone is 8 times more likely to absorb a photon.

For a photon to be absorbed, its energy must be greater than the electron-binding energy of the orbital electron, and a photon most likely is absorbed when its energy is slightly higher than the electron-binding energy. As the energy of the incident photon continues to increase above the electron-binding energy, the probability of photoelectric absorption decreases rapidly. The probability of photoelectric absorption is nearly inversely proportional to the cube of the incident photon energy.

In practice, there are 2 ways to increase the amount of photoelectric absorption. The first involves increasing the average atomic number in a patient, which is achieved by using contrast agents. Barium has an atomic number of 56, and iodine has an atomic number of 53, both of which are much higher than any anatomy, even bone. The second way to increase the amount of photoelectric absorption is to decrease the energy of the incident photons, which is achieved by decreasing the peak kilovolt (kVp) setting. Decreasing kVp reduces the kinetic energy of the electron in the x-ray tube that is traveling from the cathode to the anode. The lower kinetic energy of the electrons results in reduced energy of x-ray photons.

Removing the x-ray from the primary beam by photoelectric absorption contributes useful information on a diagnostic image by increasing the subject and image contrast, thereby creating the “whiteness” on an image. When one tissue has more photoelectric absorption (eg, bone) compared with the background tissue (eg, soft tissue), that difference is a high-contrast difference within the image. Photoelectric absorption is one of the ways x-ray energy is deposited into a tissue. This deposited energy is the root cause of the radiation dose, which can lead to biological damage.

**Compton Scatter**

Compton scatter is the other predominant photon interaction within the diagnostic energy range. Compton scatter occurs when an incident photon interacts with an orbital electron but the incident photon is not absorbed completely. Some of the incident photon’s energy is used to break the electron-binding energy of the orbital electron and liberate it. The freed electron is called the Compton electron, and some of the incident photon’s energy is used to give the Compton electron kinetic energy. The sum of the energy used to break the electron-binding energy and the kinetic energy given to the Compton electron does not equal the energy of the incident photon. The remaining energy is used in the form of a scattered photon. The scattered photon has less energy than the incident photon and departs the atom in a different direction from the incident photon’s original direction (see Figure 1).

The energy of the scattered photon depends on the angle at which it is scattered. At low scattering angles less energy is imparted to the Compton electron, meaning the scattered photon has higher energy. As scattering angle increases to 180°, the incident photon imparts more energy to the Compton electron and, therefore, less to the scattered photon. Photons that are bounced back at 180° are referred to as backscatter.

The probability of Compton scattering occurring depends on the density of the material at which the incident x-ray photons are directed. Unlike photoelectric absorption, Compton scatter does not depend on the atomic number of the material. Materials with higher densities are more likely to produce Compton scatter. Bone is approximately twice as dense as soft tissue; therefore, bone is twice as likely to lead to Compton scatter. As with photoelectric absorption, the probability of Compton scatter depends on the energy of the incident photon. As the energy of the incident photon increases, the probability of Compton scatter decreases, but at a slower rate than the decrease of photoelectric absorption. The probability of Compton scatter is related inversely to the energy of the incident photon; photoelectric absorption is inversely related to the cube of the incident photon energy.

CT techniques traditionally use 100 kVp to 120 kVp, which means the predominant photon interaction is Compton scatter. Most of the photons are removed from the primary beam via Compton scatter, whereas radiographs are produced by removal of photons from the primary beam via photoelectric absorption. The
combination of a high kVp setting and a relatively high milliampere seconds (mAs) used can lead to a high Compton scatter effect, especially when compared with conventional radiographic techniques. Compton scattered photons are the primary source of radiation to medical imaging and health care personnel.15

Radiation Biology

When radiation interacts with an organism, the damage occurs via a direct or indirect mechanism at a molecular level. This molecular damage then affects the organism on a cellular level, which can manifest as either a nonstochastic or stochastic effect.

Molecular Effects

Direct

When radiation interacts with cells and directly causes a mutation of the DNA, it is referred to as a direct interaction.16 Radiation that has a high linear energy transfer (LET) is more likely to cause direct damage to DNA.16 Alpha particles and neutrons are examples of radiation with high LET. Electromagnetic radiation, such as x-rays and gamma rays, has a low LET and can cause direct DNA damage but is associated with a low probability of doing so. Because CT uses x-rays to form the image, most biological damage caused by CT scans is not because of direct damage to DNA but through indirect effects.17

Indirect

Low LET radiation most often does not interact directly with the DNA, but instead interacts with water. The low LET radiation ionizes the water, breaking it into an electron and a positive water ion (HOH+). The freed electron is captured by another water molecule, which then becomes a negative water ion (HOH–). The positive and negative water ions are not stable and break into smaller molecules. The HOH+ breaks into a hydrogen ion (H+) and a hydroxyl radical (OH*). The HOH– breaks into a hydroxyl ion (OH–) and a hydrogen radical (H*).18 Radicals are atoms or molecules with unpaired electrons. Radicals have a neutral charge, but the unpaired electrons make the radicals highly reactive. Radicals can break the bonds of other molecules, such as DNA. In the presence of oxygen, indirect damage is enhanced through the bonding of radicals. The oxygen enhancement ratio compares biologic response in the absence of oxygen to the biologic response in the presence of oxygen. The oxygen enhancement ratio of low LET radiation, including x-rays, is between 2 and 3, which means x-rays are 2 to 3 times more damaging in a well-oxygenated environment.19

Cellular Effects

When a cell absorbs radiation, the possible outcomes depend on the amount of absorbed dose and the cell’s radiosensitivity. If a cell has an adsorbed dose of 1000 Gy, the cell will most likely experience instant death from severe structure and chemistry disruptions.20 Reproductive death is a possibility at a lower absorbed dose of 1 Gy to 10 Gy. Reproductive death is survival of a cell but inability to divide. Mitotic death also is in the same absorbed dose range, and the cell dies during the division process. With a lower absorbed dose, a delay in the mitotic process can occur until the cell has repaired itself. Apoptosis (programmed cell death) can occur at varying absorbed doses.21 Apoptosis occurs when a cell senses that it has been damaged and releases proteins that begin to break down the cellular structure. The process of apoptosis can be initiated at different dose levels depending on the cell’s radiosensitivity.
The law of Bergonié and Tribondeau states that a cell’s sensitivity to radiation damage is dependent on the cell’s metabolic rate, the maturity of the cell, and the amount of time a cell remains in mitosis.\textsuperscript{21} Rapidly reproducing cells have higher radiosensitivity. Epithelial cells are highly radiosensitive because they repopulate quickly. Nonspecialized cells are more sensitive than specialized cells. For example, a fetus has more stem cells compared with an adult, which makes a fetus more radiosensitive. Finally, cells that spend more time in the mitotic phase are more sensitive.\textsuperscript{21}

**Nonstochastic Effects**

The term stochastic is synonymous with random; therefore, nonstochastic effects are nonrandom, meaning that they will occur based on the dose received. Nonstochastic effects also are called deterministic effects or threshold effects because there is a known threshold below which the effects are not observed.\textsuperscript{24} Once the radiation dose reaches the threshold, the effect appears. As the dose increases, the severity of the effect worsens. The classic example of a nonstochastic effect is a sunburn. During the summer, an individual can be outside without sunscreen for 10 minutes without getting a sunburn (ie, 10 minutes is the threshold dose for summer sun). At the 10-minute mark, the individual begins to burn, and the longer the person stays outside, the worse the sunburn will be.

Rare nonstochastic effects that occur with CT are radiation-induced erythema and epilation, with threshold doses of 2 Gy and 3 Gy, respectively. For cataracts, the threshold dose is 2 Gy to the lens of the eye.\textsuperscript{25} Threshold doses are not absolute for all patients. Just as some people can be out in the sun longer without burning, people have different radiation threshold doses. As with sunburns, there is no way to know each person’s threshold dose until the threshold has been reached. Most nonstochastic effects have a relatively short latency period between when the dose is received and the appearance of the effect. Erythema has a latency period in the range of 16 to 48 hours. Cataract formation is an exception to brief latency; cataracts might not appear until years after the cataract threshold dose has been exceeded. Current research on radiation-induced cataracts indicates that the radiation dose threshold might be lower than previously indicated.\textsuperscript{26}

**Stochastic Effects**

Stochastic effects are random. Unlike nonstochastic effects, stochastic effects do not have a threshold dose level. They often are referred to as nonthreshold effects. Stochastic effects can occur at any level of radiation.\textsuperscript{27} As the radiation dose increases, the probability of a stochastic effect occurring increases, but the severity of the effect does not increase. Because only probability changes with dose, probabilistic effects is a term sometimes used to describe stochastic effects.

Stochastic effects include inheritable genetic effects and cancer. Stochastic effects are considered independent of one another. This means that the chance of a stochastic effect occurring from a single dose of radiation does not depend on any previous radiation exposures. The chance of getting cancer from a given CT examination is independent of previous CT scans. If a CT examination is medically necessary, then it should be performed regardless of past radiation exposure. If follow-up CT examinations are scheduled at regular intervals, the patient benefits from minimizing the frequency of follow-up imaging. Although the risk associated with each scan is independent from past scans, each scan carries a small risk. If the number of scans is reduced, then risks are reduced. For example, people have a small risk of getting in a car accident every time they drive. The risk associated with driving one day does not depend on whether they drove last week, but if people reduce the number of times they drive, they decrease the chance of getting into an accident. It works the same way with undergoing a CT scan. Reducing the number of CT scans reduces potential risk, but each CT scan is no more risky than another, assuming all deliver the same dose. Keeping the dose from each CT scan as low as possible while acquiring the diagnostic information required is the goal. The nonthreshold nature of stochastic effects is the basis of the ALARA (as low as reasonably achievable) principle.\textsuperscript{28} Even low doses have a small chance of a stochastic effect occurring; therefore, ALARA concepts should guide all CT scans.

Stochastic effects have a relatively long latency period. For example, leukemia has a latency period of 7 to 10 years and solid tumors have a latency period of 20 to 30 years.\textsuperscript{29} Inheritable genetic effects are considered nonsomatic, which means they occur in the offspring of...
the person exposed to the radiation. Cancer and non-
stochastic effects are somatic effects that occur in the
person irradiated. To date, inheritable genetic effects
have not been observed in a human population, but
they are theoretically possible.\(^{30}\)

**Radiation Units**

The concepts on which units used to describe
radiation are based can be complex. The only way to
measure absolute dose to a material is through calorim-
etry, which is the measurement of heat generated by
radiation. This technique is extremely impractical, how-
ever. Dose in medical imaging is measured indirectly.

**Exposure**

The intensity of x-rays can be characterized by
measuring the number of ions produced in a volume
of air or gas. An ionization chamber measures the
charge from the number of ion pairs created within a
gas caused by incident radiation.\(^{31}\) An ion pair consists
of the negative electron removed from an atom and the
remaining newly positive atom. The ionization cham-
ber consists of a gas-filled chamber with 2 electrodes:
the anode and cathode. Applying a voltage potential
between the cathode and anode creates an electric field
inside the gas-filled chamber.\(^{32}\)

When the gas in a chamber is ionized by incoming
radiation, ion pairs are created. The positive ions move
to the negative electrode, and negative electrons move
to the positive electrode, generating a current that is
measured by an electrometer. As more radiation passes
through the ionization chamber, more ion pairs are
created and the current measured by the electrometer
increases. Thus, the current on the electrometer is pro-
portional to the amount of ionizing radiation passing
through the chamber. The traditional common unit,
roentgen (R), is the amount of ionization produced in a
volume of air. The international unit of exposure is
coulombs per kilogram.\(^{33}\) A coulomb is a unit of charge
equal to the charge of $6.3 \times 10^{18}$ electrons. Roentgen is
the unit most often displayed on calibration meters.\(^{34}\)

**Absorbed Dose**

Measuring the ionization occurring in air is rela-
tively simple, but it does not indicate the potential risk

of radiation to a patient. The metric of absorbed dose is
the amount of energy absorbed into any material, not
just air; the measure represents the amount of energy
deposited in a specific volume of tissue.\(^{35,36}\) The inter-
national unit for absorbed dose is gray (Gy), which
equals 1 joule of energy per kilogram of material.\(^{35}\) The
traditional common unit of absorbed dose is radiation
absorbed dose (rad). Rads can be converted to grays
using the formula $100 \text{ rad} = 1 \text{ Gy}$.

**Equivalent Dose**

Absorbed dose does not describe how energy is
deposited. The amount of damage that can be caused
by radiation depends on how the energy is deposited
into tissue. For example, energy deposited rapidly at
the surface of a tissue volume causes more damage than
radiation that distributes energy more evenly through-
out a volume. The way in which energy is deposited
is based on the type of ionizing radiation used. Large
particulate types of radiation, such as alpha particles,
deposit their energy quickly and can produce more
biological damage than can x-rays. In contrast, x-rays
deposit their energy more slowly throughout the vol-
ume and, therefore, produce less damage from the same
amount of absorbed dose. The rate at which radiation
deposits its energy is called the *linear energy transfer*.

Equivalent dose is the product of absorbed dose and
a radiation weighting factor. The international unit for
equivalent dose is the sievert (Sv). The traditional unit
is the roentgen equivalent man (rem). The units can
be converted as such: $1 \text{ Sv} = 100 \text{ rem}$. The radiation
weighting factor for x-rays is 1.0, which means 1 Gy of
whole-body absorbed dose is 1 Sv of dose equivalent.\(^{36}\)

**Effective Dose**

Even though measuring gray and sievert provides
information on absorbed and equivalent doses, another
measure is needed to determine potential risk for expo-
sure to only specific anatomy. Various organs have
different sensitivities to radiation. For example, 1 Gy
of absorbed dose to the hand has a different effect than
does exposure of 1 Gy to the lens of the eye. Therefore, it
is not possible to use total absorbed doses or equivalent
doses when comparing exposure to different tissues.
Because a given examination can expose organs with
using the linear nonthreshold model for population cancer risk assessment. In addition, largely in response to media coverage, the American Association of Physicists in Medicine (AAPM) has issued a public statement regarding radiation dose in medical imaging (see Box). Some have suggested positive biologic effects of radiation. Radiation hormesis is a controversial theory that suggests low levels of radiation are beneficial. Proponents suggest that small doses initiate the body’s repair mechanisms, allowing the body to defend against potential threats, such as viruses. Many research papers have shown the beneficial effects of small doses of radiation to a wide variety of animal populations. Some evidence has demonstrated that low doses of radiation can improve physiological performance, immune system function, and overall health and life span.

## Dose Measurements

### Dose Index

Computed tomography dose index (CTDI) is the total dose absorbed in an acrylic phantom. The standard size of the phantom is 15 cm wide and 32 cm in diameter for a body phantom or 16 cm in diameter for head or pediatric phantoms. Phantoms have 1-cm holes.

### Current Radiation Risk Estimates

The dose received from most CT scans is well below the threshold dose associated with nonstochastic effects. Therefore, the risk most people are concerned about is cancer. Because the latency period for cancer can be 20 to 30 years, it is difficult to estimate accurately the probability of getting cancer from a known dose, although groups continue to explore the best methods and recommendations for estimating risk of cancer from radiation.

The National Research Council of the National Academies of Science, Engineering, and Medicine published a series of reports on radiation and health effects called the Biological Effects of Ionizing Radiation (BEIR). The most recent of these, BEIR VII, states that no lower threshold for radiation exposure exists and that risk increases with increased exposure. The report specifically provides information on cancer incidence and mortality. The report also estimates risk for cancer and other health effects.

Assuming that the sex and age distribution is close to that of the U.S. population, the BEIR VII risk model predicts that approximately 1 person in 100 (1%) could develop cancer (solid cancer or leukemia) from a dose of 0.1 Sv above background radiation. This is a small increase when considering that approximately 42 of 100 people (42%) could develop solid cancer or leukemia from other causes. Lower doses would produce proportionally lower risks. For example, the committee predicts that approximately 1 person per 1000 would develop cancer from an exposure to 0.01 Sv. BEIR VII recommends

### AAPM Position Statement on Radiation Risks From Medical Imaging Procedures

The American Association of Physicists in Medicine (AAPM) acknowledges that medical imaging procedures should be appropriate and conducted at the lowest radiation dose consistent with acquisition of the desired information. Discussion of risks related to radiation dose from medical imaging procedures should be accompanied by acknowledgment of the benefits of the procedures. Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short periods are too low to be detectable and could be nonexistent. Predictions of hypothetical cancer incidence and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged. These predictions are harmful because they lead to sensationalistic articles in the media that cause some patients and parents to refuse medical imaging procedures, placing them at substantial risk by not receiving the clinical benefits of the prescribed procedures.

---

**Box**

**AAPM Position Statement on Radiation Risks From Medical Imaging Procedures**

The American Association of Physicists in Medicine (AAPM) acknowledges that medical imaging procedures should be appropriate and conducted at the lowest radiation dose consistent with acquisition of the desired information. Discussion of risks related to radiation dose from medical imaging procedures should be accompanied by acknowledgement of the benefits of the procedures. Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short periods are too low to be detectable and could be nonexistent. Predictions of hypothetical cancer incidence and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged. These predictions are harmful because they lead to sensationalistic articles in the media that cause some patients and parents to refuse medical imaging procedures, placing them at substantial risk by not receiving the clinical benefits of the prescribed procedures.
drilled through the center and along the periphery at 12 o’clock, 3 o’clock, 6 o’clock, and 9 o’clock positions (see Figure 2). These holes allow the 100-mm pencil ionization chamber to measure exposure at multiple locations. Holes not occupied by the pencil chamber are filled with acrylic plugs. The CTDI is measured only using axial techniques without table movement.

The equation,

$$CTDI_{100} = \frac{1}{nT} \int_{50\text{mm}}^{50\text{mm}} D(z) dz$$

shows how to calculate the CTDI$_{100}$ where $n$ is the number of axial slices per rotation, $T$ is the thickness of each axial slice per rotation, and $D(z)$ is the exposure measure with a 100-mm pencil chamber. CTDI typically is reported in mGy. The CTDI$_{100}$ is measured for the center and all 4 peripheral locations.

The x-ray emission spectrum contains a range of energies. Lower-energy photons are more likely to be absorbed along the periphery of the patient (or phantom). The 32-cm body phantom has approximately 2 times the absorbed dose along the phantom’s periphery than at its center. This is referred to as beam hardening. Lower-energy soft photons are removed along the periphery and only higher-energy hard photons reach the center. A weighted CTDI (CTDI$_w$) is calculated to better represent the dose to the acrylic phantom. CTDI$_w$ is calculated by adding one-third of the CTDI$_{center}$ to two-thirds of the average CTDI$_{periphery}$.

The CTDI represents dose to a phantom and does not reflect the absorbed dose to the patient. The CTDI is not the dose delivered to the patient but is proportional to the patient dose. The higher the CTDI, the more radiation was delivered to the patient. If the same patient received 2 head CT scans, one with a CTDI of 40 mGy and the second with a CTDI of 60 mGy, the second scan with the higher CTDI would result in a higher dose to the patient. CTDI was developed as a standardized way to measure doses on various manufacturers’ CT equipment. Because the CTDI is the absorbed dose, it is reported in mGy.

**CTDI Volume**

With the advancement of helical scanning techniques, the CTDI evolved to better represent dose using varying scanning pitches. Pitch is the total collimation width divided by the table travel per rotation. If the table moves less than the collimation width per tube rotation, the pitch is less than 1 and the radiation beam overlaps. When the table moves more than the width of the collimation per tube rotation, the pitch is greater than 1 and there are gaps in the beam coverage of the patient. A pitch of less than 1 results in a higher dose to the patient, and a pitch of greater than 1 reduces patient dose. CTDI volume (CTDI$_{vol}$) is the CTDI$_w$ divided by the pitch. The CTDI$_{vol}$ is one of the values displayed on the patient protocol page of modern scanners.

**Dose-Length Product**

The CTDI provides the dose per slice but does not represent the total amount of dose absorbed. Dose-length product (DLP) is the product of CTDI$_{vol}$ and scan length. It is an estimate of a patient’s total radiation received for a particular scan. DLP also is displayed on the patient protocol page of modern scanners.
protocol page. The DLP can be used to estimate effective dose quickly by multiplying the DLP by a conversion factor based on the type of examination. For example, if a patient received an abdominal CT scan with a DLP of 220 mGy-cm, multiplying it by the abdomen factor of 0.015 mSv/mGy-cm would give an estimated effective dose of 3.3 mSv.

**Size-specific Dose Estimate**

CTDI is based on the dose to a phantom designed to represent standard-sized patients. When patients differ in size from the phantom used to calculate CTDI, the actual dose to the patient is not represented in the CTDI_{vol} displayed by the scanner. Size-specific dose estimate (SSDE), which was first mentioned in AAPM Report No. 204, adjusts the CTDI accordingly. Patients whose body habitus is smaller than that represented in the phantom have a higher SSDE, and patients who are larger than the phantom measurements have a smaller SSDE compared with the CTDI. The SSDE can be calculated using different methods, depending on whether the anteroposterior (AP) and lateral patient measurements are readily available, typically from localizers. For example, the effective diameter of the size-specific phantom for dose estimate should be the square root of the patient’s AP dimensions multiplied by the patient’s lateral dimensions.

**Dose Refinement Techniques**

The control of patient dose essentially depends on the potential differences in electronic field across the anode and cathode and the product of current (milliamperage, or mA) and rotation time in seconds (s), or mAs. Most, if not all, manufacturers use current modulation, automatic kilovolt (kV) selection, organ-specific current modulation, and iterative reconstruction to optimize doses that yield the optimal image quality necessary for a particular diagnostic task.

**Current Modulation**

The mAs is proportional to the number of x-rays produced per tube rotation. The dose received by patients is directly proportional to the number of x-rays the patient receives. Originally, CT techniques used a fixed current. This meant the technologist selected a current based on patient size and the anatomy to be scanned. The selected current would be used for every rotation through the scan area. In the late 1990s, current modulation was introduced. Although manufacturers have their own variations of current modulation, all operate on a similar principle. The CT equipment adjusts current automatically, accounting for varying attenuation because of anatomy or body habitus, to maintain image quality.

Current modulation did not always reduce patient dose. Doses for larger patients tended to increase following the introduction of current modulation. The underlying principle of current modulation is to maintain image noise. This requires more exposure for larger patients compared with smaller patients to achieve a similar amount of image noise.

**Automatic kV Selection**

The potential kV difference between the anode and cathode in the x-ray tube influences the energy and quality of the x-rays produced. In the past, radiologic technologists could reduce patient dose by selecting a higher kVp technique. Doing so allows use of a lower mAs and reduces patient dose. Conversely, selecting a lower kV and higher mAs increases patient dose. In CT, reducing kVp and slightly increasing the mAs lowers patient dose.

In radiography, increasing the kVp by 15% and correspondingly reducing the mAs results in lower patient exposure. However, increasing kVp by 15% without reducing mAs results in increasing patient dose. In CT, decreasing kVp without fully increasing mAs results in reductions of patient exposure. This reduction in patient exposure results in increased image noise.

Typically, increasing image noise decreases contrast resolution, but in CT examinations, especially those using iodinated contrast, decreasing the kVp increases photoelectric absorption within the patient and the iodine. The increased photoelectric absorption counterbalances the increased noise and leads to nearly the same contrast resolution. At the same contrast-to-noise ratio, 90 kVp yields a 29% dose reduction compared with 120 kVp.

Some manufacturers have developed software algorithms that automatically select the best kVp for patients depending on their size, along with image contrast requirements for specific scans. First, the scanner
models describe important physical aspects of the CT system, including focal spot, detector geometry, photon statistics, x-ray beam spectrum, and scattering. These models are incorporated into the iterative reconstruction technique to produce the image. To optimize the image, modeling is applied multiple times, hence the term iterative. Use of iterative reconstruction methods can yield images with lower noise and higher spatial resolution than images acquired with filtered back projection.

The main disadvantage of iterative reconstruction has been the time required to create the images. The mathematical models and calculations require a lot of computing power and time. The more iterations completed, the less noise in the image but the more time required. With computer technology advancements, the time required for iterative reconstruction has diminished and the technique is being incorporated into modern CT scanners. Because iterative reconstruction reduces image noise, CT technologists can reduce dose by lowering mAs. The use of iterative reconstruction could reduce dose by as much as 65%.

Patient Protection

Lead Shields

The proper use of lead shielding on patients can be confusing because of differing reports in the literature. For example, for decades it has been common practice to shield all patients of reproductive age receiving ionizing radiation from radiography. As CT became common and radiographers cross-trained into roles as CT technologists, they have had to revise how they shield patients. Methods of shielding patients during CT scanning differ from shielding in radiography. In conventional radiography, the x-ray tube remains stationary, which makes it easier to position lead shielding accurately. The technologist places shields between the patient and the x-ray tube to protect the patient from leakage radiation and misdirected primary radiation, or the technologist places the shield over radiosensitive organs to protect them from scatter radiation. Proper use of shielding can reduce patient dose, but if the shielding is placed over the anatomy of interest erroneously, a repeat examination will be required and will result in increased patient dose.

Determines the size and density of the patient’s anatomy of interest by using localizer radiographs. Smaller patients typically require lower kV. The scanner automatically selects higher kV for larger patient sizes to improve beam penetration. The secondary consideration is the amount of contrast resolution required for the diagnostic task. For example, locating urinary tract stones does not require as much contrast resolution as does diagnosing liver lesions.

**Organ-specific Modulation**

Some manufacturers have developed techniques that reduce the tube current from the CT system as the x-ray tube passes over radiosensitive organs; the techniques are referred to as organ-specific modulation. For example, the tube current would be decreased as the tube rotates around breast tissue. This causes a breast to receive less absorbed dose, reducing the effective dose of the scan. The technique requires careful selection of appropriate protocols and indication of proper patient position. If, for example, the technologist selects that the patient is prone in the system, whereas in reality the patient is in a supine position, the CT system would decrease dose on the wrong side of the patient.

**Iterative Reconstruction**

Reconstruction techniques such as filtered back projection or iterative reconstruction are based on complex mathematical algorithms. In brief, reconstruction is a mathematical method that generates CT images from projection data collected at several different angles. CT images have been reconstructed from raw data using filtered back projection since the modality was first introduced. Image noise needs to be kept as low as possible to maintain high-contrast resolution. Use of filtered back projection limits how much noise can be removed from images without sacrificing spatial resolution. The soft reconstruction filter reduces the amount of noise in the image but degrades spatial resolution. When contrast resolution is not as diagnostically important, but spatial resolution is required to see fine details, technologists use a bone filter. Aside from changing the reconstruction filter, another option for decreasing image noise is to increase the mAs, which also increases patient dose.

Iterative reconstruction has many advantages to filtered back projection. Highly accurate mathematical
Therefore, shielding in CT should be approached differently than it is for shielding in conventional radiography and fluoroscopy. During a CT scan, the x-ray tube and detectors rotate 360° around the patient. Placing a shield only on one side of patients does not fully shield them. The shielding should be wrapped around the patient. A patient dose savings of 5% to 78% can be achieved when lead shielding is placed carefully just outside of the area of interest.

Incorrect use of shielding in CT has the potential to increase patient dose more than just requiring a repeat exposure because it is covering important anatomy. The automatic kV selection and the current modulation programs use localizer information. If the lead apron is in the localizer image, the dose optimization programs falsely identify the patient as being larger or more attenuating, such as more muscular. Therefore, the current modulation and kV selection algorithms might select higher technical factors than are required, which would result in higher dose to the patient. When the scan area of interest is close to the patient’s gonads, technologists can acquire the localizer image before placing the lead apron around the patient to prevent the current modulation and automatic kV selection from selecting incorrect higher techniques. This approach still includes the risk of placing the lead apron in the active scan area, which forces higher current in that area, resulting in unnecessary dose to the patient or obscuring the anatomy of interest.

It has been suggested that shielding in CT actually provides little dose savings, especially when the shielding is far from the scan field of view. For example, wrapping a shield around the waist of a patient having a head scan provides more reassurance to the patient than exposure reduction. The scatter produced within the head reaches the gonads via internal scatter. A shield wrapped around the patient cannot intercept it.

**Bismuth Shields**

The tissue-weighting factor for determining effective dose for breast tissue is 0.12, making the breast one of the more radiosensitive organs. During diagnostic thoracic CT examinations, the mean glandular dose to breast tissue can average 22 mGy. Bismuth shielding was developed to reduce the dose to breast tissue. Bismuth is a chemical element with the symbol Bi and atomic number 83. It has one more proton than lead, which has an atomic number of 82. It would seem that if the technologist places the shield anteriorly on the breasts, the x-ray beam passes through the shielding and photoelectrically absorbs the lower energy photons, reducing the dose to the breast.

However, there is more to the use of the shield. When the x-ray beam passes posteriorly to the patient, the shield attenuates remnant photons before they reach the detectors. This attenuation reduces the detector signal, making the image appear noisier, thus reducing contrast resolution. Compensating for the added noise requires an increase in tube current, which reduces dose savings. When the bismuth shielding is used in conjunction with current modulation, the results have been unpredictable. At times, dose can be increased to breast tissue because the current modulation interrupts the increased attenuation from the patient and adjusts the current higher. In addition, the bismuth shielding can cause image artifacts. This and other disadvantages have led to recommendations being made for alternatives to bismuth shields.

According to the AAPM:

**Bismuth shields are easy to use and have been shown to reduce dose to anterior organs in CT scanning. However, there are several disadvantages associated with the use of bismuth shields, especially when used with automatic exposure control or tube current modulation. Other techniques exist that can provide the same level of anterior dose reduction at equivalent or superior image quality that do not have these disadvantages. The AAPM recommends that these alternatives to bismuth shielding be carefully considered and implemented when possible.**

The use of organ-specific current modulation is a better alternative to the use of bismuth shielding. The current is reduced automatically as the x-ray tube passes anteriorly over the patient, thus reducing breast dose. As the x-ray tube passes posteriorly, no attenuation of the beam occurs, as with shielding.

**Staff Protection**

**Leaded Apparel**

Most often, CT technologists are not in the room during scanning, which is a best practice because of the...
Accrediting Agency Requirements

The American College of Radiology (ACR) and The Joint Commission have instituted education requirements for technologists who perform diagnostic CT examinations.

American College of Radiology

For a site to meet ACR accreditation requirements, the facility must have initial and continuing education requirements for CT technologists. Initial education requirements include:

- American Registry of Radiologic Technologists (ARRT) certification as a registered technologist.
- A radiography or CT certification or unrestricted state license with documented training and experience in CT.
- Experience in operating CT equipment.
- Training and experience in radiation physics and protection.

Passing the ARRT advanced examination for CT certification is recommended, but it is not required at this time.

The Joint Commission

The Joint Commission requires technologists who perform diagnostic CT examinations to have advanced-level certification by the ARRT or the Nuclear Medicine Technology Certification Board in CT. Alternatively, they must meet one of the following requirements:

- State licensure and documented training in CT.
- Registration and certification by the ARRT and documented training in CT.

Structural Shielding

Because staff members usually remain in the control room during CT scans, their primary protection comes from the structural shielding in the walls. Regulations vary from state to state, but shielding design should be performed by a qualified medical physicist during a room’s design phase. This should be followed by conducting a safety survey after construction and before the equipment is put to clinical use. Shielding designs take into account the workload, use of adjacent areas, and how often adjacent areas are occupied. For example, if a waiting room is located next to the CT scanner, the area is considered uncontrolled and must be shielded to keep the doses below 1 mSv per year.

The physicist calculates the amount of shielding required to reduce the exposure in the adjacent areas to acceptable dose levels using guidelines set out by NCRP Report No. 147. After installation of the shielding and CT scanner, the physicist conducts a safety survey to verify that the appropriate amount of shielding was installed, including lead-equivalent windows.

Technologists should not assume that lead in the walls stops all radiation, only that it lowers doses to acceptable levels. Technologists are considered radiation workers and, therefore, are permitted an annual dose of 50 mSv or less. The shielding in the walls is designed to prevent technologists from reaching close to that limit, but Compton scatter radiation still passes through the walls.

A common misconception is the belief that the control room must have a door or other solid structure separating it from the scan room. The scattered photons do not bend around corners; therefore, it is acceptable to have an opening between the control room and the scan room. Still, technologists should ensure that shielded barriers are between them and the CT equipment during active scanning.

Accrediting Agency Requirements

- The American College of Radiology (ACR) and The Joint Commission have instituted education requirements for technologists who perform diagnostic CT examinations.

Structural Shielding

- Because staff members usually remain in the control room during CT scans, their primary protection comes from the structural shielding in the walls.
- Regulations vary from state to state, but shielding design should be performed by a qualified medical physicist during a room’s design phase. This should be followed by conducting a safety survey after construction and before the equipment is put to clinical use. Shielding designs take into account the workload, use of adjacent areas, and how often adjacent areas are occupied. For example, if a waiting room is located next to the CT scanner, the area is considered uncontrolled and must be shielded to keep the doses below 1 mSv per year.

The physicist calculates the amount of shielding required to reduce the exposure in the adjacent areas to acceptable dose levels using guidelines set out by NCRP Report No. 147. After installation of the shielding and CT scanner, the physicist conducts a safety survey to verify that the appropriate amount of shielding was installed, including lead-equivalent windows.

Technologists should not assume that lead in the walls stops all radiation, only that it lowers doses to acceptable levels. Technologists are considered radiation workers and, therefore, are permitted an annual dose of 50 mSv or less. The shielding in the walls is designed to prevent technologists from reaching close to that limit, but Compton scatter radiation still passes through the walls.

A common misconception is the belief that the control room must have a door or other solid structure separating it from the scan room. The scattered photons do not bend around corners; therefore, it is acceptable to have an opening between the control room and the scan room. Still, technologists should ensure that shielded barriers are between them and the CT equipment during active scanning.
Certification in nuclear medicine technology by the ARRT or Nuclear Medicine Technology Certification Board and documented training in CT.

Conclusion

Because of its speed and diagnostic abilities, CT will continue to be a valuable tool for patient care. As CT technology progresses, the amount of radiation required to produce acceptable images will continue to decrease, but there is an eventual limit to how low the dose can go. The low-dose threshold is difficult to predict, but some radiation always will be necessary to produce a CT image. As of mid-2016, the cancer risk associated with an effective dose less than 100 mSv was not well understood and might not exist. Without further evidence and with most CT examinations well under an effective dose of 100 mSv, as well as technologists and other operators following radiation protection best practices, the cancer risks associated with CT scans should not be a primary concern for staff or patients.

Scott L Cupp, MS, DABR, is senior diagnostic medical physicist for Penn Medicine’s Department of Radiology in Philadelphia, Pennsylvania. He has been an adjunct faculty member for the Hospital of the University of Pennsylvania radiologic technologist education program since 2005.

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

© 2016 American Society of Radiologic Technologists

References


   a. 6
   b. 12
   c. 24
   d. 48

2. In CT scanning, most of the photons from the primary beam are removed through:
   a. coherent absorption.
   b. Compton scattering.
   c. linear energy transfer.
   d. the Planck constant.

3. Low linear energy transfer radiation from CT scans most often interacts with:
   a. DNA.
   b. water.
   c. ribosomes.
   d. protons.

4. Which of the following is an example of a nonstochastic radiation-induced effect?
   a. brain tumor
   b. cataracts
   c. leukemia
   d. inheritable genetic mutations

5. The average latency period for leukemia is ______ to ______ years.
   a. 1; 2
   b. 3; 5
   c. 7; 10
   d. 20; 30

6. According to Biological Effects of Ionizing Radiation (BEIR) VII, on average ______% of people develop cancer for reasons other than radiation exposure.
   a. 4
   b. 13
   c. 29
   d. 42

continued on next page
7. The American Association of Physicists in Medicine publicly stated that the radiation risk might be nonexistent for a single medical image exposure when below:
   a. 50 mSv.
   b. 200 mSv.
   c. 1 Sv.
   d. 10 Sv.

8. What controversial theory suggests that low levels of radiation are beneficial?
   a. radiation hormesis
   b. stochastic effects
   c. nonstochastic effects
   d. threshold level

9. What CT dose metric is used to estimate effective dose?
   a. linear CT dose index (CTDI$_{100}$)
   b. weighted CTDI (CTDI$_w$)
   c. dose-length product (DLP)
   d. size-specific dose estimates (SSDE)

10. Which of the following CT dose metrics takes into account the size of the patient compared with a standard CTDI phantom?
    a. CTDI$_{100}$
    b. CTDI$_w$
    c. DLP
    d. SSDE

11. Which of the following CT dose refinement techniques can reduce dose to the breast?
    a. automatic kV selection
    b. optimal tube potential
    c. organ-specific current modulation
    d. iterative reconstruction

12. The lead placed in the walls of a CT suite is designed to limit the CT technologist’s exposure to a dose level less than ______ mSv per year.
    a. 0
    b. 1
    c. 5
    d. 50
Your Shining Moment

Do more than you thought possible.

Get the funding you need to achieve the success you deserve.

Support provided by individual donors, ASRT Foundation Patrons, the American Registry of Radiologic Technologists, Elekta, HEALTHeCAREERS, Siemens and Varian Medical Systems.

SCHOLARSHIP OPPORTUNITIES OPEN TO ASRT MEMBERS.

Make a Gift, Make a Difference

foundation.asrt.org/scholarships

©2013 ASRT Foundation. All rights reserved.
Directed Reading Evaluation
Radiation Protection in Computed Tomography

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?
   - O Interested in the topic
   - O Topic pertained to my area of practice
   - O Needed CE credits immediately
   - O Other

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

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

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

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

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

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

8. Overall, how valuable are the DRs to you?
   - O Very valuable
   - O Valuable
   - O Somewhat valuable
   - O 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 in Computed Tomography

Expires: December 31, 2019
Approved for 1.50 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.

0 1 2 3 4 5 6 7 8 9

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 11
2 12
3
4
5
6
7
8
9
10

No Photocopies Accepted
A

ccording to a study published by the *Journal of the American College of Radiology*, supplemental screening ultrasound and magnetic resonance imaging examinations increased in New Jersey after the state’s breast density law went into effect in 2014. Under the New Jersey breast density law, mammography reports are required to acknowledge that cancer detection in dense breasts is more difficult, but it does not require that patients be informed of the density of their breasts. The law also requires insurers to cover supplemental imaging.

Sanders et al examined data from patients with core biopsy-proven malignancy at an outpatient breast center in New Jersey from November 2012 to October 2015. During this period, which included the 18 months before implementation of the law and the 18 months after implementation, the number of screening sonograms at the facility increased 651%, from more than 1500 before implementation to more than 11 400 after implementation. The authors also noted that physicians at the facility were requesting screening ultrasound examinations even for patients who did not have dense breast tissue, suggesting that they felt “obligated to order additional imaging to prevent legal liability.”

The number of cancers found by screening mammography during the study period did not change significantly, but cancers found by screening ultrasound and MR imaging increased by 600% and 189%, respectively. According to the data, breast MR imaging diagnosed 56 cancers. In 28 of those cases, the patient had a negative sonogram within the prior 3 months, which suggests that negative results on sonograms do not reliably exclude malignancy but that negative findings on MR imaging reliably confirm the absence of malignancy.

In the study report, the authors encouraged health care providers to discuss with patients the risk of increased breast density, to recommend annual screening mammography beginning at 40 years of age, and to suggest supplemental imaging when appropriate.

**NCI Launches Largest-ever Study of Breast Cancer Genetics in Black Women**

A collaborative research project, funded by the National Cancer Institute (NCI), is investigating how genetic and biological factors contribute to breast cancer risk among black women. Black women are more likely to die of their disease and are more likely to be diagnosed with aggressive subtypes of breast cancer than are white women.

The Breast Cancer Genetic Study in African-Ancestry Populations initiative will attempt to identify reasons for these disparities, which studies suggest point to various genetic, environmental, and societal factors, including access to health care. Investigators who are part of the African-American Breast Cancer Consortium, the African-American Breast Cancer
Epidemiology and Risk Consortium, and the NCI Cohort Consortium will share biospecimens, data, and resources from 18 previous studies in an effort to “narrow the gap of cancer disparities and ensure that all Americans reap the benefits from the promising advances of precision medicine,” said Douglas R Lowy, MD, acting director of NCI.

The genomes of 20,000 black women with breast cancer will be compared with those of 20,000 black women who do not have breast cancer. The genomes also will be compared with those of white women who have breast cancer. The project will investigate inherited genetic variations associated with breast cancer risk in black women compared with white women. In addition, researchers will examine gene expression in breast cancer tumor samples to investigate the genetic pathways involved in tumor development.

“This $12 million grant—in combination with previous investments—should help advance our understanding of the social and biological causes that lead to disparities in cancer among underserved populations,” said Robert Croyle, PhD, director of NCI’s Division of Cancer Control and Population Sciences, which is administering the grant. “A better understanding of the genetic contributions to differences in breast cancer diagnoses and outcomes may lead to better treatments and better approaches to cancer prevention.”

For more information about cancer, visit the NCI website at cancergov, or call NCI’s Cancer Information Service at 800-4-CANCER.

Innovative Device Allows 3-D Breast Imaging With Less Radiation

A new device called a variable angle slant hole (VASH) collimator has the potential to deliver better image quality and more precise location (depth information) within the breast while reducing the amount of radiation dose to the patient during molecular breast imaging or breast-specific gamma imaging procedures.

According to Drew Weisenberger, leader of the Jefferson Lab Radiation Detector and Imaging Group, when the collimator device is used in a molecular breast imager, the device captures 3-D molecular breast images at higher resolution than do current 2-D scans in a format that can be used alongside 3-D digital mamograms. The new collimator replaces a component in existing molecular breast imagers. A traditional collimator only allows the system to pick up the gamma rays that come straight out of the breast, through the holes of the collimator, and into the imager. The VASH collimator captures “a whole range of angles of projections of the breast without moving the breast or moving the imager,” Weisenberger explained. “You’re able to come in real close, compress the breast, and get a one-to-one comparison to a 3-D mammogram.”

The VASH collimator is constructed from a stack of 49 tungsten sheets, each one a quarter of a millimeter thick and containing an identical array of square holes. The sheets are stacked like a deck of cards, with angled edges on 2 sides. The angle of the array of square holes in the stack can be slanted by 2 small motors that slide the individual sheets by their edges. The result is a systematic varying of the focusing angle of the collimator during the imaging procedure.

In a recent test, the researchers evaluated the spatial resolution and contrast-to-noise ratio in images of a breast phantom. They found that using the VASH collimator with an existing breast molecular imaging system returned 6 times better contrast of tumors in the breast. This could reduce the radiation dose to the patient by half from current levels while maintaining the same or better image quality.

“We hope to build on this to improve the imaging of other organs,” Weisenberger said.

FDA Approves Bioresorbable Vascular Scaffold

Abbott’s Absorb GT1 Bioresorbable Vascular Scaffold is a coronary artery stent that dissolves in approximately 36 months, leaving behind only 2 pairs of small metallic markers so physicians can see where the stent was placed. Absorb benefits patients and physicians because it replaces the permanent metal stents that restrict vessel motion for the rest of the patient’s life. The naturally dissolving polymeric scaffold and polymer allow the artery to pulse and flex naturally, responding to the demands on the heart and reducing the potential for more blockage.
The U.S. Food & Drug Administration’s Circulatory System Devices Panel voted to approve Absorb in March 2016 because the benefits of the device outweigh potential risks. Abbott conducted a comparison of Absorb and a metal stent (Xience, Abbott Vascular). After a year, the 2 types of stents showed similar results. Gregg Stone, MD, chair of the Absorb clinical trial, called the device a “major advance” for treating coronary artery disease, and Deepak Nath, PhD, noted that the absorbable stent gives patients “peace of mind,” allowing them to get back to their daily routines.

Absorb is available in the United States and in more than 100 countries across the globe, and has been used to treat more than 150,000 patients worldwide.

Can Mammography Screen for Heart Disease?

Just as microcalcifications on mammograms can be a sign of breast cancer, calcium deposits on blood vessels can be a sign of atherosclerosis, the hardening of the arteries linked to heart attacks and strokes. However, it is likely that a radiologist who sees calcium deposits in blood vessels on a mammogram would consider it an incidental finding and not report it. That practice might change based on new information published in the *Journal of the American College of Cardiology: Cardiovascular Imaging* that links incidental findings on mammograms with heart disease.

Researchers compared the results of mammograms with computed tomography scans of the coronary arteries. They found a good correlation between the finding of calcium-laden blood vessels on mammograms and finding calcium deposits in the coronary arteries. If future research confirms this link—and if these mammographic findings lead to preventive measures or treatments that lower the incidence of heart attacks, strokes, and premature cardiovascular-related deaths—mammography could become a common screening test for both breast cancer and cardiovascular disease.

PET-CT Helps Determine Chemotherapy Regimen for Hodgkin Lymphoma Patients

Patients who receive a diagnosis of Hodgkin lymphoma typically undergo a chemotherapy regimen that includes doxorubicin, bleomycin, vinblastine, and dacarbazine (ABVD). A study published in the *New England Journal of Medicine* suggests that using information from PET-CT scans, physicians can adapt treatment for individual patients. In the study, patients were scanned after 2 cycles of standard chemotherapy. Based on those results, patients either continued with the standard therapy or continued therapy omitting bleomycin.

Bleomycin can cause severe respiratory adverse events and decreased lung function. Study participants who stopped receiving bleomycin were spared its adverse effects, and their 3-year overall survival rate was slightly higher than patients who did not receive it. Peter Johnson, MD, FRCP, MA, stated that, “[We] worry about the long-term side effects from the treatments we use...personalizing treatment based on how well it works is a major development for patients with Hodgkin lymphoma.” PET-CT allows physicians to see which patients have a more “difficult-to-treat” form of cancer so they can select stronger chemotherapy regimens and spare other patients severe adverse effects.

To read the study, visit asrt.org/asrt?6UFx2R.

Potential Role for Coronary Computed Tomography Angiography in Asymptomatic Patients

According to a study published by the journal *Radiology*, coronary artery disease (CAD) is the leading cause of death in men and women worldwide, accounting for 17 million deaths annually. Furthermore, of those diagnosed with CAD, 30% to 50% are considered to have low-to-moderate risk of clinically important disease. Current therapeutic strategies are focused on cardiovascular risk and serum cholesterol levels; however, medical imaging has been showing promise as a validated prognostic indicator by providing direct assessment and quantification of atheromas in the coronary vasculature. Although intravascular ultrasound is one such option, its invasive nature limits its use to high-risk patients in which cardiac catheterization is indicated clinically. In contrast, computed tomography angiography (CTA) is a noninvasive alternative that
Research & Technology

Measuring the Effect of Breast Density Legislation on a State’s Patients

relies on coronary artery calcium scoring as a measure of CAD. Until recently, this technique was limited by an inability to quantify noncalcified “soft plaques,” meaning evaluation of total plaque burden (calcified + noncalcified) was out of reach, thus limiting risk stratification.

Innovation of new analytic methods for the quantification of total plaque burden are now available and initial reported results show added benefit of the improved CTA approach in patients clinically indicated for such imaging. The study conducted by Rodriguez et al was based on the hypothesis that, in asymptomatic patients, the risk factors for the presence of noncalcified plaque might differ from those related to calcium scores. By studying 200 patients, as part of a prospective randomized control study, researchers found that in asymptomatic individuals, noncalcified plaque indices were correlated positively with systolic blood pressure, diabetes, and low-density lipoprotein cholesterol levels. This resulted in evidence supporting the use of coronary CTA to assess total and noncalcified plaque in individuals with these elevated clinical risk markers.

Evaluating the Effectiveness of Automatic Tube Voltage Selection in CT

Developing new methods of radiation dose reduction across all types of computed tomography (CT) imaging studies has been an on-going focus of radiology-related research. The challenge comes in balancing this reduction while maintaining optimal contrast-to-noise ratios necessary for producing images of diagnostic quality. Automated tube voltage selection (ATVS) is one such method, which involves using algorithms that consider several imaging factors before automatically selecting the optimal combination of tube voltage and current. The primary factors taken into account include the individual patient’s attenuation profile (determined by scout imaging), the body region of interest, as well as the type of examination being performed (noncontrast, contrast-enhanced, or angiographic studies).

To date, only small single-center studies have measured the effectiveness of ATVS technology in CT to reduce radiation exposure to the patient and only for specific clinical indications. However, in the journal Radiology, Spearman et al took the analysis of ATVS to the next level conducting an international retrospective review across 86 imaging centers, including data from all anatomic regions of interest and for all CT examination types. CT data were recorded for a period of 6 weeks before and 6 weeks after implementation of an ATVS algorithm. The results of the review showed that across all body regions and CT applications, a 15% dose reduction was achieved in examinations performed with ATVS technology when compared with examinations performed before ATVS implementation. Furthermore, the dose reduction was most pronounced for head CT studies (temporal bone, sinus, standard head CT) as well as for CT angiographic examinations. In addition, the authors recognized that ATVS might not be suitable for the few applications (renal stone protocols, spine CT) in which an increase in radiation dose was observed. Perhaps of greatest concern was that despite the availability of ATVS, the technology was used in only 35% of examinations analyzed in their investigation.
Every year, many Americans receive diagnostic testing, which might include medical imaging. Determining the appropriate medical imaging examination for a patient can be challenging as technology evolves. Technologists ensure that the imaging examination performed is appropriate by using professional reasoning and acting in the patient’s best interest. Performing appropriate imaging examinations is imperative to providing patient-centered care and central to technologists’ continued relevance in the health care system. The use of clinical decision support (CDS) systems allows clinicians to use appropriateness criteria when selecting imaging examinations and assists in providing effective use of radiology services while enhancing the quality of patient-centered care.

According to the Centers for Medicare & Medicaid Services (CMS), the use of CDS systems “increases quality of care, enhances health outcomes, helps to avoid errors and adverse events, improves efficiency, reduces costs, and boosts provider and patient satisfaction.” Use of CDS systems is becoming more widespread, and CMS will soon mandate that all ordering physicians use imaging decision support. CMS postponed its original January 2017 implementation deadline, and the mandate now is expected to begin in summer 2017.

According to the American College of Radiology (ACR), approximately 30% of imaging examinations are either ordered incorrectly or the wrong examination is ordered. Physicians will be required to order advanced imaging studies in computed tomography, magnetic resonance imaging, nuclear medicine, and positron emission tomography with CDS software that uses the ACR Appropriateness Criteria. The Appropriateness Criteria provides “evidence-based guidelines to assist referring physicians and other providers in making the most appropriate imaging or treatment decision for a specific clinical condition.” This use of CDS systems in medical imaging represents the profession’s dedication to providing safe, accurate, efficient, and timely patient-centered care and demonstrates the continued growth of informatics in radiology departments across the United States.

The medical imaging profession is pioneering the use of informatics as a means to improve patient care and is the sole specialty mandated for CDS use thus far. The Protecting Access to Medicare Act, passed in 2014, mandates the use of CDS systems and represents a significant effort in shifting health care from volume to value of clinical care. CDS systems will be integrated with ordering physicians’ computerized provider order entry systems and should be virtually invisible to the user. The most often used example of a CDS system is a drug-allergy interaction alert. However, it can include other features (see Box). CDS systems should be viewed as a computer-based intervention that enhances decision-making and uses clinical knowledge and patient information to improve the delivery of health care services.
Clinical Decision Support Features

<table>
<thead>
<tr>
<th>Alerts and reminders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical guidelines</td>
</tr>
<tr>
<td>Clinician–patient assessment forms</td>
</tr>
<tr>
<td>Data flow sheets</td>
</tr>
<tr>
<td>Documentation templates</td>
</tr>
<tr>
<td>Information buttons</td>
</tr>
<tr>
<td>Order facilitators</td>
</tr>
<tr>
<td>Patient data reports and dashboards</td>
</tr>
<tr>
<td>Protocol/pathway support</td>
</tr>
<tr>
<td>Task assistants</td>
</tr>
<tr>
<td>Tracking and management systems</td>
</tr>
</tbody>
</table>

Advanced health care information systems are in higher demand because of the American Recovery and Reinvestment Act for health care and efforts to maintain existing Medicare and Medicaid reimbursement levels. As CDS system implementation continues, technologists should expect to see a shift toward ordering physicians’ stronger adherence to the ACR Appropriateness Criteria when using imaging technologies. This shift will be unique to each practice and might affect modality use. For example, ultrasonography examinations could increase and computed tomography examinations might decrease. Adherence will result in greater accuracy in clinicians’ selection of appropriate imaging examinations.

The Appropriateness Criteria covers approximately 90% of clinical scenarios, leading to better diagnosis and care. The ACR has “an exclusive agency agreement with the National Decision Support Company to provide the technical platform, support and licensing of its copyrighted appropriateness criteria under the name ACR Select.” ACR Select is embedded into the electronic health record and computerized provider order entry platforms, and its use is traceable. When an independently licensed practitioner orders an imaging examination, ACR Select generates a decision support number to identify the recommendation, while also recording the appropriateness number for the procedure. Lower numbers might require a consultation with a radiologist, and higher numbers represent an appropriate examination selection. Decision support analytics included in ACR Select allow for individual physicians to be queried for review of compliance with the CMS mandate. Mandates for CDS system use are on the horizon and will lead to increased accuracy and relevance of medical imaging examinations and improved, patient-centered care.

**References**


Kori Stewart, MHS, R.T.(R)(CT), CIIP, is a clinical assistant professor and clinical director for the CT, MRI and ultrasound certificate programs at the University of Hartford in West Hartford, Connecticut, and maintains clinical practice as a per diem technologist. She is pursuing a PhD in biomedical informatics and serves on the Connecticut Society of Radiologic Technologists’ executive board as secretary and alternate delegate. Stewart has been an ASRT member since 2009.

The fourth edition of Fractures of the Pelvis and Acetabulum is a 2-volume set covering the principles of operative management of fractures as they relate to the pelvis and acetabulum. More than 80 international surgeons collaborated on the set. The expert content they provide, along with the more than 2000 images and illustrations, demonstrates the decision-making that goes into assessing injuries using data such as patient history, physical examination, and radiographic image interpretation. The set includes access to video presentations that demonstrate surgical approaches and reduction techniques performed by world-renowned experts.

Given the complexity of the topic and content of these books, it is clear that the intended audience is the trauma orthopedic surgeon. With the exception of chapter 1 in each volume (anatomy of the pelvis and acetabulum), I do not recommend this text to my fellow radiologic technologists. The ability to assess the quality of content is above my level of expertise, but I will say that the many illustrations are well done and do the text justice.

Mark J Schubert, R.T.(R)
Radiology Education Coordinator and Adjunct Faculty
Sentara Healthcare and Tidewater Community College
Virginia Beach, Virginia


Image analysis is a critical aspect of radiography. If an image is not obtained correctly, an inaccurate or unrecognized diagnosis could result. Image analysis includes correct anatomical positioning and proper technical settings that enable the radiologic technologist or physician to visualize the structures in question. Although primarily intended to provide radiologic science students with a well-detailed analysis of the most common radiographic procedures, Radiographic Image Analysis also is an excellent reference for radiologic technologists.

The portable and durable hardcover textbook has several significant features that make it beneficial to
readers, including its numerous images, well-organized content, glossary of abbreviations, bibliography, image analysis form/checklist, and supplemental materials that include test and image banks. The first 2 chapters provide a review of imaging guidelines and specific digital imaging information. Chapter 2 discusses pitfalls or errors that can occur with digital imaging equipment, such as histogram analysis errors or misuse of the image receptor. The remaining chapters are ordered in a manner similar to most positioning courses, beginning with chest and abdomen and progressing through extremities, vertebral column, cranial and facial bones, and contrast examinations.

The radiographic imaging chapters include the most common radiographic positions and projections, making this textbook a complementary resource to any positioning course. Basic positioning information and pathologic considerations are presented at the beginning of each chapter before each position or projection is introduced, and the accompanying images are labeled clearly with the radiographic anatomy. In addition, the pathologic conditions demonstrated in the numerous radiographic images are described clearly, and optimal radiographic images accompany images showing suboptimal positioning or errors.

One of the most important attributes of the text is the amount of suboptimal radiographic images included. The reader can view these images alongside illustrations of the positioning error. For example, an image of a rotated lateral wrist includes a description of the positioning error in the text, a description of how to produce an accurate radiographic image, and a photograph that demonstrates the accurate position. Almost every positioning error is included for each anatomic procedure.

A downfall to the textbook is that it lacks color images. Understandably, the radiographic images will be produced in black and white, but the text could be enhanced if the photographs of the models were in color. In addition, readers, especially first-year students, might find the extremely detailed positioning descriptions challenging to grasp. This level of detail usually is not encountered in traditional positioning procedure textbooks. For example, in a traditional book, a mispositioned lateral elbow might only be described as the lateral epicondyles not being superimposed, but this text describes the anatomical positioning error from several perspectives, such as the forearm being too high or too low, the hand being supinated or pronated, or the shoulder being too high or too low. This level of detail might overwhelm the first-year student but could enhance the critical-thinking skills of the second-year student.

Overall, Radiographic Image Analysis is a well-organized textbook that features extremely detailed image critique and correction methods. It is intended for students but could be a valuable resource for radiologic technologists working in the general clinical setting. Image analysis is one of the most important aspects of radiography, and this text raises the level of critical thinking needed for application in the medical imaging profession.

Tricia Leggett, DHEd, R.T.(R)(QM)  
Vice President for Student Success  
Zane State College  
Zanesville, Ohio


Differential Diagnosis in Musculoskeletal MRI presents an overview of common and rare musculoskeletal disorders and pathologies as they appear during magnetic resonance (MR) imaging. The volume and variety of potential abnormalities in the clinical setting are extensive, yet the authors have done an exceptional job of providing detailed descriptions of imaging findings for each of the topics presented. As the title implies, the book is meant to serve as a useful resource for diagnosticians, including radiologists and orthopedic specialists; however, the comprehensive level of the content also is valuable for MR technologists who coordinate with medical staff on musculoskeletal imaging protocols.
Chapter 1 provides a concise overview of MR physics and fundamentals, as well as the usefulness and applications of MR in musculoskeletal imaging. Chapters 2 through 5 address imaging of the joints of the upper extremities, including the shoulder, elbow, wrist, and hand. The joints of the lower extremities—including the hip, knee, ankle, and foot—are covered in chapters 6 through 8. Chapter 9 details bony and soft tissue tumors and provides information regarding tumor classification, grading, and staging; patient presentation age and frequency; and imaging evaluation. Finally, chapters 10, 11, and 12 present benign and malignant lesions found in bones, joints, and soft tissues, respectively. Aside from a brief list of MR and diagnostic abbreviations, no other supplemental teaching tools or instructional resources are included.

Although the detailed descriptions of imaging findings and the additional comments included for each abnormality are useful, the strength of this book lies in its more than 2000 images. In each chapter, numerous high-resolution MR imaging sequences are provided in a variety of weightings and anatomical planes. For some pathologies, additional radiographic and computed tomography imaging findings are presented for comparison or correlation. Unfortunately, most pictures are limited to only a few inches in each dimension. In addition, some of the topics have limited text or images, leaving several instances of dead space throughout the book. Increasing the size of the images and the font could have filled these spaces and made better use of the page. Nevertheless, the volume and quality of the images, coupled with the thorough explanations of the imaging findings, make this book a valuable resource. The authors are medical doctors and professors of radiology and imaging sciences, making them experts on the content and the ideal choice as information sources.

The authors’ attempts to create a resource addressing the entire field of musculoskeletal imaging have produced a large, well-designed, hardcover textbook. The medical images are printed in grayscale, but some of the text and charts are printed in color. The book, at more than 5 pounds, is too bulky for easy transport, but radiologists, orthopedic surgeons, and radiologic technologists will benefit from having this invaluable reference source on their bookshelf.


Emergency Imaging is a terrific resource for a greater understanding of traumatic injuries as well as chronic and acute pathologies seen in emergency medical imaging. This comprehensive guide provides succinct imaging considerations of 232 traumatic and emergent conditions and contains more than 1700 high-quality images from general radiography, computed tomography (CT), magnetic resonance (MR) imaging, and ultrasonography. The 8 main sections break down into logical subsections, making for a well-organized reference that can be used either as a refresher or to acquire new knowledge. The book’s intended audience is radiologists, emergency physicians, and medical interns and residents, but the book can enhance the professional abilities of radiologic technologists as well.

Although interpreting images and making diagnoses is beyond the scope of practice for radiologic technologists, Emergency Imaging can further technologists’ understanding of the diagnostic procedures performed on a daily basis. Radiologic technologists who have a strong understanding of the hows and whys of medical imaging—including why physicians order certain examinations and what radiologists look for when evaluating diagnostic images—are stronger practitioners and, therefore, greater assets to patients, physicians, and imaging departments.

The general radiographer will find the chest and musculoskeletal sections particularly useful. Radiographic
pathologies as well as various fractures and dislocations are described in concise detail and with high-quality images. CT technologists will discover a wealth of information in the brain, head and neck, spine, and abdomen and pelvis sections. The abdomen and pelvis section covers an assortment of neoplasms from incidental liver masses to metastatic tumors and a host of other conditions and injuries. MR technologists will find the brain and spine sections helpful, especially in the areas of herniated discs, spinal cord and nerve pathology, and radiculitis. The section devoted to pediatric emergency imaging will be useful to those who work in facilities that treat children.

Each chapter begins with an approach or overview of a particular anatomic region, including clinical criteria for ordering examinations, useful imaging modalities, and typical diagnosis measurements and indicators. An anatomic checklist cues the reader to the anatomy that must be evaluated or assessed on images. An imaging subsection follows and includes information about contrast administration and indications for ordering examinations. Also included are CT techniques and protocols, ultrasonography protocols, MR sequences, and desired radiographic views based on or related to the presentation of injuries and symptoms. A subsection on clinical presentations and differential diagnosis follows. The chapters conclude with numerous descriptions of traumatic injuries and pathologies, each demonstrated by 4 to 6 images.

_Emergency Imaging_ is a valuable resource for any radiologic technologist and deserves a prominent place among the medical references and important textbooks on the bookshelves within an imaging department.

_Todd Van Auken, MEd, R.T.(R)(MR)_
_Clinical Coordinator_  
_St Petersburg College_  
_St Petersburg, Florida_
A strategic plan is a critical element of any successful organization. With long-term planning, the current status is identified and a path is developed to meet future goals, whereas strategic planning starts with the end in mind and works backward to achieve desired goals. Earlier this year, at its spring meeting, the Joint Review Committee on Education in Radiologic Technology (JRCERT) completed a review of its strategic plan (see Box). Many radiology administrators actively are involved in strategic planning. As the Association for Medical Imaging Management representative on the JRCERT board of directors, I have had the honor to assist the JRCERT with its strategic planning process.

The JRCERT prides itself as being the only agency recognized by the U.S. Department of Education and the Council for Higher Education Accreditation for the accreditation of traditional and distance delivery educational programs in radiography, radiation therapy, magnetic resonance, and medical dosimetry. Specialized accreditation awarded by the JRCERT offers institutions significant value by providing peer evaluation of the educational process and by assuring the public that students receive a quality professional education in the radiologic sciences. In addition, the public can be confident that graduates of a JRCERT-accredited program will have developed the requisite skills and behaviors to provide safe, high-quality patient care.

A strategic plan should set priorities to focus energy and resources on strengthening operations and ensuring that employees are working toward the goals identified in the strategic plan. Furthermore, it should be assessed regularly to ensure that business decisions are correlated with the strategic plan.

No absolute rules or frameworks are required for strategic planning; however, there are some common goals:

- Analysis or assessment – understand current internal and external environments.
- Strategy formulation – develop a basic plan and a high-level strategy.
- Strategy execution – translate the plan into operational and action items.
- Evaluation management – assess the performance of meeting action items.

**Conclusion**

As a radiology administrator, it is of utmost importance that our technologists are educated properly to maintain our profession’s credibility. I encourage educational programs in the radiologic sciences to become JRCERT accredited to promote a culture of excellence. Furthermore, I challenge each radiology administrator to make it a priority to hire graduates from JRCERT-accredited programs so that our profession can continue to solidify itself as one of the premier providers of quality health care.
JRCERT Update

JRCERT’s Strategic Planning Vision From a Radiology Management Perspective

Box

JRCERT Strategic Plan

1. Meet the accreditation needs of the profession, reflect the highest levels of volunteer and professional competency, and achieve excellence in the accreditation process:
   a. Develop new tools that represent best practices for understanding how to achieve and maintain accreditation.
   b. Develop a timely, efficient, and effective accreditation process.
   c. Develop and expand the knowledge base of JRCERT staff through regular continuing education.
   d. Evaluate the accreditation standards to achieve commendable accreditation status.
   e. Develop standards that reflect the mission and values of the JRCERT.

2. Promote and assure an understanding of the value of the JRCERT accreditation process:
   a. Pursue programmatic accreditation of all programs in the radiologic sciences.
   b. Gather information to be knowledgeable about state and federal regulations and to promote programmatic accreditation in all state regulations.

3. Address the changing social, economic, and regulatory conditions affecting specialized accreditation:
   a. Increase awareness of federal regulations that affect the JRCERT as an accreditor, and respond to the external environment to ensure continued success.
   b. Ensure the strategic plan allows for flexibility and ease of response to external pressures and changes.

4. Allow JRCERT the opportunity to grow and maintain financial strength:
   a. Explore cost-saving measures.
   b. Evaluate the efficiency of the current accreditation process (efficiency affects cost).
   c. Enhance existing revenue streams.
   d. Explore new revenue stream opportunities.

References


Jason Scott, MBA, R.T.(R)(MR), CRA, FAHRA, is chief patient experience officer and director of the imaging/pulmonary/neurodiagnostics/wound care department for Witham Health Services in Lebanon, Indiana. He also serves on the JRCERT board of directors. He can be contacted at jscott@witham.org.
The 2000 U.S. national census revealed that 1 in 5 residents were non-English speakers, and 25% of them had little or no understanding of the English language. Professional medical interpretation services is a profession that although widely available, is seldom used for those who need it most. The lack of use generally stems from a facility’s unwillingness to pay for such services. However, unfortunate mistakes in the clinical setting along with the potential liabilities when using family members, friends, or unqualified office staff to interpret for the patient demonstrate the importance of professional medical interpretation services.

The medical field is one in which diversity is commonplace and each facility needs to be prepared to accommodate patients with special needs. One critical need is clear communication. Without clear communication, it is impossible to ensure that the patient will be seen for the correct examination or be given the proper treatment. Patients and their providers need to have an open line of accurate communication to prevent mishaps. This flow of communication becomes more difficult when there is a language barrier. For those who require interpretation services, many avenues are available to provide the necessary help.

Although many people rely on family members to fill this interpreter position, that is not the best option. An affordable, accessible, and professional interpreter is the best option.

Interpreter Qualifications

According to the National Board of Certification for Medical Interpreters, a medical interpreter must have—and be able to prove they have—an excellent command of the English language and the language for which they are interpreting. The candidate also must meet the minimum age requirements and have graduated from an approved interpreter education program with a minimum of 40 contact hours. These skills and experience are foundational to accurate interpretation because if one is missing the odds of a successful translation greatly decrease.

Key elements of professional medical interpretation services are technical knowledge and experience with medical terminology translations. Medical terminology is considered its own language and has quirks that vary from the traditional English language. Because of this, there are fewer direct translations into another language, so interpreters must be able to translate complex words and phrases accurately without omitting crucial facts. Ad hoc interpreters, such as family members and bilingual personnel without formal training, often are used. Studies analyzing audiotaped pediatric encounters have shown that those serving in this capacity were more likely than professional interpreters to commit errors of potential clinical consequence, such as omitting questions about drug allergies or instructions on prescription dose, frequency, and duration. In Washington state, all personnel performing interpreter duties in hospitals and other institutions must be certified by the Department...
of Social and Health Services. This certification process ensures that those who are in the position to provide interpretation services are qualified to do so. Those who apply for an interpreter certification must pass a written and oral examination to receive their certification.⁴

**Informed Consent Requirements**

One of the most important tenets of medical care is informed consent. Failure to obtain informed consent from a patient can result in any member of the multidisciplinary team being named in a lawsuit.⁶ The requirements of informed consent include⁶:

- Discussing the patient’s role in the decision-making process.
- Describing the clinical issue and suggested treatment.
- Discussing alternatives to the suggested treatment, including the option of no treatment.
- Discussing risks and benefits of the suggested treatment and comparing them with the risks and benefits of alternatives.
- Discussing related uncertainties.
- Assessing the patient’s understanding of the information provided.
- Eliciting the patient’s preference and, thereby, consent.

The very foundation of informed consent is rooted in these requirements. However, obtaining a complete informed consent often can be difficult—even with patients who are native English speakers—because of the complex language in consent forms. In an analysis of 1057 low-risk encounters in which informed consent was deemed necessary, 9% contained all the elements required of a complete informed consent process.⁴ The study found that the average consent form is written at a 12th grade level or higher, and 5% of forms are written at an 8th grade level or below. Because of this, the only reasonable option for patients who have limited English language proficiency is the use of a qualified medical interpreter.

**Reasons for Requiring Professional Interpreters**

Many situations in health care arise in which using a family member or, in the case of imaging studies, pantomiming the instructions will work without causing harm to the patient. However, other situations require a legal signature for a document, and in these circumstances, a professional interpreter should be used. For example, when a patient comes to the emergency department for treatment, it is considered implied consent for procedures and treatment because they entered the facility for care. Should that same patient be referred to another provider for follow-up services, a consent form must be signed again before services can be rendered. A consent form is a legally binding document; therefore, the patient should be fully aware of and understand all possible risks and complications of the treatment. If language barriers exist, consent can be obtained only through some form of interpretation.

According to Ku and Flores, limited English proficiency patients are more likely than others to report being in fair or poor health, defer needed medical care, leave the hospital against medical advice, miss follow-up appointments, or experience drug complications; they also are less likely to have a regular health care provider.⁴ Language barriers were key to the unfavorable outcomes with these patients. The language barrier also might diminish a provider’s ability to ascertain the symptoms and causes of illness or injuries accurately. This can result in a delay in care and treatment, and depending on the disease pathology, could worsen a traumatic or life-threatening condition, such as cancer or stroke.

In situations that require a signed informed consent, such as invasive procedures, it is of the utmost importance to have a professional interpreter translate for patients to ensure they are aware of all risks and possible complications. Technologists frequently encounter patients who have a language barrier. Many are patients who need routine examinations, such as a chest radiograph or orthopedic examination, but some need spinal injections, arthograms, steroid injections, or other more invasive studies that might require oral or intravenous contrast administration.

For more complex examinations, technologists must insist on having the assistance of a professional medical interpreter. If technologists rely on themselves to pantomime information or use a family member who is not trained in medical terminology, the risk of significant
Medical Mistakes and Risks

Numerous risks arise when proper interpretation services are not available. These risks can range from simple clerical errors to mistakes with serious clinical consequences. During a 7-month period, HealthLink recorded the mistakes made by ad hoc and professional interpreters and found that the ad hoc interpreters’ mistakes were more likely to carry serious clinical consequences. They also discovered that of the mistakes made, 52% were omissions, 16% were false fluencies, 13% were substitution of a word with a different meaning, 10% were the addition of personal opinions, and 8% were addition of a word or phrase.

One case that demonstrated serious consequences of ad hoc interpretation involved a patient and her hysterectomy surgery. The patient was admitted for surgery and when she needed help with the informed consent paperwork, her bilingual son served as the interpreter. He described the procedure to his mother and she signed willingly. The next day, however, when she learned that her uterus had been removed and that she could no longer bear children, she became angry and threatened legal action against the hospital. In this family’s culture, it was inappropriate for a man to discuss his mother’s private parts with her, and the embarrassed son had explained that a tumor would be removed from her abdomen and pointed to that general area.

Another case involved a misunderstanding between a young boy and a paramedic. The boy uttered the word intoxicado, which the paramedic interpreted to mean intoxicated, rather than the intended meaning of nauseated. The boy was admitted for a full drug abuse work up. Eventually, it was discovered that he had brain damage caused by a ruptured brain aneurysm and, as a result, he became quadriplegic. He sued the facility and won $71 million in a malpractice suit.

Although these examples are sensational, they are not isolated; cases such as these are reported annually. Mistakes without such heavy consequences are most common, such as errors with prescription medication dosage and frequency. For example, a patient might be told to spread hydrocortisone cream on his or her whole body instead of only the area with the rash. Examples such as these demonstrate the importance of accuracy when providing interpretation services for informed consent, medical history, and patient instructions.

Cost and Options

As of 2007, 12 U.S. states and the District of Columbia reported that the cost of an interpreter is covered by insurance. For those who do not live in one of those states, according to Dr Flores it would cost an average of $4.04 per patient visit to add medical interpreters to the cost of health insurance. Dr Flores also asserts, “With the increasing numbers of patients who do not speak English, it makes sense to do this on a national level.” Several types of interpreter services are available to patients and facilities. The most traditional is when a contracted individual accompanies the patient to the appointment and provides face-to-face interpretation. The second option is a call-in service. With this option the facility uses a pair of cordless phones: one for the patient and one for the provider. The provider dials the number and requests the appropriate language from an operator. Then the patient and the provider become “live” with the interpreter, with minimal delay. To use this option, providers are given a toll-free number to call with an account number. Once they give the account number to the operator and state the desired language, they are connected, and the facility is billed by the minute. This service allows facilities to have an interpreter for many languages available 24 hours a day, 7 days a week. When using a traditional in-person interpreter service, providers typically need to schedule with them 3 days in advance of the patient’s appointment. When in-house or on-call interpreters are available, staff simply needs to wait for them to reach the department or facility. Using a combination of these 2 options, facilities nationwide should be able to provide appropriate interpretation services for their patients.
Conclusion
With the growing number of non-English speaking people in the United States, the health care industry must adjust to meet the needs of its new population dynamic. Interpretation service options are available to fit any facility’s needs and demands, no matter how great or small, and providing these services in some form is important to reducing medical mistakes. Open and accurate communication is vital so that radiologic technologists can provide the highest quality service to their patients.

Amanda Garlock, MS, R.T.(R)(MR), is a magnetic resonance imaging technologist for Swedish Hospital in Everett, Washington. She also serves as president-elect of the ASRT Board of Directors and is the mother of twin boys.

References
Job Application Tips


Whether you are a radiologic technologist right out of school—fresh in the field and motivated to find work—or experienced in medical imaging and looking for a new challenge, it is important to be the best job candidate you can be.

Finding Job Openings

Methods of finding potential positions have changed significantly over the years. When I started in the profession, it was common practice to walk into a hospital, ask to speak with the radiology manager, and fill out an application on the spot. This might still happen on occasion, but more often, the application is online and handled by a human resources department. An application might not make it into the radiology manager’s hand until the human resources staff thoroughly evaluates it.

Centralized job-posting websites are a great place to start searching for a position. The ASRT JobBank® is an excellent searchable database. Technologists can search by location or by category (eg, PACS administrator).

Each job posting likely receives many applications. Therefore, job seekers should find as many open jobs as possible that fit their criteria and complete applications for each job that meets their needs. Technologists need to consider whether they are willing to work long shifts and whether they need a position that offers certain benefits. Many factors determine whether a job is a good fit for a person’s specific circumstances.

Applicants should read the full job posting to determine whether the position will work for them before beginning the application process. Filling out applications for unwanted jobs wastes the applicant’s and the reviewer’s valuable time. In addition, if applicants apply for jobs for which they are not qualified, frustration can set in if interview requests are not received. This stage can take a lot of time and research, but when applicants make the effort, they might find a step in their career ladder, not just a job.

Job seekers also should talk to colleagues, instructors, fellow students, or trusted advisors while searching. The radiologic sciences is a small profession, and most technologists have a lot of information about radiology facilities and their work environments.

When planning to apply to a certain facility, technologists should speak with people about that facility to learn about its culture. Some radiology departments are vast, with many independent sections, such as fluoroscopy, computed tomography, or an orthopedic clinic. Technologists should consider whether they want a job that offers a variety of tasks, or whether they would prefer working with the same group of people and doing the same types of tasks every day. This is a personal choice that has a large role in a technologist’s success in a position.

Technologists also should consider whether the facility is known for advancement opportunities. If a technologist is fresh out of school and hopes to earn an advanced certification, such as mammography or magnetic resonance, it is important to consider whether an organization will support those goals. It is not always
Another vital part of the résumé is education. Job applicants should list education experience, including the school attended, and degree earned. If a position lists educational requirements, technologists should ensure they meet those requirements. If several positions that require a higher level of education are of interest, consider what steps need to be taken to be eligible for such positions.

Another section should list professional affiliations, licensures, and certificates. An active American Registry of Radiologic Technologists (ARRT) certification and memberships to professional societies, such as the American Society of Radiologic Technologists (ASRT) or a local affiliate society, belong in this section. Membership in a professional society demonstrates that candidates are active members of the profession and that they take pride in being a radiologic technologist.

Optional information on a résumé might include awards and recognition, volunteer experience, and published articles. Although not mandatory, this information could help an applicant’s job prospects. Awards show the hiring manager that a candidate respects his or her job and is willing to go above and beyond the minimum requirements. This might include employee of the month recognition or awards received while a student. Volunteer work offers additional insight to employers. Although the donation of time reflects well for all applicants, new graduates looking for a job who do not have relevant work experience should consider volunteering. The ASRT, state affiliate societies, the ARRT, and local hospitals offer many volunteer opportunities that can increase an applicant’s job market prospects, expand knowledge, and help the community or profession. As a hiring manager, if I receive a résumé that lists volunteer experience, I know that the applicant is motivated and cares about participating in the professional or local community.

A section listing published articles might be more suited to technologists who have a lot of experience in the profession or who are seeking positions in academia, but students and new technologists can take advantage of publishing opportunities as well. Collaborating with a more experienced technologist on a scholarly research article, submitting a manuscript to the ASRT

**The Cover Letter**

The cover letter is sometimes ignored by many applicants now that online application systems are common. As a hiring manager in radiology, I find the cover letter to be an essential component of an application. The cover letter is the candidate’s one chance to detail his or her accomplishments. Applicants should use this opportunity to describe why they are the best candidate for the position and why the manager should choose them for an interview. Radiology is a small and competitive profession, and an applicants’ experience and accomplishments can look very similar. Technologists should use the cover letter to make their application look different and help set them apart from the competition.

The cover letter explains in more detail the objective stated in the résumé. It should be written in a logical sequence with clear and concise sentences and fit on one standard page. Overuse of adverbs and adjectives can clutter your cover letter and make it hard to understand. One way candidates can craft the cover letter is to relate each aspect of the job description to their experience to demonstrate they are the best choice for that position. For example, technologists can begin with their education and training that are specific to the job and follow this with their job experience or additional training.

The cover letter also is a good place to mention experience with equipment. As a manager, I look to see whether applicants have experience with the equipment we use. This can ease the onboarding process and help applicants become accustomed with our department quickly if they are selected for hire. I do not hire technologists based on the equipment they have used, but it can help candidates’ chances if they are familiar with several types of equipment. Most experienced technologists have worked on several different radiographic units. Students also often have used various equipment during their clinical rotations. It is difficult to fit all this information into a résumé, and the cover letter gives applicants the opportunity to expand on their abilities in hopes of landing an interview.

**Before the Interview**

Although the process varies by institution, applications typically are screened by human resources staff. If the application meets the job requirements, the human resources department forwards the application materials to the radiology hiring manager. In many areas of the country, the radiology manager might get a lot of applications for one position. This can be true for benefited full-time positions and per diem positions. If a candidate’s résumé and cover letter catch a hiring manager’s eye, he or she reaches out for an interview.

After applying for a job, candidates should be ready to receive phone calls requesting an interview. Be prepared to offer interview dates and commit to one as soon as possible. Managers do not want to wait 2 weeks for applicants to have a spot open in their schedule. Most employers would move to the next application and fill the position. It also is a possibility that communication will come via email, especially if your application was submitted through an online system. Make sure to monitor your email inbox following the submission of a job application.

Once applicants have scheduled an interview, they should continue to prepare. Gaining knowledge by researching the facility and the position can help during the interview and provide candidates with a level
of confidence. In addition, candidates should prepare for interview questions by reviewing their application, résumé, and cover letter to be ready to describe their specific attributes. Multiple websites and books are available on interview techniques, common interview questions, and ways candidates can present themselves professionally. Technologists can formulate answers to common interview questions and practice with a friend or colleague. This type of preparation helps candidates gain confidence before the actual interview. It also is common for interviewers to ask applicants if they have any questions. Therefore, it is important to have a few questions prepared ahead of time. Some questions might be answered during the interview, so candidates should have several in mind.

The Interview

The first thing I see when I greet applicants is their appearance. This is not the most important thing I look for, and it does not necessarily indicate that the candidates will be good technologists, but it does indicate professionalism. All job candidates should dress professionally for an interview. Business professional is the appropriate attire for a management or leadership position in health care, but business casual typically is appropriate for a technologist position. I have had applicants show up to interviews in gym clothes or wearing flip-flops, and my first impression of them was not what they were hoping for when they applied. If there are special circumstances, these should be mentioned to the interviewer before the scheduled interview. For example, applicants have come to an interview directly from another job, and they have asked me if it would be acceptable to wear their uniform. This was perfectly fine because I know that technologists often have busy schedules and sometimes keep multiple per diem positions.

Candidates should be prepared to interview with a small group or with several different people individually. Interviewers can include members of the radiology department as well as human resources staff. This gives the facility an opportunity to get varied opinions of the candidate and provides the candidate a chance to get answers from multiple angles. Applicants should not be surprised or intimidated by this. Everyone there wants to find the best technologist for the job, and if an applicant is prepared and looks professional, he or she has no reason to be nervous.

I have an iterative group of questions I use to determine whether the applicant is qualified, ready to work, and fits the department culture. I base a good deal of the interview on the fact that one of the best predictors of future success is past success. Past success can be in a prior job (in or out of the medical imaging profession) or during the applicant’s education. The key is for applicants to have examples and to be ready to describe them in the interview. A few questions I use to discuss past success include:

- What is an accomplishment that was important to you in your last job?
- How have your past experiences helped you accomplish your goals?
- What does success mean to you?
- Why did you leave (or why are you considering leaving) your last position?

Of course there are many ways to ask these questions, and each interview will be different. Candidates should consider things they did well and how they helped the department and facility at each former position. A common type of interview question attempts to determine how an applicant has dealt with past challenges. A successful department member can deal with challenges and excel despite them. Before the interview, candidates should think of a challenging aspect of their current or past position. They should be ready to explain how they were able to continue working effectively. Because this can be a difficult question to answer, preparation is important.

New graduates should be prepared to answer questions about why they chose the medical imaging profession. The radiography education program gives candidates some experience in hospital settings and the opportunity to speak with multiple technologists. General answers, such as “I want to help people,” are adequate, but a personal story or experience can be much more memorable to the interviewer. Candidates who have a story behind their decision to join this profession should be excited to talk about it. In addition, new technologists should be prepared to talk about past work experience outside of medical imaging. Any job success is a good indicator of future success.
I often bring applicants on a quick tour of the department. If a hiring manager offers this, it can give candidates an opportunity to see the equipment they might be using and let the interviewer know whether they have experience with a specific vendor or unit. Most interviewers also ask the applicants if they have any questions about the position or the facility. If an applicant has a good question prepared or if one arises during the interview, asking it helps to create a connection with the interviewer, which can help separate the applicant from others.

Candidates should ask about the compensation, benefits, and other financial incentives. If there is a specific financial requirement, candidates should provide that information. Discussing requirements to work weekends, holidays, or being on call also is important. Most employers prefer to have this information discussed at this stage rather than after an offer is made.

When the interview ends, candidates should thank the person or team who held the interview and shake hands. The interviewers most likely will say when a decision will be made, but if they do not, it is reasonable to ask.

Moving Forward
Candidates should not expect a phone call with an offer right away. A manager must complete several steps before he or she can make an offer to an applicant. These steps often are collaborations between the human resources department and the radiology management team. At this stage, applicants can send an email or handwritten note to the interviewers thanking them for the opportunity to interview.

An offer for a position might come directly from the hiring manager or from staff in the human resources department and usually includes a pay rate or salary level. Most organizations allow some time for the candidates to think about it and decide whether it is the right career choice for them.

Conclusion
Getting a job offer is not easy. It takes thoughtful effort to put together application materials that will stand out in today’s market. Radiologic technologists should consider volunteering, publishing, or obtaining further certifications or education to make themselves desirable candidates in the medical imaging profession so that they can serve the public and the profession in their best capacity.

Jonathan B Havrda, MPH, R.T.(R)(CT)(BD), is director of radiology and PACS administrator for Cottage Hospital in Woodsville, New Hampshire. He is a member of the Radiologic Technology Editorial Review Board and the American Registry of Radiologic Technologists Bone Densitometry Practice Analysis Committee.

Reference
The radiologic science profession has given me so much over the years, and I am a big believer in giving back. It was this desire to give back that prompted me to fill out an application to participate in an ASRT Foundation and RAD-AID International community outreach project. I did not know what to expect when I filled out the application, but I knew it was something I wanted to do.

When I received the call to travel to Luang Prabang, Laos, and help provide training at a pediatric hospital that opened in May 2015, I was not sure I could make it work. I have been an educator and clinical coordinator for the past 9 years, but spending 2 months away from home seemed like an impossible amount of time. Looking back, I am glad I went.

Because the hospital’s main purpose is to treat pediatric patients, I focused my training on best practices and helping personnel understand the affect they have on patients’ lives. I trained 2 people during my time there. They had backgrounds in nursing but had no formal training or experience in radiography.

After my arrival, I developed a deeper appreciation for community outreach efforts. Although the hospital had the appropriate equipment, the necessary training would not have been available without such efforts.

On average, the hospital saw 65 to 70 patients a day. While I was there, the hospital’s new inpatient ward opened, which held 9 patients. This allowed patients to stay overnight. Disease and malnutrition are widespread in the country, so it did not take long for the new ward to fill up. Patients from all over the region flocked to the hospital for care; some of the patients walked for days to see the medical staff. Without the support of dedicated volunteers, people in the area would not have access to this type of care.

This experience made me realize that no matter how large the world seems, we are brought together by the people in it. This project is near and dear to my heart. The lasting impression of helping children in recovery will always be a part of me, and I am forever grateful for the opportunity.

Tiffani Walker, MSRS, R.T.(R), is radiology clinical coordinator for North Central Texas College in Gainesville, Texas.

Making the World a Better Place

I am fortunate to have been selected as a Siemens ASRT Foundation Community Outreach Fellow to work with radiographers in Luang Prabang, Laos. When I was selected, I was certain I wanted to be a part of this important work and give back to the profession I love. However, I had to overcome several obstacles, such as defending my dissertation and missing my graduation, work, and grandson’s first birthday. Fortunately, my dissertation was accepted, I learned I could attend a
later graduation ceremony, work approved my leave of absence request, and I made plans to see my grandson as soon as I returned home.

With everything in order, I informed the selection committee that I could be a part of the project.

It was a great honor for me to be a part of global outreach and to be able to help provide life-changing services to an entire region. While in Laos, I worked alongside new radiologic technologists to assist them with patients, determine areas of additional training they needed, and facilitate ways for them to learn. It was rewarding to share my more than 30 years of experience with others and help them grow in the profession. My years as an educator were useful in helping to find ways to provide additional training and build their skillset.

Working alongside the staff reaffirmed for me how important this type of work is for our profession. Although I could not verbally communicate with patients because of the language barrier, the patients and their families were similar to those I had seen throughout my career. The anxiety of the unknown and having to hold still for examinations was written on their faces. It reminded me that fear exists everywhere, no matter the language or the culture. After a few examinations, I began sharing different ways to ease this fear for everyone involved. One of the most effective ways I found while I was there was giving patients a Scooby-Doo sticker that said “I had an x-ray!”

Sharing ways to improve the patients’ experience, and showing the effect we have on our patients’ lives meant a lot to me. Now that I have returned home, I plan to continue supporting the education of the staff I met in Laos. I want to help create video lessons they can use now and reference in the future. I also have encouraged them to join a professional society for resources and recommended some free online tools that will aid them.

**Toni Chamberlain, EdD, R.T.(R)(M),** is medical radiography curriculum chair for ECPI University’s Newport News and Northern Virginia campuses. She is in the process of developing an online bachelor of science in radiologic sciences program and becoming a hospice volunteer.

---

**Bringing Magnetic Resonance Imaging to Millions in Ethiopia**

Because it is common to receive magnetic resonance (MR) imaging in the United States, it is easy to forget that this modality is new or nonexistent in other parts of the world. In the spring of 2016, I helped bring this important technology to Black Lion Hospital in Addis Ababa, Ethiopia, as a Siemens ASRT Foundation Community Outreach Fellow in partnership with RAD-AID International.

Black Lion Hospital is an 800-bed teaching hospital that serves 4.5 million people. Until mid-January 2016, the hospital only provided radiography, computed tomography, and ultrasonography imaging. That changed when the hospital installed a Philips Achieva 1.5T MR system. With its installation, it became the second MR system in the capital city, the other located in a privately owned facility.

Installing the equipment was the first step toward improving patient care at the facility. However, the 6 radiologic technologists and 18 residents at the hospital needed to be trained how and when to use the new system.

I had the opportunity to change the lives of the people of Ethiopia. I was selected to provide additional resources and education on basic MR physics, protocol selection, and clinical recognition of pathology. In addition, I provided MR safety education and the policies and procedures that would help ensure the department produced high-quality images consistently.

Before my arrival, the local technologists received 2 weeks of applications training from Philips. This enabled me to provide more in-depth training because I did not have to train them on the basics of operating the system. Working 12-hour days gave me the time I needed to observe and assist them as well as provide the information that would help them in their daily scanning. The sheer number of patients at the hospital made it necessary that I train the technologists as they saw patients. Sick patients lined the halls—in wheelchairs, stretchers, standing, some lying on the floor—many of them waited for hours before they could be seen by a health care professional. On one day, 34 patients were scanned, and in the 3 weeks I was there, approximately 300 patients were scanned.
Bart Pierce, BS, R.T.(R)(MR), FASRT, MRSO, is an MR imaging technologist II working for the Corvallis Clinic in Corvallis, Oregon, and is a member of the adjunct faculty at Portland Community College in Portland, Oregon, teaching MR imaging physics. He also is the RAD-AID program director for Ethiopia, a life member of the Oregon Society of Radiologic Technologists, and a Fellow with the ASRT.

Sharing Skills and Knowledge Is a Professional Responsibility

I have long believed that it is my professional responsibility to use my skills and talents to give back to the community, which is why I have been involved in various volunteer and community service projects for most of my adult life. My selection as the Siemens ASRT Foundation Community Outreach Fellow deepened my commitment to giving back.

I worked in the information technology profession for years and was in my mid-forties before I went back to school to earn my radiography and radiation therapy certifications. Combining my previous experience with my new education, I worked as a PACS manager implementing the system for a large teleradiology practice. While there, I earned my Certified Imaging Informatics Professional certification.

Also during this time, I became aware of the community outreach efforts of RAD-AID International and the ASRT Foundation and wanted to be involved. After discussing these volunteer opportunities with my wife and employer, I completed the application process, but work conflicts kept me from participating for a few years.

In fall 2015, things changed. A week after leaving my position at the teleradiology practice, I was contacted about volunteering in Ghana. After 2 teleconferences to explain more about the project, I eagerly accepted the Fellowship opportunity that Siemens created through the Foundation.

I arrived at Korle Bu Teaching Hospital with a to-do list. However, like most implementations, the priorities changed daily to accommodate the needs of the hospital and the people I was training. By the time I left, the hospital’s new PACS server, with new software installed, was storing images from computed tomography and MR imaging examinations. In addition, the radiologists onsite had been trained to use the system and were excited about how it
would elevate the level of care they could provide their patients. It was a group effort to accomplish the goals of the project in the few weeks the outreach team was in Ghana.

A personal benefit was that I was able to be a part of this important work in an environment that was unlike anything I had ever experienced. Being a part of this community outreach effort was a profound experience for me, and I am very grateful for it. I have told everyone who will listen what a privilege it was for me to be able to be a part of the project.

Dale Gerus, BSBA, R.T.(R)(T), CIIP, is the informatics program manager for RAD-AID International. He lives with his wife, Pam, in Akron, Ohio.

Bridging the Global Gap in Health Care

We sometimes forget how fortunate we are to live where we do. We have clean drinking water, developed roads, personal and public transportation, and housing. For most of us, these basic necessities are just a part of our daily lives. However, people all over the world live without the basics we often take for granted, including access to medical imaging services.

Such is the case of Arusha, a city of approximately 1 million people in northern Tanzania, where I worked as a Siemens ASRT Foundation Community Outreach Fellow with RAD-AID International in spring 2016. The people I encountered were extremely poor and did not have access to many basic services.

A state-of-the-art radiology facility recently was built in Arusha with top-of-the-line equipment for mammography, computed tomography, MR imaging, ultrasonography, dual-energy x-ray absorptiometry, and radiography. With the completion of the facility, the next step was to educate local professionals on how to use this equipment to provide the best patient care and improve the procedures available to individuals.

That is where the RAD-AID team and I came in. We were there to assess and improve the radiology services in the region by providing training and education to radiologists and radiologic technologists. We worked with individuals there to identify what additional training the staff needed and to develop a plan for ongoing training after we left.

I drew on my experience working in all types of hospitals, including private, for-profit, children’s, union, and urban hospitals, to provide the best training assessment I could. Seeing the lack of processes at the facility opened my eyes to the different levels of care being provided in different parts of the world.

I feel fortunate to have been involved in this project. I have worked for more than 40 years as a radiologic technologist, and this opportunity embodies the main reason I love this profession. It brings me joy to help others, and that is exactly what is at the heart of the work being done on these community outreach projects.

Gary Whitlock, R.T.(R), is retired and volunteers as associate program manager Tanzania for RAD-AID International. He resides in Silver Lake, Kansas.
Students learn the as low as reasonably achievable (ALARA) concept during didactic classes before going to a clinical site and arrive there with the understanding that they should wear a lead apron during certain examinations, including while performing portable radiography.

According to the American Society of Radiologic Technologists Practice Standards, the radiographer’s scope of practice includes “applying principles of ALARA to minimize exposure to patient, self and others.” Standard four, objective 4.3, of the Standards for an Accredited Educational Program in Radiography states that programs must assure “students employ proper radiation safety practices.” Therefore, all technologists should wear lead aprons while performing mobile radiography and make sure student radiographers also are shielded.

Some students have indicated that clinical instructors said that they do not have to wear a lead apron while performing a portable examination, and even though this is contrary to what they have been taught in didactic classes, students abide so as to not disobey.

To test whether radiation safety should be a concern during portable radiography, column author Matthew Cardinal stood directly behind the x-ray tube and controls on the portable x-ray machine during an anteroposterior chest examination performed by a student.

His distance was approximately 12 inches from the tube and 72 inches from the image receptor (IR), which was behind the patient’s torso. He placed his own hand on an 8-inch × 10-inch DirectView IR (Kodak), which he positioned against his chest outside the lead apron he was wearing.

The average-sized male patient was seated upright on a stretcher. The technical factors used were 100 kVp at 2.0 mAs. The source-to-image distance was 60 inches. The portable machine was an Optima XR220amx digital radiography system (GE Healthcare). After the exposure was taken, the IR was processed and showed an image of his hand with an exposure index number of 602 (see Figure).

**Conclusion**

Although the exposure index number was low, and the image is faint, there is enough scatter radiation to show the body part exposed to radiation. This experiment demonstrated that enough scatter radiation is produced at 180° from the central ray of the x-ray tube to warrant wearing lead aprons at all times during any type of portable radiograph examination.

Sandi Watts, MSHA, R.T.(R), is program director with the radiography program for Southern Illinois University in Carbondale, Illinois.

Matthew S Cardinal, MEd, R.T.(R), is program director for Richland Community College’s radiography program in Decatur, Illinois.
Figure. Portable radiograph of a hand exposed to scatter radiation during a portable chest radiograph examination. Image courtesy of the authors.

References
The lateral L5-S1 spot projection frequently is performed during a routine lumbar spine examination. This view improves visualization of the lumbosacral joint space, the most common site of spondylolisthesis, or forward slipping of one vertebra over another. A properly positioned image should demonstrate:

- The body of L5 and the upper sacrum.
- An open lumbosacral joint space.
- Minimal rotation.
- Close collimation.

It is sometimes challenging to obtain an optimal lateral L5-S1 image because the appropriate degree of central ray angulation varies with each patient, and adaptive positioning is essential. Several positioning strategies can help improve image quality for this routine projection.

The central ray should be directed approximately 1.5 inches (2-3 fingerbreadths) inferior to the iliac crest and 2 inches posterior to the anterior superior iliac spine (ASIS). For patients with a relatively straight lower back, the central ray can be directed to the midcoronal plane, or it can be directed 1 inch posterior to the midcoronal plane for patients with a more significant lordotic curve. The image should be collimated to about 6 inches × 8 inches with the top of the light field 1 inch above the iliac crest.

To demonstrate an open lumbosacral joint space, the patient’s spine should be horizontal and aligned parallel with the image receptor. However, the lumbar spine often sags or tilts when a patient lies in a lateral recumbent position. Many positioning texts recommend placing a radiolucent sponge under the patient’s side, just above the level of the iliac crest, to support and align the lumbar spine. If a true horizontal position is achieved, the central ray should be directed perpendicular to the image receptor.

If the patient’s spine cannot be aligned, the central ray should be angled—typically caudally—until it is parallel with the patient’s interiliac plane. Alternatively, the appropriate amount of central ray angulation can be determined by palpating the spinous process of L5 with one hand and the tip of the sacrum with the other. The central ray should be angled until it is perpendicular with an imaginary line between these 2 points.

The lateral lumbar spine image also can be used to help confirm the amount of angulation needed for the spot projection. Because of the divergent nature of the x-ray beam, if the lumbosacral joint space is open on a lateral lumbar spine projection centered at the level of L3, the central ray should be angled 5° to 7° caudally for the lateral L5-S1 projection. If the joint space is not well demonstrated on the lateral lumbar spine projection, little or no angle might be needed for the L5-S1 projection.

These adaptive positioning techniques, in concert with astute patient assessment and careful image evaluation, can be used to obtain high-quality spot images.
Susie Moseley, BS, R.T.(R), is education and curriculum coordinator for the American Society of Radiologic Technologists in Albuquerque, New Mexico. She may be reached at smoseley@asrt.org.

References
Identifying Domestic Violence in Patients

Janet P Foushee, R.T.(R)

Domestic violence is a public health concern affecting millions of Americans. According to a 2011 National Data on Intimate Partner Violence and Sexual Violence Survey, 1 in 4 women (24.3%) and 1 in 7 men (13.8%) have experienced severe physical violence by an intimate partner. Abuse is neither unusual nor limited to “certain groups.” Targets of abuse include children; people with physical disabilities or illnesses; the elderly or frail; and people with dementia, a learning disability, or a mental health issue. Domestic violence occurs in all social classes, ethnic groups, cultures, and religions. It also occurs in heterosexual, homosexual, and transgender relationships. Most people are unaware of how common it is because sufferers often do not disclose the abuse (see Box).

Abuse can be deliberate, or it can be the result of a lack of knowledge or understanding. It sometimes is a learned behavior that stems from being brought up in a home in which abuse is the typical way a family interacts. Health care organizations fill an important role in helping to protect and support patients who might be experiencing abuse or neglect.

Health care professionals have a duty to keep patients safe and free from harm while in their care. Medical imaging professionals should be aware of signs of abuse so that they can identify and support these vulnerable patients.

Abuse is the treatment of a person in a cruel or violent manner, especially repeatedly. Abuse can take

Box

Domestic Violence Statistics

- Domestic violence is the single greatest cause of injury to women.
- Of women seeking medical assistance in emergency departments, approximately 37% are there because of injuries inflicted by a current or former spouse or partner.
- Nearly 50% of men who abuse their female partners also abuse their children.
- 72% of all murder-suicides involve an intimate partner; 94% of the victims of these murder-suicides are women.
- 6% of children are exposed to intimate partner violence each year, and 90% of these children are eyewitnesses to the violence.
- 21%-60% of people experiencing intimate partner violence lose their jobs because of reasons stemming from the abuse, such as days away from work, the abuser preventing the person from going to work, or harassing the person while at work.
- Up to 50% of homeless women and children in this country are fleeing domestic violence.
- Women face the greatest risk of assault when they leave or threaten to leave the abuser, or report the abuse to authorities.
- Women are not the only victims of domestic violence. Men also suffer from domestic abuse and might be even more ashamed to seek help.
- 25% of women will experience domestic violence in their lifetime. That is a higher risk factor than many cancers and other diseases.
experience in combination with what he or she has observed or has been told that indicates the possibility that a child is being abused or neglected or is in danger of being abused or neglected. The health care professional does not need to be certain that abuse or maltreatment has taken place. Reasonable suspicion is enough to begin an investigation. If the radiologic technologist suspects that a child is being abused, he or she can and should intervene by sharing concerns with the referring physician or nurse or consulting an on-site social worker. Most states’ child abuse reporting laws employ the reasonable suspicion standard.

**Identifying Abuse**

While obtaining the patient’s medical history, radiologic technologists should pay close attention to what the patient is or is not saying. Technologists should be aware that the patient might be fearful of the abuser and be afraid to share openly with health care workers. They should listen carefully to the patient’s medical history and note whether it is inconsistent with the injury or medical condition. They should look for signs of withdrawal, nervousness, and avoidance of eye contact during interactions with the patient. If the patient describes what happened, the technologist can document the patient’s direct quotes. The imaging professional should display compassion and understanding while interacting with the patient.

Imaging professionals should avoid asking yes or no questions. Open-ended questions usually yield almost 3 times the rate of patient disclosure of abuse. Using follow-up questions can clarify details about pertinent information. In addition, patients should not be interrupted while giving an account of the injuries; they need time to formulate and verbalize memories of what occurred. Patients are more likely to open up to providers who show sympathy and concern and follow up on nonmedical clues raised by patients, such as stress levels. During patient interactions, radiologic technologists should display a caring attitude while maintaining professional boundaries by responding to the patient’s needs and supporting colleagues in providing quality patient care without discrimination or prejudice. It is the radiologic technologist’s responsibility to act in the best interest of the patient. At High

many forms including physical, sexual, emotional, verbal, and economical. Domestic violence does not always present as physical abuse. Emotional and psychological abuse often can be just as extreme as physical violence. Some studies show that the harmed person might heal more easily from the physical violence than from emotional or psychological abuse. Lack of physical violence does not mean the abuser is any less dangerous or that the person feels any less trapped by the abuser. Abuse includes any behaviors that intimidate, manipulate, humiliate, isolate, frighten, coerce, threaten, blame, hurt, injure, or wound someone.

The terms *domestic violence* and *domestic abuse* are synonymous and refer to abuse within families, most commonly to abuse within the context of a couple or family. Children who grow up in homes where domestic violence occurs are at a higher risk of being abused. They also are more likely to become abusers because the behaviors they have witnessed in their home life have become normalized. Many signs indicate that an abusive relationship is present. The most telling sign is fear of one’s partner. If the person feels as though he or she has to walk on eggshells around the partner, or constantly has to watch what he or she says and does to avoid a confrontation, chances are the relationship is unhealthy and abusive.

Recent policy improvements for identifying victims of abuse are in effect under the Affordable Care Act, and screenings for domestic violence are a routine aspect of preventive care. As members of the health care team, medical imaging professionals have a responsibility to help patients who experience abuse by identifying, supporting, and intervening appropriately. Medical imaging professionals must familiarize themselves with their facility’s policies and procedures to know how to proceed in cases of suspected violence. Radiologic technologists should refer to their organization’s policies and procedures or consult with the physician or on-site social worker to learn about their role in identifying and intervening in domestic abuse cases.

Health care professionals are obligated to report reasonable suspicion that child abuse or neglect is occurring or is likely to occur. Reasonable suspicion is based on a health care professional’s training and
Identifying Domestic Violence in Patients

Social Effects

According to the Centers for Disease Control and Prevention, domestic violence is a serious public health problem. Intimate partner violence often is accompanied by emotionally abusive and controlling behavior. Domestic violence affects people in every community, regardless of age, economic status, sexual orientation, gender, race, religion, or nationality. Domestic violence can result in physical injury, psychological trauma, and in severe cases, even death. Besides the immediate injuries to the survivors, abuse can have lifelong consequences. Multiple studies have shown that survivors of abuse are more likely to report a range of acute and chronic negative mental and physical health outcomes. During the past decade, studies have improved our understanding of the biological response to acute and chronic stress that links domestic violence with negative health outcomes. For example, many survivors engage in unhealthy, self-destructive behaviors such as smoking, heavy or binge drinking, and unprotected sex leading to an increased risk of sexually transmitted diseases.

The economic effects of domestic violence are astonishing. In the United States, people who experience abuse lose a total of 8 million days of paid work each year. The repercussions of missing work, lost wages, and unexpected medical bills could have a negative effect on the family, including reduced income, which might affect the family’s ability to buy food or pay bills, putting the family under more stress and increasing the possibility of violence. In 2003, the Centers for Disease Control and Prevention estimated that the cost of intimate partner violence exceeded $8.3 billion per year.

Conclusion

Domestic violence and abuse can happen to anyone, yet the problem often is overlooked, excused, or denied. No one should have to live under stress from an abusive person. Change can occur and life can improve only after the abused person leaves the relationship. Health care providers can play a role in helping identify and support the abused patient and should remember that no one is immune. No one.
Janet P Foushee, R.T.(R), is education specialist for High Point Regional University of North Carolina Health Care in High Point, North Carolina.

References


For more information, visit the National Coalition of Domestic Violence at ncadv.org.
Effective communication skills in the clinical environment are essential when providing quality patient care. First year radiography students are exposed to clinical situations that require them to explain procedures to patients in a clear, concise manner. This can be challenging for new students because they do not have experience communicating with patients. Furthermore, many patients have low levels of health literacy.\(^1\)\(^-\)\(^4\)

Health literacy is the degree to which patients are able to comprehend verbal or written information related to their care so they can make informed decisions about diagnostic tests and treatments.\(^1\)\(^-\)\(^5\) Patients often are provided with information that is too complex or uses unfamiliar terminology and jargon. In the imaging environment, experienced technologists use their clinical skills to assess a patient’s health literacy level and then tailor their explanations accordingly.\(^6\) However, new radiography students have not yet developed this skill. A 2015 study involved medical students who were instructed to create patient education pamphlets that were evaluated using a standardized assessment instrument. The authors concluded that written exercises geared toward communicating medical information to patients is an effective way to improve students’ verbal communication skills.\(^7\) To help students develop their ability to explain procedures at an appropriate level, instructors in the radiologic sciences can assign creation of a patient education brochure as a course project.

The brochure assignment requires students to select an imaging procedure from a prepared list including various contrast and noncontrast studies. Although not distributed in the clinical setting, the intended audience for the brochure is a typical patient. The brochure should include the following information in a 6-panel design:

- A brief explanation of the procedure.
- Preparation for the examination.
- What to expect during the procedure.
- Postprocedural instructions.

Beyond the required information, students have artistic license to create their patient education brochure. Initially, students must submit a proposal to their instructor outlining each panel of the brochure and its content. Students use available literature on the average reading proficiency and health literacy level of patients in the United States to design a brochure that clearly explains a procedure and what the patient should anticipate. Because the proficiency levels of the general population are lower, patient educational materials and instructions should be written at a fifth grade reading level.\(^4\) Additional guidelines include limiting the number of key points and using common language in short, concise sentences with at least a 12-point font. Headings should be used and information given in bullet point format when possible.\(^2\) Finally, the proposal should include a list of resources the student has identified to assist with brochure development. The instructor can then make additional suggestions and help the student identify

**Using Brochures to Teach Clinical Communication Skills**

Thomas G Sandridge, MS, MEd, R.T.(R)
Students often struggle with limiting the amount of text and writing concisely in lay terms, but this is fundamental in helping them formulate appropriate responses to patient questions. For contrast studies, examination information should include additional resources to assist with research and project preparation.

Once the instructor accepts the proposal, the student begins by composing a brief description of the procedure while identifying the anatomy it will demonstrate. Students often struggle with limiting the amount of text and writing concisely in lay terms, but this is fundamental in helping them formulate appropriate responses to patient questions. For contrast studies, examination information should include
a description of necessary patient preparation procedures with an explanation as to why the preparation is necessary. For contrast and noncontrast studies, the brochure should include an explanation of why removal of specific articles of clothing and jewelry is necessary. The brochure should outline the anticipated patient experience during the procedure, including any discomfort the patient might experience. Finally, the brochure should include any postprocedural care instructions for contrast studies and information about how the patient will receive the results once the study is complete (see Figure).

Conclusion

A key part of the assignment is learning why certain things are done as part of an imaging examination, such as contrast preparation or removal of clothing. Understanding these aspects of medical imaging will help students formulate appropriate responses to patient questions. The preparation of patient education brochures early in a radiologic sciences education program is an effective way to stimulate student thinking about clinical communication skills and how to convey information to patients in ways that are effective and easy to understand.

Thomas G Sandridge, MS, MEd, R.T.(R), is director of the Northwestern Memorial Hospital School of Radiography in Chicago, Illinois.

References

What is qualitative research? How does it differ from quantitative research? Under what circumstances is one type of study more appropriate than the other? Are there instances where one might consider a “mixed methods” approach using elements of both? A researcher beginning a project faces a bewildering array of decisions regarding the approach he or she will take to answer the questions associated with the problem being investigated. An analysis of peer-reviewed articles published in Radiologic Technology from September/October 2010 to July/August 2016 yielded 90 total articles. Quantitative survey studies or other quantitative research (eg, correlative studies) represented the largest percentage of articles, 36.6%. Experimental studies represented 24.4% of articles; 20% were literature reviews, and 13.3% were case or technical reports. Mixed-methods studies (using both qualitative and quantitative methods of data collection) represented 3.3%, while purely qualitative studies represented only 2.2% of published articles.

Quantitative vs Qualitative Research

Quantitative studies are appropriate for examining relationships between and among variables, describing trends, attitudes, or opinions of a population, as well as for testing the effects of a treatment or intervention on an outcome.1 Although quantitative analysis allows for a high degree of precision in research, it represents a 2-D view of findings as compared to the rich, deep descriptions offered by qualitative approaches. The role of the researcher in a quantitative study is to remain “distant and independent of what is being researched” (ie, as objective as possible).2

Conversely, in qualitative research, the researcher is aware of the socially constructed nature of reality and is embedded intimately in the context of the study—the research setting, participants, and the data being collected. The qualitative researcher is a reflexive practitioner, aware of his or her own political and cultural perspectives, yet willing to engage in self-questioning and self-understanding.3 Qualitative research gets at the how and why of the story, in ways that quantitative research cannot. The key concept of the study is often referred to as central phenomenon in scholarly writings. Other important differences include sample size, methods of data collection, analysis, and interpretation. Researchers within the radiologic science profession might consider using qualitative approaches alone or in combination with quantitative methods when planning future studies. Many comprehensive resources provide detailed information on designing qualitative research studies, and some are referenced in this column.

Developing the Qualitative Research Question

Developing the research question is the initial step in any research project. This frames the outline

Tricia Leggett, DHEd, R.T.(R)(QM)
and process for the work to follow. Once the area for investigation is determined, the research problem will be posed. The research problem is a topic or issue that specifies the value of the research study. In general, completion of sentences such as, “This study needs to be conducted because...” or “The topic for this research is...,” indicate the beginnings of the qualitative research study. Next, narrowing the broad topic is the basis for the purpose statement (a statement that provides the premise for the research project). The purpose statement typically is a single sentence that describes the specificity of the research study (eg, the central phenomenon, the participants, and where the researchers are located). The framework of the purpose statement might look similar to this example:

The purpose of this qualitative study is to understand the primary motivating factor for graduating radiologic science students in ambulatory care clinical settings.

Once the purpose statement is created, the researcher must develop qualitative research questions. For qualitative research, a central question often is followed by 3 to 5 subquestions to further refine various aspects of the central question. The central question typically is open-ended to avoid being too focused or making assumptions before data collection. The more specific subquestions are categorized as to either issue or procedure and follow the same guidelines as with the central question. Issue subquestions narrow the focus of the central question and typically are placed immediately after the central question; the procedures’ subquestions might evolve after the research has begun because they address the process of the study and data analysis. It is important to note that subquestions assist in the formulation of surveys, structured interviews, or focus groups needed to collect pertinent data. The Box illustrates some common guidelines in developing qualitative research questions.

### Qualitative Data Collection

Qualitative data collection often is open-ended to produce emerging themes during analysis. Common methods include interviews, focus groups, observations, reviewing document studies, key informants, alternative (authentic) assessments, and case studies.

An interview, rather than a paper-and-pencil or electronic survey, is selected when interpersonal contact is important and when opportunities for follow-up of interesting comments are desired. Interview data can be recorded digitally (with participant permission), summarized in notes, or a combination of these methods. Detailed recording is a necessary component of interviews because it forms the basis for analysis.

A focus group can be considered an in-depth group interview. Typically, a group of about 10 participants is invited to a session that lasts approximately 2 hours. The researcher initiates discussion by asking open-ended questions so that the participants are motivated but not guided to discuss the relevant topic. The researcher listens and observes the discussions that follow, intervening as little as possible as long as the discussion remains on the topic. In such discussion, the participants are expected to unfold their knowledge and express their opinions about the subject matter.

Observations are guided by a structured protocol that can take a variety of forms, ranging from the request for a narrative describing events to a checklist or a rating scale of specific behaviors or activities. This level of standardization helps assure consistency with
the data collection. Field notes frequently are used to provide more in-depth background or to help the observer remember events, if a form is not completed at the time of observation. Field notes contain the description of what was observed and must be factual, accurate, and without bias.4

Incorporating social media into qualitative research is emerging as evidenced by the development of an innovative data collection meta-framework by Onwuegbuzie et al.5

**Qualitative Data Analysis and Interpretation**

Qualitative researchers must work directly and intimately with their data. This usually begins with reading interview transcripts or other textual material multiple times to identify emerging themes and categories. Researchers might analyze data inductively or deductively, depending on whether the study is exploratory or confirmatory. Many qualitative studies include elements of both. “Inductive analysis involves discovering patterns, themes, and categories in one’s data.”6 Deductive analysis begins with an existing framework. Often, researchers begin data analysis inductively, as a means for developing the conceptual framework and resulting codebook. The researcher then can move forward in a deductive manner, using the codes to identify and categorize pertinent quotes within the transcripts. Interpretation is the researcher’s process of making meaning of patterns, themes, and categories. In so doing, he or she determines ways in which the results answer the research questions and sometimes the results raise new questions. Some researchers code and extract pertinent passages from the transcript manually, some use the comment feature in Microsoft Word, and some use more sophisticated software programs designed to assist with qualitative analysis, such as Atlas.ti, NVivo, and NUDIST.

**Validity of Qualitative Research**

The validity of qualitative research refers to the extent to which findings accurately depict the phenomenon it is designed to investigate.6 Qualitative research studies can be validated by 1 of 3 generally accepted methods, or ideally by triangulation, which uses at least 2 of the methods. The first method to ensure valid data is the use of contradictory evidence, or deviant cases. This mode investigates any data that could be incorrect or the analysis might be misrepresented because of potential researcher bias. This is especially important because the data collection process needs to be as objective as possible. The next method is respondent validity, which provides the participants the opportunity to review the data and subsequent analysis for accuracy. Any inaccuracies can be corrected before further progress in the research study. Constant comparison is the final method, and it affords the ability to compare individual data sets to a larger set of data for consistency and continuity. This truly promotes a holistic analysis of the data.7

**Designing a Qualitative Research Study**

**Case Study Research**

Case reports appearing in Radiologic Technology often involve the in-depth presentation of a particular imaging challenge or patient pathology. Case study research as a qualitative approach uses a particular design and methods of data collection. Typically, “case studies are the preferred strategy when ‘how’ or ‘why’ questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context.”8 Case study research can be used to explore, describe, or explain.9 The case might involve an individual, multiple individuals, groups, organizations, or a particular event.9 A multiple case study, as the name implies, uses sets of cases. The research setting is essential in providing context for the study. Often, multiple methods of data collection are used to triangulate findings. Sometimes quantitative methods of data collection and analysis are used as well. An example of a multiple case study research published in Radiologic Technology is Mazal and Ludwig’s study, “Using Mobile Electronic Devices to Deliver Educational Resources in Developing Countries.”9

Four users of electronic radiography texts represented the set of cases. Email-based, open-ended dialogue
Writing & Research

Qualitative Research: An Introduction

with each recipient represented the qualitative data collected, analyzed, and interpreted for this study.

**Participatory Action Research**

Qualitative methods, in addition to their use in research studies, can be used for evaluation purposes. Yates used the participatory action research approach as a means of program assessment and policy development. As the name implies, participation by all stakeholders is key to this type of research. Rather than imposing research on “subjects,” people being studied also participate in the research or evaluation to varying degrees. Often a strong social justice focus on the research study or evaluation process exists. Participatory action research:

- Is about the improvement of practice and creation of knowledge in social groups.
- Can start anywhere and proceeds through complete cycles of planning, acting, reflecting, and observing.
- Involves participation in all stages of those affected by changes in social practice and discourse.
- Is participatory, often conducted by an action group with at least one expert.

Action research is based in social inquiry and often is used to solve a pressing problem. Participatory action research involves collaboration and critical reflection of the researcher’s own practices. An important feature of participatory action research is the preservation of the voices and practices of people being studied. Data frequently is collected in the form of interviews, focus groups, and written text (e.g., open-ended survey questions). When used effectively, participatory action research is a continuous cycle of “planning, acting, observing, and reflecting” that results in continuous improvement. The research has the potential to work well in educational settings, particularly in programs accredited by the Joint Review Committee on Education in Radiologic Technology, where the goal is continuous program improvement.

Participatory action research can be effective in solving problems in imaging departments, where patient, staff, and physician input could improve delivery of service for continuous quality improvement. An example of a participatory action research article published in *Radiologic Technology* is the Lopez et al study, “Florida Mammographer Disability Training vs Needs.” That study was designed to address the problem of lack of access to screening mammography for women with disabilities. Demographic and qualitative interview data were collected from 3 participant groups: mammographers, other health care providers (e.g., physicians and nurses), and women with disabilities. The researchers concluded that mammographers were receiving disability training primarily on the job, and that they would benefit from training in “both technical and social aspects of performing mammography on women with disabilities, including positioning, disability etiquette, and disability advocacy.”

**Narrative Research**

Narrative research is best described as the study of lives through storytelling. Narrative research can be a singular approach or a research method of data collection used with other qualitative approaches. It can be biographical or autobiographical and “is best for capturing the detailed stories or life experiences of a single life or the lives of a small number of individuals.” In biographical narrative research, the researcher spends considerable time with the participant, often meeting on multiple occasions to gain an in-depth understanding of the person’s stories. In so doing, the researcher and participant develop a collaborative relationship. In general, most participants do not tell their stories in a strictly chronological order and it is the researcher’s task to order the stories and other data into a coherent whole. Aside from oral narratives, materials such as other people’s stories about the person being studied, letters, emails, diaries, and school records can be collected, analyzed, and interpreted. Narrative research is based on the premise that knowledge is socially constructed and situated within the context of the participants’ “personal experiences (their jobs, their home), their culture (racial or ethnic) and their historical contexts (time and place).” The researcher studies himself or herself in autobiography, and life history is the study of a person’s entire life. Narrative research can be focused upon individuals
who have shared similar experiences or centered on a particular research context, such as a hospital or school.\textsuperscript{16} Charmaz’s “Narrative Medicine: A Model for Empathy, Reflection, Profession, and Trust” is an example of the narrative method used in the context of medicine published in the \textit{Journal of the American Medical Association}.\textsuperscript{17} In the article, she stated, “The effective practice of medicine requires narrative competence, that is, the ability to acknowledge, absorb, interpret, and act on the stories and plights of others.” She described narrative knowledge as a process by which physicians can share in a discourse with patients to understand their stories and suffering: “Along with scientific ability, physicians need the ability to listen to the narratives of the patient, grasp and honor their meanings, and be moved to act on the patient’s behalf.” Through this physician–patient discourse and through the physician’s engagement in self-reflection, care for sick patients can be delivered in a more sympathetic and humane manner.

\textbf{Grounded Theory Research}

The purpose of grounded theory research is to generate, rather than test, a theory.\textsuperscript{3} Grounded theory research is characterized by an iterative process used by the researcher. The researcher goes out to the field (i.e., the natural setting in which the participants live and work) to collect data from individuals who share some common experience, or phenomenon. Data collection methods can include quantitative and qualitative data; but qualitative methods are used more commonly.\textsuperscript{16} The researcher goes back and forth from interviews to analysis, returning to the field to collect more data, until the themes and categories generated are saturated and no new information can be added. According to Creswell, “This process of taking information from data collection and comparing it to emerging categories is called the constant comparative method of data analysis.”\textsuperscript{14} The themes and categories centered on the shared experience of the participants (the phenomenon) are then used to identify causal conditions, strategies, intervening conditions, and consequences. In this manner, a hypothesis or theory emerges. Therefore, the theory is “grounded” in data from the field.”\textsuperscript{16} An example of grounded theory research in medicine appeared in \textit{Social Science and Medicine}. In it, Charmaz provides a step-by-step guide to conducting grounded theory research by applying it to a discovery of a theory of chronic illness.\textsuperscript{16}

\textbf{Phenomenological Research}

Phenomenological research is “the study of the lived experiences of persons.”\textsuperscript{16} Phenomenological studies focus on a shared human experience, such as surviving breast cancer, experiencing the death of a child, or winning the lottery. The researcher collects data from participants (usually a small number) who have experienced the phenomenon, and through the process of analysis and interpretation, generates a description of the participants’ “meaning, structure, and essence of the lived experience.” Qualitative data can be collected in the form of in-depth interviews (often multiple interviews with each participant), open-ended survey questions, diaries, journals, art forms, and other media in which the participant describes or depicts his or her experience. Phenomenological studies frequently are used in the context of medicine and the descriptions they provide might inform the development of policies and practices. An example of a phenomenological research study performed in the context of emergency medicine was published in the \textit{Journal of Emergency Nursing}. Granero-Molina et al focused on the lived experience of medical professionals providing end-of-life care to patients in the emergency department.\textsuperscript{19} The authors examined factors that undermined the dignity of these patients including “architectural and organizational characteristics, professional’s attitudes, and decisions made by family members.”

\textbf{Ethnographic Research}

Ethnographic research is the study of an entire cultural group. An ethnographer “describes and interprets the shared and learned patterns of values, behaviors, beliefs, and language of a culture sharing group.”\textsuperscript{16} The researcher gathers information in the field. Qualitative data frequently consists of direct observation and in-depth interviews, although materials such as art
forms and cultural artifacts might be useful as well. A fascinating and heartbreaking example of an ethnographic study relating to medicine is captured in Anne Fadiman’s book, *The Spirit Catches You and You Fall Down: A Hmong Child, Her American Doctors, and the Collision of Two Cultures*. The book describes a Laotian refugee family’s experiences in the American medical system through the course of long-term treatment of a child with severe epilepsy. The clash of cultures creates profound challenges in caring for the child, with devastating consequences.

**Conclusion**

The intent of this column is to provide an introduction to qualitative research and to present an overview of a limited number of possible approaches. Increasing the number of qualitative and mixed-methods studies published in *Radiologic Technology* will enrich the body of knowledge within the radiologic science profession.

Jennifer Yates, EdD, R.T.(R)(M)(BD), is program director for Merritt College in Oakland, California. She is a member of the Radiologic Technology Editorial Review Board and can be reached at jyates@peralta.edu.

Tricia Leggett, DHEd, R.T.(R)(QM), is vice president for student success for Zane State College in Zanesville, Ohio. She is vice chairman of the Radiologic Technology Editorial Review Board and can be reached at tleggett@zanestate.edu.

**References**


Have you considered writing for Radiologic Technology or Radiation Therapist? The ASRT Author Guide is an interactive and user-friendly guide that provides information about writing, formatting, and submitting various types of manuscripts to the journals. It also includes resources such as templates, checklists, and American Medical Association style reference help.

Columns
All our members have experiences to share, and writing a column to communicate insights and problem-solving strategies is a good way to get started publishing in an academic journal. The journals' various column types offer a fit for nearly every type of information a radiologic technologist might want to share about working in the radiologic sciences. The Case Summary column, for example, presents an unusual or challenging patient case or assignment, and Patient Care, In the Clinic, and Setup Solutions columns offer tips for creating a good patient experience and practical technical advice others can use on the job. Managers and educators can describe unique approaches to professional growth and teaching strategies in the Management Toolbox or Teaching Techniques columns.

Peer-reviewed Articles
Having a peer-reviewed article published can be an important step in a radiologic technologist’s career. Publishing research demonstrates professional growth and might give authors an edge over other job candidates. In addition, published peer-reviewed article authors can receive continuing education credit for their research. If the idea of research seems daunting, keep in mind that the ASRT Editorial Review Board members are available to mentor new writers and answer questions about the peer-review process. The ASRT editors also can answer questions, but the Author Guide should be a potential author’s first stop. The Guide lists reviewers’ specialties and contact information, provides checklists they use to review research articles, and explains how to submit a manuscript.
Directed Reading Articles

Writing a Directed Reading article might be a good choice for authors who are curious about a disease process or how imaging is used to aid diagnosis, treatment, and follow-up of a particular condition. Directed Reading articles are longer review articles that pull together information from various sources to provide continuing education credit for our members. Authors of Directed Reading articles receive monetary compensation and continuing education credit after their article is published.

Author Guide Resources

The guidelines contain important elements of publishing, such as ethical considerations, HIPAA regulations, and plagiarism concerns. Author checklists also are available to keep writers on track during the process. The checklists and citation style models are available in a printable format for easy reference. Another feature visitors to the site might find helpful is Writing Tips: brief lessons on common grammar and style issues. Visit the Author Guide often to see new tips.

ASRT journal columns contribute to the body of knowledge in the medical imaging profession. Publishing a column is a great way to grow professionally and build your résumé—and it is easier than most might think! We encourage all our readers to write for the ASRT journals to share their unique expertise and wisdom gained while providing quality, safe patient care in the medical imaging profession.

To view the Author Guide, visit asrt.org/authorguide.

Lisa Ragsdale, MA, ELS, is a former scientific journal editor for the American Society of Radiologic Technologists, who managed Radiologic Technology.
Radiologic science educators in bachelor’s degree programs are grappling with whether to continue teaching film-screen radiography. The American Registry of Radiologic Technologists plans to remove film-screen imaging topics from certification exams in January 2017.¹ This is reason enough for some programs to remove it from their curriculum. Others are trying to balance the value of film-screen radiography curriculum to future radiologic technologists with its exclusion from the Registry exam. Although the Registry determines what concepts are included on the certification exam, it does not determine what helps educators teach those concepts effectively.

According to the most recent practice analysis report conducted by the Registry in 2012, 39% of radiographers used film-screen technology daily.² It is difficult to determine whether that percentage has declined since then, but if only one-third of radiographers used film-screen systems daily in 2012, future radiographers will be seeing it less. Because of this decline, many wonder whether film-screen radiography principles are needed to teach medical imaging concepts, or if the principles can be taught effectively with digital radiography technology.

Educators have 2 choices in this matter: continue to teach film-screen radiography alongside digital radiography or teach digital radiography exclusively. Over 200 targeted surveys were emailed by the author to students and educators in radiologic science programs in the United States. The surveys explored whether bachelor’s degree programs should continue to include film-screen radiography as part of the curriculum. Twenty-seven surveys were returned.

The majority (78.3%) of survey responders did not place a high priority on knowledge of film-screen radiography. However, they were split fairly evenly on whether an education devoid of film-screen concepts hinders technologists. Therefore, leaving film-screen radiography behind might not mean lowering the quality of future radiologic technologists, but keeping it could mean graduating technologists who are better prepared.

Another compelling reason it should remain in the curriculum is that technologists might work at a site that uses film-screen radiography. For example, some orthopedic clinics still use film-screen radiography because of its superior spatial resolution. “Radiographic film usually has resolving capabilities in the range of 100 lp/mm, far beyond the ability of any screen or human eye.” Film is limited by the screen, which can resolve 7 lp/mm to 15 lp/mm, depending on the speed. Conversely, digital radiography is dependent on matrix size, storage space, and other factors.³ Typically, digital image receptor’s spatial resolution is equivalent to about 2 lp/mm to 4 lp/mm.⁴

In addition to the resolution difference, digital radiography is not as accurate as film-screen radiography.

Joshua Ricketts

Film-Screen Radiography in Bachelor’s Degree Program Curriculum

Digital radiography can be off 0.1 mm to 2.6 mm depending on the distance being measured. This might not seem like much, but it could make a difference in fracture reduction and fixation. If orthopedic offices continue to use film-screen radiography because of the accuracy and superior spatial resolution, that is reason enough to continue to teach film-screen radiography, at least in bachelor’s degree programs.

Film-screen radiography also is much more sensitive to changes in the prime factors and collimation. Using film-screen radiography hones a radiographer’s skills in adjusting these factors. Digital radiography does not eliminate the artistry of medical imaging, but film-screen radiography requires more finesse.

Educators who responded to the survey were united in the idea that film-screen radiography is better at showing the effects of technique changes, with 100% of them selecting excellent to describe this ability. Combined, educators and students gave digital radiography an overall good rating (43.5%) for its ability to show the effects of technique changes. However, 50% of educators gave it a poor rating for this ability.

In addition, the way students learn plays a large part in determining how to teach them efficiently and effectively. According to the survey, a majority of students who responded agree that having something in front of them that they physically can touch and manipulate makes concepts easier to learn, comprehend, and remember than seeing this information on a screen. When asked whether a tangible or digital medium is more effective for learning, the majority (95.5%) of students said that a tangible medium is more effective. This is purely subjective, but it is the preference of those learning while using 2 very different media. It is one more factor for educators to consider when planning curriculum.

Another factor that might help educators determine the place of film-screen radiography in their programs is radiation dose. Patient dose has been a primary concern in radiography since shortly after the discovery of x-rays. The as low as reasonably achievable (ALARA) concept guides all radiologic technologists in protecting their patients against unnecessary radiation exposure. Students and educators mostly agree that technologists who learned on film-screen radiography are more careful when adjusting factors than those who learned on digital systems only. They also agree that technologists who learned on film-screen radiography better understand the effects of technical factors. An understanding of technical factors is foundational to reducing patient dose, and technologists who have this understanding tend to be more precise when setting their technical factors. Therefore, film-screen radiography is a valuable part of radiologic science education.

The costs of keeping film-screen radiography in the curriculum might be high, but the benefits might outweigh them. Not only will these programs be graduating students who understand technical factors and can use them to minimize patient dose, they will be creating technologists who can work anywhere, are valuable to the profession, and who raise the standard of the profession. It might not be feasible for all radiologic science programs, but programs that want to turn out top radiographers would do well to use film-screen radiography in their curriculum.

The radiologic science community has a clear opinion concerning the visualization of technique changes and which technology shows them most effectively. This, as well as the superior spatial resolution and accuracy that causes orthopedic clinics to continue to use film-screen radiography, is the reason educators should continue to teach film-screen radiography. Until digital radiography can match the spatial resolution and accuracy of film-screen radiography, we will see it used, even on a limited basis. However, digital radiography will never match film-screen technology’s ability to show the effects of technique changes. That alone should be reason to keep it in the radiologic science bachelor’s degree program curriculum.

Conclusion

Film-screen radiography’s place in the imaging world is evident. Teaching the process helps create more conscientious radiographers with regard to technical factors and patient dose. Continuing to teach film-screen radiography will maintain a culture of care in these areas. In the end, educators must decide what is best for their institutions. This should mean choosing what is best for their students. Keeping film-screen radiography as a teaching tool in the curriculum might be best for students and the radiologic science profession.
Joshua Ricketts is a student of medical imaging technology at the Oregon Institute of Technology in Klamath Falls, Oregon.

References
We are writing in reference to the peer-reviewed manuscript titled “Relationship Between the Number of Clinical Sites in Radiography Programs and Job Placement Rates of Graduates” in the July/August 2016 Issue of Radiologic Technology (Vol. 87, No. 6). As faculty members in medical imaging education programs, we found the authors’ investigation to be timely and relevant. We do, however, have a question regarding the statistical analysis and results described in the article, and we were hoping the authors could share some insight.

Throughout the article, the significance of the reported Spearman’s rho statistic is described as nonsignificant; however, the reported P value is 0.018, which would be statistically significant using the common significance level (α) of 0.05. We recognize that the correlation is weakly negative and the coefficient of determination is small, but this should not affect the interpretation of the test’s statistical significance. If the authors chose to set α = 0.01, this should have been stated with corresponding justification.

Thank you very much for your assistance; we look forward to the authors’ response.

Austin Turner, MS, R.T.(MR), CNMT, PET
Crystal Botkin, MPH, CNMT, PET
St Louis, Missouri

The Author Responds
Thank you to the readers for their words of encouragement relative to our recent publication. We also appreciate their bringing to our attention the oversight of identifying a lower than typical alpha (α) level. In fact, we used α = 0.01 in evaluating the statistical significance of the study. As the readers noted in their question, lower alpha levels are not common; however, they may be used by authors who wish to decrease the probability of committing a type I error. Given the possible effect of falsely identifying an association between the number of clinical sites and graduate employment rates, we wanted to be certain in identifying any relationship that may have existed.

Angela Harrell, MHA, R.T.(R)
Fort Wayne, Indiana

Eric Matthews, PhD, R.T.(R)(CV)(MR), EMT
Kirksville, Missouri
Stand Out to Future Employers

Earn a spot in the 2017 ASRT Student Leadership Development Program.
Selected students will get to attend the 2017 ASRT Educational Symposium and Annual Governance and House of Delegates Meeting, June 22-25, in Orlando, Florida.

Apply by Dec. 19.
www.asrt.org/studentleadership
Funding provided by the ASRT Board of Directors.
©2013 ASRT. All rights reserved.

BE A SPEAKER
AT THE 2017 Radiation Therapy Conference

Submit your abstract by Feb. 15, 2017.
www.asrt.org/radiationtherapyabstracts

SEPT. 24-26, 2017 • SAN DIEGO
CONTINUING EDUCATION is Easy & Affordable

Radiography - PREP $159 (20 CEUs) New!
Ultrasound Secrets $159 (20 CEUs) New!
Anatomy & Physiology $129 (20 CEUs) New!
Breast Imaging Case Reviews $99 (11.5 CEUs) New!
Mammo & Breast - PREP $159 (27 CEUs)
Essentials of Radiography $129 (24 CEUs)
Intro to Digital Radiography $89 (14 CEUs)
Radiographic Pathology $79 (13 CEUs)

FREE Shipping! More programs available!

www.REShomestudy.com 1-800-966-0452

Courses approved by ASRT

Radiologic Educational Services
PO Box 11820, Olympia, WA 98508

RADIologic SCIENCES
BACHELOR OF SCIENCE • MASTER OF SCIENCE

Enroll Now!

• 100% online
• In-state tuition for all online students, regardless where one lives
• Emphasis on management/education
• Designed for the working professional
• Students can start the program any semester

B.S. degree: sah.siu.edu/radsonline
M.S. degree: sah.siu.edu/graduate/msrs

allied.health@siu.edu • 618/453-7211
rmck@siu.edu • 618/453-7260

SIU Southern Illinois University

An R.T.’s Best Friend!
ASRT’s JobBank® is the source for job seekers in the radiologic sciences.

www.asrt.org/jobs

©2013 ASRT. All rights reserved.

Learn CT at Home!
Realistic Simulated Scanning

• Quickly learn to scan common CT Exams
• Learn all of the CT basics needed
• Learn Cross Sectional Anatomy
• Identify Common Pathology
• And so much more

Get a copy of the software today!
www.radtechedu.com 1.877.437.2799

Rad Tech Education LLC

EDUCATING SONOGRAPHERS SINCE 1985

ULTRASOUND CROSS TRAINING WITH BURWIN

www.burwin.com
1-877-625-6297 (Central Time)
1-800-322-0737 (Atlantic Time)

Radiologic Educational Services
PO Box 11820, Olympia, WA 98508

CONTINUING EDUCATION is Easy & Affordable

Radiography - PREP $159 (20 CEUs) New!
Ultrasound Secrets $159 (20 CEUs) New!
Anatomy & Physiology $129 (20 CEUs) New!
Breast Imaging Case Reviews $99 (11.5 CEUs) New!
Mammo & Breast - PREP $159 (27 CEUs)
Essentials of Radiography $129 (24 CEUs)
Intro to Digital Radiography $89 (14 CEUs)
Radiographic Pathology $79 (13 CEUs)

FREE Shipping! More programs available!

www.REShomestudy.com 1-800-966-0452

Courses approved by ASRT

Radiologic Educational Services
PO Box 11820, Olympia, WA 98508

RADIologic SCIENCES
BACHELOR OF SCIENCE • MASTER OF SCIENCE

Enroll Now!

• 100% online
• In-state tuition for all online students, regardless where one lives
• Emphasis on management/education
• Designed for the working professional
• Students can start the program any semester

B.S. degree: sah.siu.edu/radsonline
M.S. degree: sah.siu.edu/graduate/msrs

allied.health@siu.edu • 618/453-7211
rmck@siu.edu • 618/453-7260

SIU Southern Illinois University

An R.T.’s Best Friend!
ASRT’s JobBank® is the source for job seekers in the radiologic sciences.

www.asrt.org/jobs

©2013 ASRT. All rights reserved.
What’s Inside?

**30%** of imaging examinations are ordered incorrectly. 
Read more on Page 193.

Enough scatter radiation is produced to warrant wearing lead aprons at all times during any type of portable radiograph examination. 
Read more on Page 214.

**39%** of radiographers used film-screen technology daily in 2012. 
Read more on Page 234.

In Ethiopia, there is 1 ‘normal’ case in every 50 MR scans. 
Read more on Page 210.

---

**Fusion Anomaly**

A pediatric patient arrived at a hospital in Lilongwe, Malawi, Africa, for a presurgical head computed tomography evaluation of an apparent fusion anomaly. Although the patient had normal appearing hands bilaterally, these axial 2-D (A) and lateral 3-D (B) images show an obvious deformity of what appeared as multiple phalanges fused to the posterior aspect of the head. Images courtesy of Jason K Lee, BS, R.T.(R)(CT), R.R.A., RPA; Miriam Nybo, R.T.(R); and Suzgo Sam Mzumara, MD, MMEd Radiology(Nrb), MBBS(Mw), Clin. Fellowship MRI(USA).

Do you think film-screen radiography should remain in the radiography curriculum? 
Share with your Community at [asrt.org/myasrt](http://asrt.org/myasrt).
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).
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.

<table>
<thead>
<tr>
<th>COURSE NAME</th>
<th>CREDITS</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Radiography</td>
<td>14 Category A Credits</td>
<td>$95.00</td>
</tr>
<tr>
<td>Cardiology Diagnosis and Treatment</td>
<td>38.75 Category A Credits</td>
<td>$129.50</td>
</tr>
<tr>
<td>The Respiratory System</td>
<td>47.50 Category A+ Credits</td>
<td>$119.50</td>
</tr>
<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>Parkinson’s Disease</td>
<td>7.5 Category A Credits</td>
<td>$59.50</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>24.75 Category A Credits</td>
<td>$109.00</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>
<tr>
<td>Introduction to Radiation Protection</td>
<td>14.5 Category A Credits</td>
<td>$95.00</td>
</tr>
<tr>
<td>The Trauma Manual</td>
<td>42.5 Category A Credits</td>
<td>$134.50</td>
</tr>
</tbody>
</table>

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

...Another excellent course! I learned things I never learned in school ...
— L.S., Lexington, NC

Join our email list at [www.GageCE.com](http://www.GageCE.com) and like us on Facebook to receive special offers and product discounts.

Thank you! We appreciate your business!