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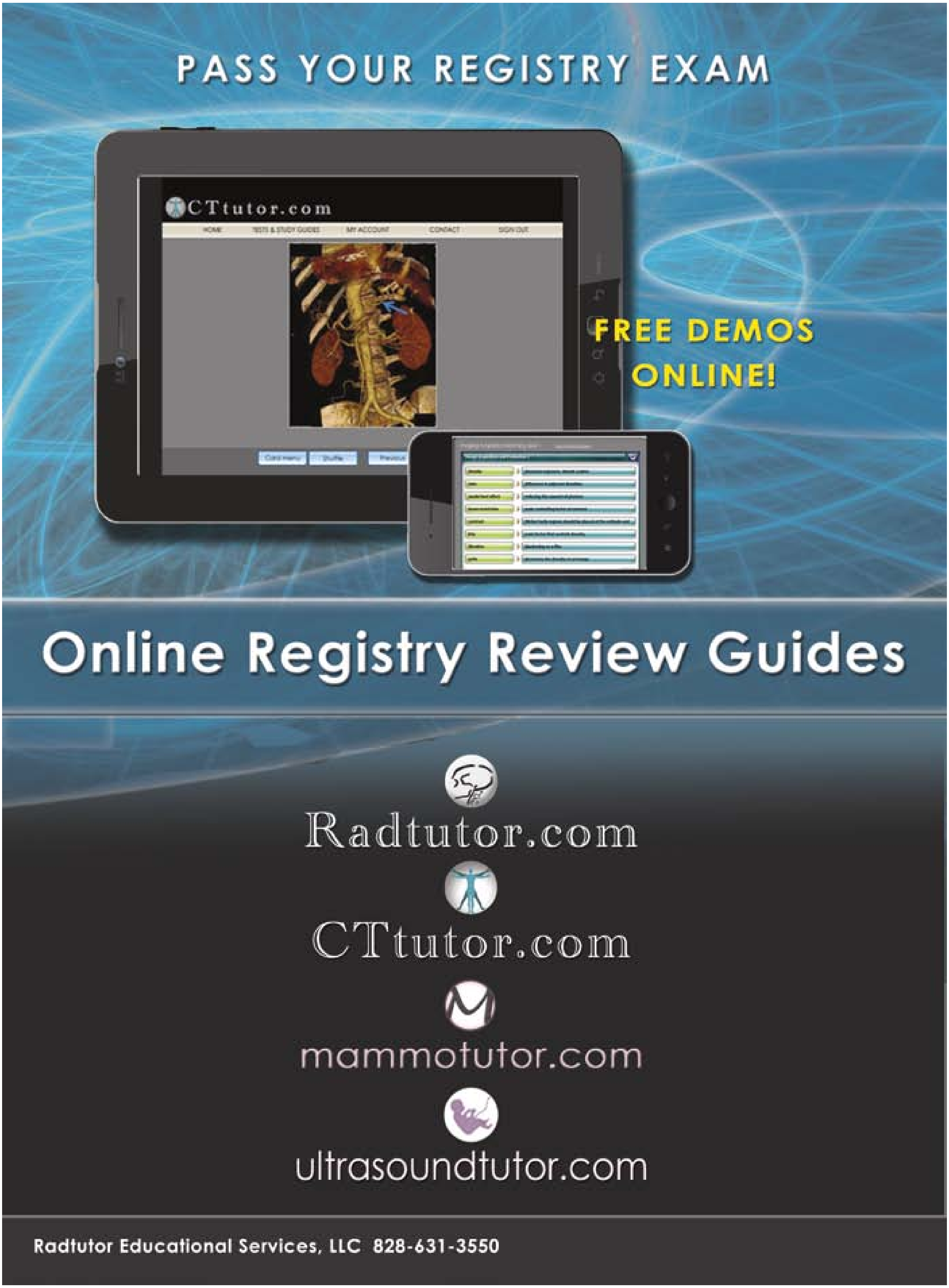
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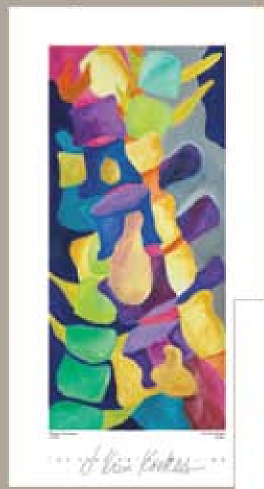

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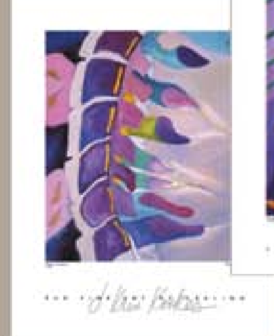

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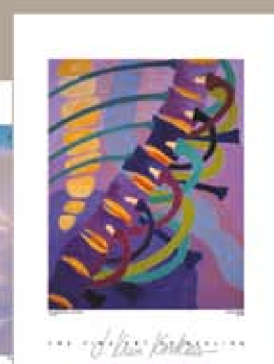

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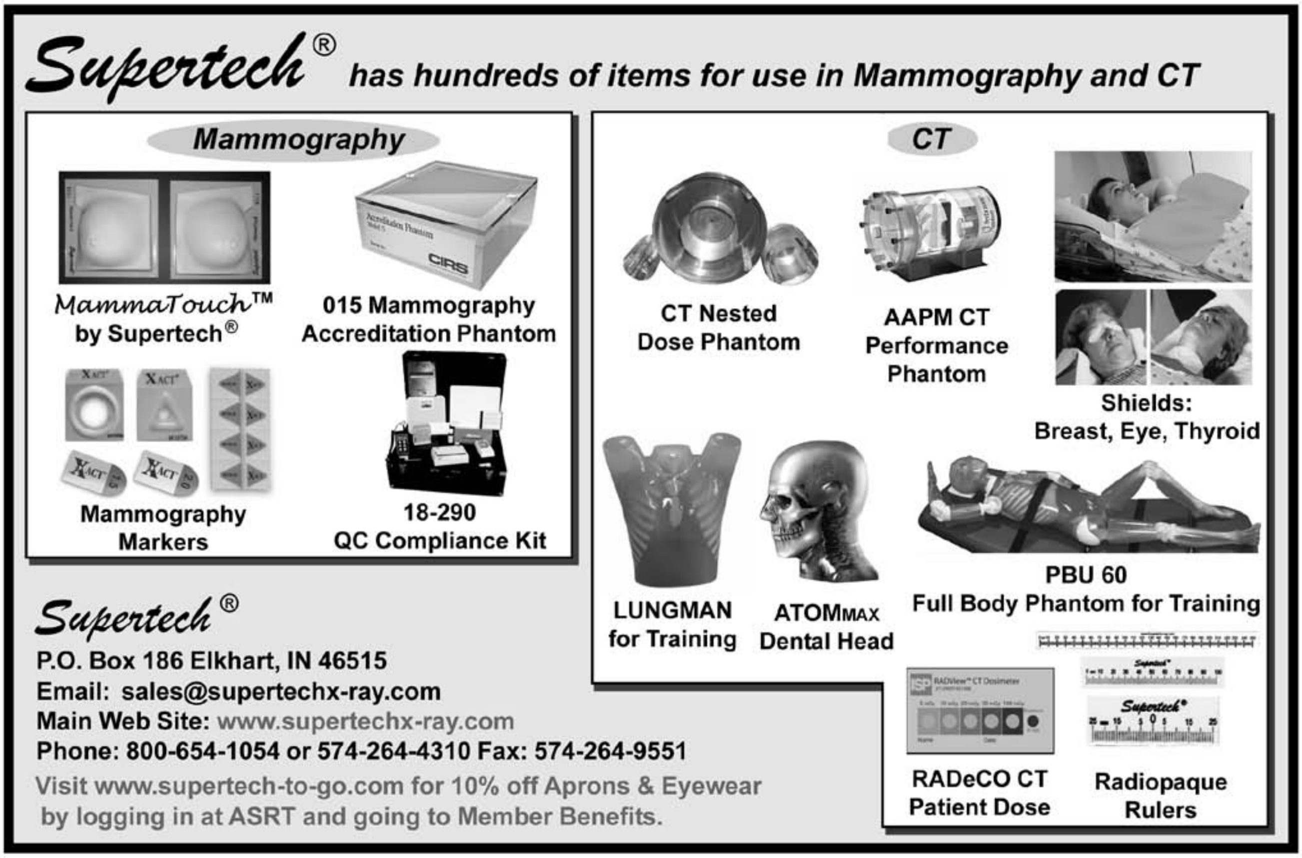
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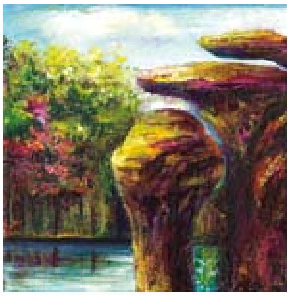

On the Cover: *"Shoulder Boulder" demonstrates the cliff-like drop off of the acromioclavicular region of the shoulder. In the fifth painting in a radiograph landscape series, Lizzy Rainey, R.T.(R), of Lafayette, Indiana, created this shoulder view that sits boldly in a serene lake surrounded by vibrant woods.*

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Lisa M Kisner

"Editor's Note" offers Radiologic Technology *readers insight into the Journal.*

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Lisa M Kisner, BA, CQIA, is an ASRT scientific journal editor. She has worked for ASRT for 10 years in a variety of capacities and now enjoys managing Radiologic Technology.

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Persistent Pain Following Lumbar Disc Replacement

KEVIN L WININGER, BS, R.T.(R), RKT
KEDAR K DESHPANDE, MD
MICHELLE L BESTER, MSN, CNP

Background *Pain patterns associated with the facet and sacroiliac joints following lumbar total disc replacement correlate with biomechanical modeling observations, such as load transfer to the posterior spinal elements in total disc replacement with an artificial disc. When conventional treatment options are exhausted, spinal cord stimulation (SCS) offers clinically favorable outcomes to treat intractable pain.*

Objectives *To contribute to the literature on neuroaugmentive techniques and on pain following disc replacement, and to highlight recent advances and forward-thinking concepts for nonsurgical intradiscal therapies.*

Results *Three years of injection therapies and physical therapy did not significantly alleviate the patient's pain. A trial period of SCS rather than reoperation (fusion surgery) was elected. A constant-current multiple source SCS system was implanted. At 12-month follow-up for this system, the patient's pain had been reduced by more than 75%, and the patient reported improved quality of life, including a return of restful sleep.*

Conclusions *SCS is a viable technique to control pain associated with artificial disc implant.*

Current anterior abdominal, transperitoneal techniques for lumbar total disc replacement disrupt stabilizing ligaments and the annulus fibrosus of the spinal motion segment (the adjacent vertebrae along with interconnecting soft tissues).[1,2] Moreover, postoperative scarring compromises the restoration of normal kinetics and biomechanics of the spine, and excessive scarring can compromise a surgeon's ability to safely approach the spine during revision surgery.[1]

Biomechanical models examining the Charité artificial disc (DePuy Spine Inc, Raynham, Massachusetts) populate the literature.[3-5] One early study with a high degree of clinical relevance for the L5-S1 disc implant came from Goel et al,[3] in which classical testing of the intact spine (the load-control only model) was integrated with the mechanical construct (a Charité implant). Test results showed slight increases in motion at the inferior endplate of the L5 vertebral body relative to the osseous-device interface — accompanied by an increase in facet loading when compared with the adjacent segments and decreases in motion and loads at adjacent levels.[3] In comparison, large increases in motion with a corresponding increase in facet loads were noted in classical testing alone (excluding the implant), though they were clinically insignificant.[3]

Siepe et al offered general remarks on pain patterns following total disc replacement.[6] First, lumbar facet/sacroiliac joint pain is a frequent and underestimated source of postoperative pain and the most common reason for unsatisfactory results following disc replacement. Next, patients who reported an early onset of pain (6 months or sooner after surgery) had 2 to 59 times higher risk of developing persisting problems and unsatisfactory outcomes. Finally, an inferior outcome and a significantly higher incidence of posterior joint pain were observed for disc replacement at the L5-S1 level and disc replacements at the combined L4-L5/L5-S1 levels, 21.6% and 33.3%, respectively. See Figure 1 for postoperative lumbar facet joint subluxation.

When pain becomes intractable to conventional treatment methods, pain management through spinal cord stimulation (SCS) can offer clinically favorable outcomes.[7] SCS systems are implantable devices that

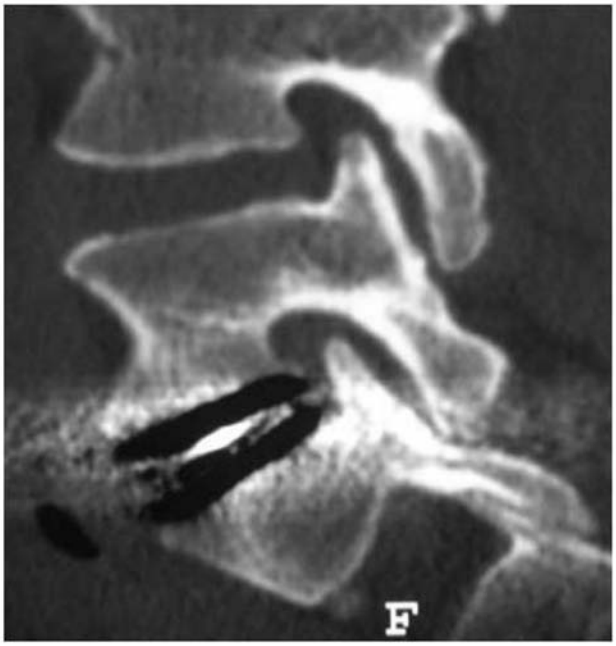

Figure 1. *Postoperative subluxation of the lumbar facet joints.*

electrically stimulate the spinal cord's dorsal structures to influence the afferent pain pathways. Influencing afferent pathways mediates the pain response. The patient often experiences a paresthesia (which serves as an analgesic) in place of the pain.[8,9] We report on the management of persistent pain following a total disc replacement at the L5-S1 level with a Charité artificial disc over a patient's 4-year history under our care, with pain control ultimately achieved by means of SCS. In addition, we outline bioengineering concepts (as well as a prospective neuromodulation technique) concerning disc regenerative medicine and intradiscal and alternative therapies, such as intradiscal electrothermal therapy (IDET).

Case Report

A 32-year-old woman was referred to our center and evaluated in May 2007 to determine appropriateness of IDET for persistent low back pain and lower limb radiculopathy following an L5-S1 total disc replacement with a Charité disc implant performed 3 months earlier. Although the surgeon intended to replace the L4-L5 disc at the same time, anatomic restraints caused by vascular problems prevented replacement at that level.

During initial consultation, the patient stated her pain had begun insidiously 13 months ago and progressively worsened. Lumbar hyperextension aggravated her pain more than lumbar flexion, although both motions negatively affected her mobility. The patient complained of sharp jabbing with positional changes, along with local pain in the lumbar spine that included radiating pain in both legs. She further emphasized that the pain was more intense on her right side. Overall, the patient reported a pain score of 6 out of 10 on the visual analog scale. The patient's medication regimen consisted of oral morphine, oxycodone (for break-through pain control), gabapentin, bupropion, and zolpidem.

A postdiscography computed tomography (CT) scan performed in November 2006 was available for our review. Findings included normal L3-L4 disc morphology; a small central disc bulge or protrusion at L4-L5 with no annular tear (but clear evidence of loss of disc height when compared with the L3-L4 disc); and diffuse mild disc bulging at L5-S1 with no annular tear. We did not consider the patient to be a candidate for IDET based mostly on these imaging findings.[10] We recommended a treatment plan that included injection therapy (eg, medial branch blocks) and physical therapy. The patient consented, and listed her goals as follows:

- Pain reduction.
- Pain medication reduction.
- Improved physical activity.
- Improved sleep patterns.

Despite compliance with her plan of care, the frequency and intensity of the patient's low back and radiculopathy pain gradually became worse (visual analog scale 9 out of 10). This included signs and symptoms of reflex sympathetic dystrophy in her right lower extremity, such as discoloration and temperature changes. We modified the patient's treatment plan to attempt to isolate the pain generators (see Figure 2). Pain relief from injections was lasting only a few weeks at best, and the patient was unable to continue physical therapy because of her pain. For these reasons, a magnetic resonance (MR) imaging examination was ordered in October 2008 to evaluate her lumbar spine. A broad-based disc bulge was identified on the MR images at the L4-L5 level, which superimposed the previously identified central disc protrusion. Indentation of the ventral thecal sac, which resulted in mild spinal stenosis and foraminal narrowing, also was noted at this level. Electrodiagnostic evidence of the patient's

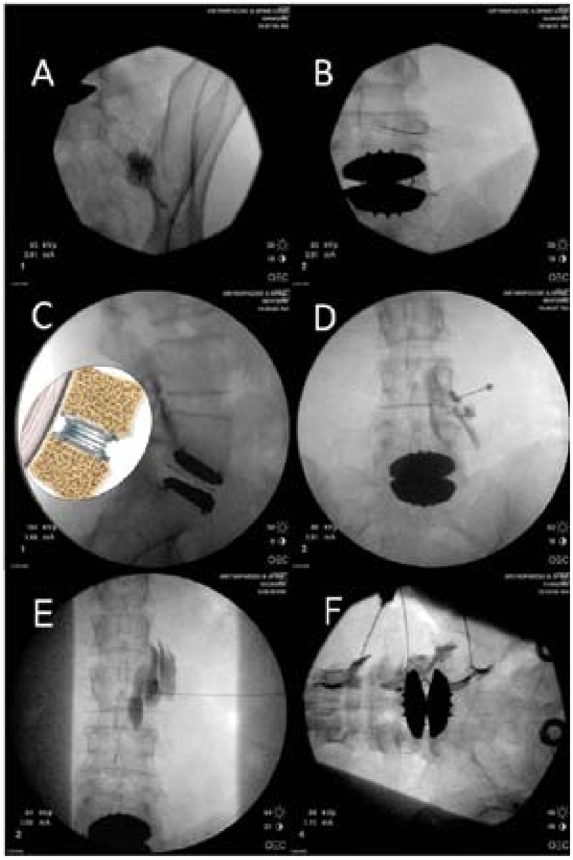

Figure 2. *Interventional pain medicine plan of care. A. Sacroiliac joint injection. B. Medial branch block. C-D. Transforaminal epidural injection, lateral view, and anteroposterior view. E. Sympathetic nerve block. F. Repeat transforaminal epidural injection. Images acquired from March 2008 to November 2009.*

radiculopathy was obtained in March 2009; a radicular L4 component was traced in her right leg and a radicular L5 component was traced in her left leg.

In addition, the patient underwent a CT myelogram in July 2009, which showed postoperative changes with scar formation at the L5-S1 segment with no observed osteolytic or osteoblastic lesions. We suggested intervening with a trial period of SCS; however, we sought a surgical opinion first. The consulting surgeon explained that the artificial disc had undergone subsidence (downward surface motion-slippage) relative to the inferior endplate of L5, and that this rendered the disc nonfunctional because it was bound in a flexed position because of this slippage. The surgeon recommended posterior salvage rather than anterior revision. As a result, fixation from L4 to the sacrum, interbody arthrodesis at L4-L5, and posterolateral fusion at L4-L5 and L5-S1 was offered. The surgeon also noted that SCS would be a viable treatment option because any decompression fusion with fixation would not address the reflex sympathetic dystrophy-type symptoms. Ultimately, the patient decided against undergoing a surgical correction, opting instead for an SCS trial.

Neuromodulation

In May 2010, we implemented a 7-day SCS trial period using dual parallel percutaneous leads (Linear Lead, Boston Scientific Neuromodulation, Valencia, California) (see Figure 3). At follow-up, the patient reported she had been pain-free throughout this period. Subsequently, in September 2010, in accordance with the patient's goals and informed consent, the leads and corresponding constant-current multiple source SCS system (Precision, Boston Scientific Neuromodulation, Valencia, California) was implanted (see Figure 4). At the 12-month follow-up, no complications (such as loss of coverage because of lead displacement, lead fracture, or erosion) or adverse side effects had been reported. Stimulation use is continuous over a 24-hour interval, and the patient attributes the following outcomes to improving her quality of life:

- Patient reports pain reduction of more than 75% (visual analog scale 2 out of 10).
- A reasonable span of time has passed with increased day-to-day activity while using less pain medication (the patient was successfully weaned off morphine).
- The patient reports normal sleep architecture (without the need for zolpidem).

Figure 5 provides detailed information concerning programming and stimulation parameters, because it is important to track this type of data from both clinical and biomedical perspectives.[11,12]

Discussion

Our decision to proceed with SCS was facilitated by our experiences using constant-current multiple source SCS systems to capture chronic benign low back pain in postlaminectomy syndrome based on topographical dermatomal representation and the sacral shift phenomenon, as well as our use of SCS to manage pain in a case involving ankylosing spondylitis.[7,13-15] Although a placebo

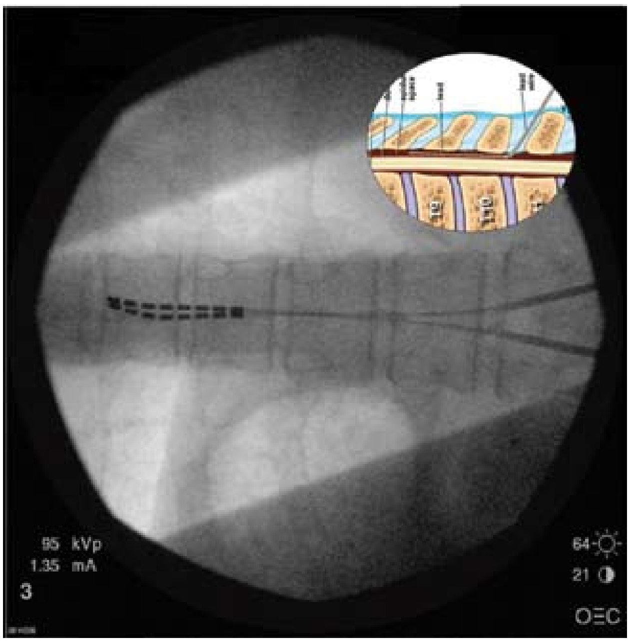

Figure 3. *Mapping results during the trialing procedure indicated best placement of the lead tips over the superior border of the T8 vertebral bodies. The left and right introducer needles enter the epidural space through the ligamentum flavum at the T11-T12 interlaminar space.*

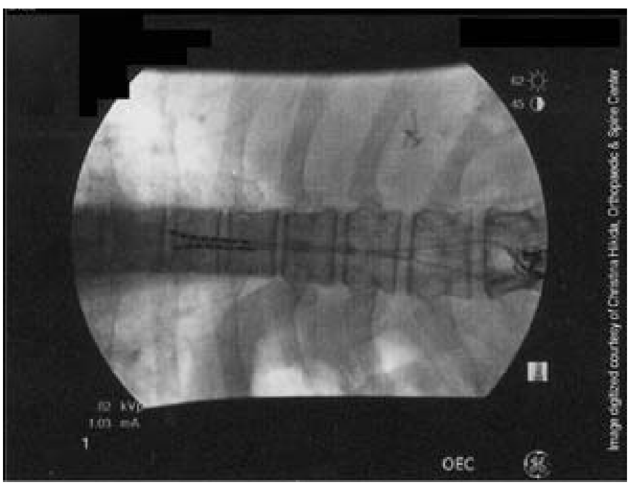

Figure 4. *Fluoroscopic image at the implant procedure showing final placement of the leads. Digital formatting courtesy of Christina Hikida of the Orthopaedic & Spine Center in Columbus, Ohio.*

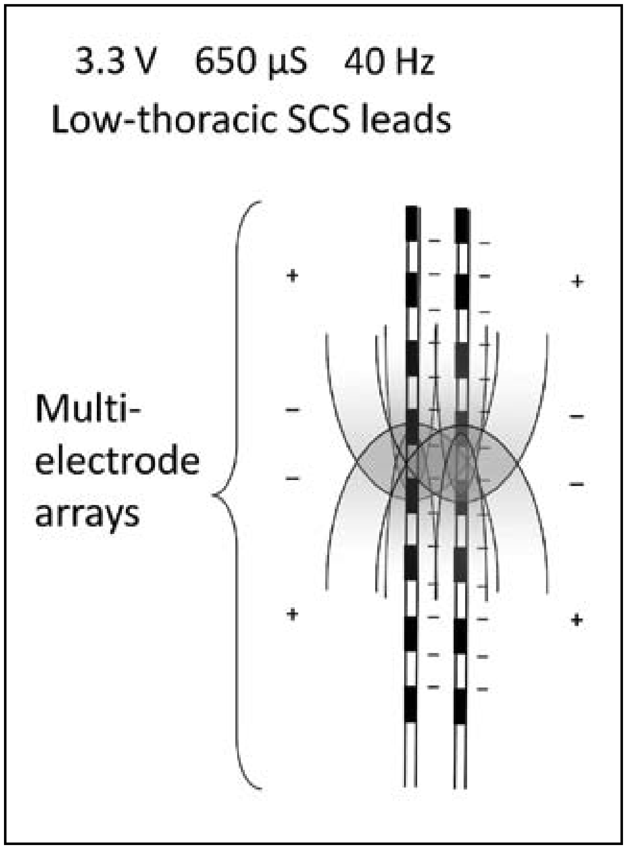

Figure 5. *A schematic showing the most used stimulation parameters; anode (+) and cathode (-) configuration; and representative electric fields.*

effect cannot be completely excluded for the results achieved in this case, given the continuation of response over the follow-up period, placebo effect is likely minimal.

We believe the initial postoperative pain patterns experienced by our patient (the facetogenic pain as described by Siepe et al[6]) correlated well with the aforementioned observations by Goel et al on L5-S1 Charité artificial disc biomechanical testing (ie, the transfer of load to the posterior spinal elements).[3] Moreover, the preferential superior surface motion at the osseous-device interface was substantiated recently by computational modeling that simulated in vivo mechanical wear of the lumbar disc prosthesis.[16] Therefore, given the nature of the initial concern for referral (ie, consultation for appropriateness of IDET because of persistent pain following a L5-S1 total disc replacement) and the nature of the vascular complications leading to the failed attempt to replace the L4-L5 disc, the balance of this article addresses recent advances in intradiscal therapies and regenerative medicine based on our experiences. It is in this context that an intriguing neuromodulation technique also will be highlighted.

Bioengineering Survey and Literature Review

Kloth et al issued a report on patient selection criteria for IDET in 2008.[17] Notably, the criteria outlined in the report supports our decision to refrain from pursuing IDET in this case. Furthermore, similar to discography, percutaneous intradiscal radiofrequency thermocoagulation, and intradiscal biacuplasty, IDET requires needle placement into the disc.

When considering needle placement into a disc, it is important to consider the long-term effects of disc puncture. On this point, the biological effects of disc puncture continue to be debated in the literature. A recently published 10-year follow-up study on provocative lumbar discography by Carragee et al claims accelerated disc degeneration was associated with disc penetration injuries during discography.[18]

Perhaps more interesting is consideration of the knowledge gleaned from investigations on central disc vascular supply relative to disc puncture. A prospective study conducted by Deshpande et al on lumbar discography first confirmed real-time intravascular uptake of iodinated contrast media in 14.3% of the studied patient population.[19] Further, although such episodes of uptake continue to be observed,[2] it has long been observed in the radiological community that the intervertebral disc might enhance on MR images if examination start is delayed over a 30-minute window after gadolinium administration.[20] Furthermore, serial MR images clearly demonstrate the phenomenon known as diffusion march (ie, the diffusion of gadolinium across the vertebral endplates and into the disc) with no intradiscal enhancement noted at 24 to 48 hours after contrast administration.[21] Thus, for interventional pain physicians, broader implications of these vascular supply studies may help remedy delivery challenges related to bioengineering designs to regenerate the intervertebral disc, such as tissue scaffolds, mesenchymal stem cell therapy, or biomolecules to act as biochemical mediators within the disc.[22-31]

Finally, we highlight a forward-thinking concept of "direct" electrical stimulation of the intervertebral disc to induce analgesia. This novel technique places a percutaneous SCS lead inside or just outside the confines of the disc, thus sparing as much disc tissue as possible.[32] However, the idea of electrically stimulating the disc in this manner has yet to be proven surgically feasible or provide clinically acceptable pain control. Thus, members of the interventional pain medicine community interested in neuroaugmentive techniques are involved in a truly transformative era of research.[11,12] Electrical stimulation of the intervertebral disc could provide benefit for the disc's cells and tissue, or provide beneficial synergies. For example, electromagnetic field stimulation has been shown in vitro to promote human intervertebral disc DNA synthesis. In addition, electrical stimulation applications could be used to promote cellular proliferation as an amplification process in autogenous disc cell therapy to regenerate disc tissue.[33]

Conclusion

As constant and deliberate progress toward advancing spine care is made, the collective knowledge pertaining to roadmaps and guidelines for interventional treatment can be used, in concert with our surgically trained colleagues to offer the best possible care for the patient with spine conditions and pain.[2] In this context — and in the case reported here — implanting the SCS system for pain control (including symptoms like those of reflex sympathetic dystrophy) achieved favorable benefits that exceeded conventional treatment options (including safe approaches to revision surgery associated with the artificial disc or IDET).

In this case, SCS was used to ameliorate persistent pain following an L5-S1 total disc replacement augmented by injection therapy and physical therapy. Outcomes were based on 12-month follow-up. No complications or adverse events were noted. The patient's pain decreased by more than 75%, and notably, the patient attributed her improved quality of life to her pain reduction. Although this report discusses the use of SCS over fusion surgery with an essentially stable spine (given the opinion of disc slippage at the superior end of the osseous-device interface, which contributes to the nonfunctional status of the prosthesis), case presentation provides only initial assessment of treatment safety, not conclusive evidence of treatment effectiveness.

Finally, this case supports the general remarks made by Siepe et al on postoperative pain patterns following total disc replacement, as well as observations based on biomechanical and computational modeling of the Charité artificial disc at the L5-S1 level — in which clinical relevance was appreciated.[3,6,14] Data on stimulation parameters is important to track from clinical and biomedical perspectives as research initiatives on neurostimulation techniques are advanced. Future studies might consider collaboration between the interventional pain physician and surgeon, as well as bioengineers, to better quantify outcomes for best overall care of the spine patient.

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Influence of Gender, Age, and Social Norm on Digital Imaging Use

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Background *The adoption of digital imaging technology is a critical investment decision, and problems related to employee acceptance of the technology often are underestimated. Literature indicates that subjective normative factors, gender differences, and age may affect employee acceptance and use of new technology. Thus, understanding these influential factors is highly important to organizations.*

Objective *To explore the relationships between gender, age, subjective normative factors, and the intention to use digital imaging technology in an environment where its use is mandatory.*

Methods *A survey was used to investigate the applicability of a modified, theoretical technology acceptance model as a proposed model of radiographers' intention to use digital imaging technology. Structural equation modeling was used to test the theoretical model, and path analysis was used to examine dependence between variables.*

Results *Although the data supports the modified versions of the theoretical technology acceptance model, the relationship between age and gender was very weak. When age and gender were removed from the model, voluntariness had a weak effect, suggesting other environmental factors play a larger role in explaining subjective normative factors within a radiologic environment.*

Conclusion *In contrast to other technology adoption studies, age and gender were not significantly associated with radiographers' acceptance and use of technology. Age and gender patterns do not apply to the adoption of digital imaging for this population. Therefore, one can conclude that in an environment in which digital imaging equipment use is mandated, additional sociocontextual variables play a role in the radiographers' intention to use the technology.*

The adoption of information technology (IT) is a critical investment decision, but problems related to employee acceptance of the technology often are underestimated.[1] Understanding the conditions in which employees embrace and use new technology should be important to an organization, especially in work environments where its use is mandated. If the new technology creates a high degree of change or if employees are not consulted prior to adopting the technology, they may resist the change. Resistance also may occur in the postadoption stage if the system does not perform as expected or if it creates a disruptive conflict in the workplace.[1] Recognition of human and organizational factors influencing the acceptance of IT is crucial because benefits can be realized only if the technology is used by the employees.[2]

Subjective normative factors, gender differences, and user age may play key roles in the use of technology in a mandated environment.[3,4] This is important to employers because of the high number of females working in health care professions and the increasing age of the workforce, and because most decisions regarding the purchase and implementation of IT occurs at an executive level within the organization.

Effect of Gender and Age in a Mandated Environment

Over the past 20 years, technology acceptance has been widely researched from multiple theoretical perspectives and in a variety of settings.[5-10] It is critical to point out, however, that most of these studies were conducted in situations where the user was given the choice to adopt or reject the innovation. In addition, the research was conducted according to theories that explicitly or implicitly applied to voluntary control of the users. In a medical imaging setting, many behaviors are not voluntary choices because the decision to implement new IT is made at an organizational level.[1,5]

Technology adoption researchers initially focused on technology use in voluntary environments in the business sector because they believed there would be little variance in technology use in mandatory environments. However, researchers have since noted that mandatory use behavior also varies, and the extent of the use will vary among individuals.[3] Therefore, 3 interrelated social forces have been identified as important factors in the adoption or rejection of new technology in the current work environment:

- Subjective norm, or the extent to which an individual is influenced by and responds to informational input from others.
- Voluntariness.
- Image.[6]

Limited studies to examine gender differences have been conducted primarily in a voluntary environment, but there is an indication that gender may be an important factor in IT system use in mandated environments.[3,4] A few studies show that subjective norm has a greater influence on women than men. These studies suggest that gender differences affect an individual's subjective norm, which also measures a willingness to accept influence to gain a favorable reaction from those mandating use of the technology.[11,12] The trend in the literature indicates that user gender and age are predictive variables in social environments in which users perceive technology adoption to be a willful or a mandatory choice, and they affect users' perceived usefulness, perceived ease of use, and intention to use the system.

Technology Adoption Models

Various models exist to predict or explain user acceptance of technologies or innovations. The basis for most of the acceptance models begins with Fishbein and Ajzen's theory of reasoned action (TRA),[13] which states that a measure of behavior will always specify the action and target being assessed. In this context, the action is system use and the target is the technology. According to TRA, user attitude and subjective norm concerning system use influences a user's intention to use the system, which in turn determines system use.

Predictive variables in this model include intention, attitude concerning the behavior, and subjective norm concerning the behavior. This suggests that any other factors influencing behavior do so only through an indirect influence on attitude and subjective norm or their relative weights. Further, it implies that the TRA model influences the impact of uncontrollable environmental variables and controllable interventions on user behavior.[14] When this model was used in a mandatory environment, the normative component was weighted more heavily than attitude concerning the behavior, suggesting that employees frequently used the system because they believed their superiors expected it.[3] In a voluntary environment, the attitudinal component was weighted most heavily. Another important aspect of TRA is the salient principle that resulting beliefs are idiosyncratic to the specific context and cannot be generalized to other systems and users. This suggests that findings from IT research in the business sector cannot be generalized to a mandated environment in the health care sector.

Grounded in social psychology, the theory of planned behavior[15] is an extension of TRA. This theory states that if the perception of behavioral control is high (ie, resources and opportunity are greater than the obstacles), an individual will more likely perform the behavior. Therefore, the perception of control over behavioral performance and intention has a direct effect on behavior, especially when volitional control is low, such as in a work environment where technology use is mandatory.

The technology acceptance model (TAM) emerged as an adaptation of the TRA specific to user acceptance of information systems.[14] This model was created to identify the effect of external factors on attitudes regarding use of and intention to use an information system. This model proposes that technology use is determined by the user's attitude toward using the system, which depends upon 2 user beliefs:

- Perceived usefulness – the user's subjective probability that using a specific application system will increase job performance in an organizational setting.
- Perceived ease of use – the degree to which the user expects the system to be free of effort.[14]

In addition, if a system is perceived to be easy to use, then it also is perceived to be useful. Therefore, perceived usefulness is influenced by perceived ease of use.[5] Within this model lies the assumption that technology use is based largely on a cognitive appraisal of how the technology will improve performance. Thus, TAM does not include TRA's subjective norm, and perceived usefulness and perceived ease of use are 2 distinct constructs and are general determinants of user acceptance.[14]

Consequently, TAM2 was developed as an extension of TAM to incorporate social influence and cognitive instrumental processes.[6] TAM2 postulates voluntariness as a variable that moderates the effect of subjective norm on intention to use technology. Building on TAM2, TAM3 incorporates perceived usefulness, ease of use, attitude, perceived behavioral control, and subjective norm as influences on behavioral intention when system use is mandated.[5] Testing the TAM3 model demonstrated that perceived behavioral control and subjective norm explained more than 50% of the variance in behavioral intention.

Rogers proposed the innovation diffusion theory (IDT), a model that is widely applied to the study of technology adoption.[7] Rogers described diffusion as the process by which an innovation is communicated through channels over time in a social system. Unlike the aforementioned theories, IDT approaches technology adoption from a sociological perspective. It focuses on how social communication structures (eg, norms, opinion leadership, and agent of change) can facilitate or impede diffusion and adoption of an innovation. IDT includes 5 innovation characteristics or attributes:

- Relative advantage.
- Compatibility.
- Complexity.
- Trialability.
- Observability.[7]

Although TAM and IDT originate from different disciplines, both theories suggest that adoption of a technology is determined by the user's perceived attributes. Some researchers have equated TAM's perceived usefulness to IDT's relative advantage construct, and TAM's perceived ease of use to IDT's complexity construct.[16,17]

Venkatesh et al conducted an empirical comparison of 8 existing technology adoption models in an attempt to combine the multitude of technology acceptance theories into a single model.[8] The authors compared:

- TRA.
- TAM.
- Motivational model.
- Theory of planned behavior.
- A combined TAM and theory of planned behavior.
- Model of personal computer utilization.
- IDT.
- Social cognitive theory.[8]

The authors found 7 constructs demonstrated a direct effect on the intention to use technology and concluded that 4 of these were significant direct determinates of user acceptance and behavior:

- Performance expectancy – an individual's perception that using the technology will help attain gains in job performance.
- Effort expectancy – the ease associated with system use.
- Social influence – the degree to which an individual perceives other important individuals believe the system should be used.
- Facilitating conditions – the individuals' perception of organizational and technical infrastructure support.[18]

The authors' findings resulted in the unified theory of acceptance and use of technology. The theory comprises 3 direct determinants of intention to use and 2 direct determinants of usage behavior, accounting for 70% variance in intention to use a technology. The research raised issues regarding the complex nature of age and gender interactions, suggesting additional research is needed in this area.[8]

Purpose

Although prior research supports technology acceptance models in a variety of settings, medical imaging offers a unique context in which technology use often is mandated. Thus, questions related to voluntariness, age, and gender remain. The purpose of this study was to explore the relationships between voluntariness, gender, age, subjective norm, and intention to use digital imaging technology in a health care environment. This study tested a modified, theoretical model of TAM2, which was chosen based on its inclusion of voluntariness and the ease of adding gender and age.

Methods

A survey method was used to investigate the applicability of the modified TAM2 as a proposed model of radiographers' intention to use direct read-out digital imaging technology. The population for this study was 120 American Registry of Radiologic Technologists-certified radiographers who used direct capture digital radiographic units in a university health care system. The system comprised inpatient and outpatient facilities throughout the area. Digital imaging units were the same and installation training was consistent across all facilities. The entire population was surveyed and participation was voluntary. The study was approved by the institutional review board. The study's goals, objectives, and the importance of the radiographers' participation were explained in a cover letter.

Instrumentation

The data collection instrument was a 34-item questionnaire divided into 3 sections:

- Intentions and use of digital imaging systems.
- Demographic characteristics.

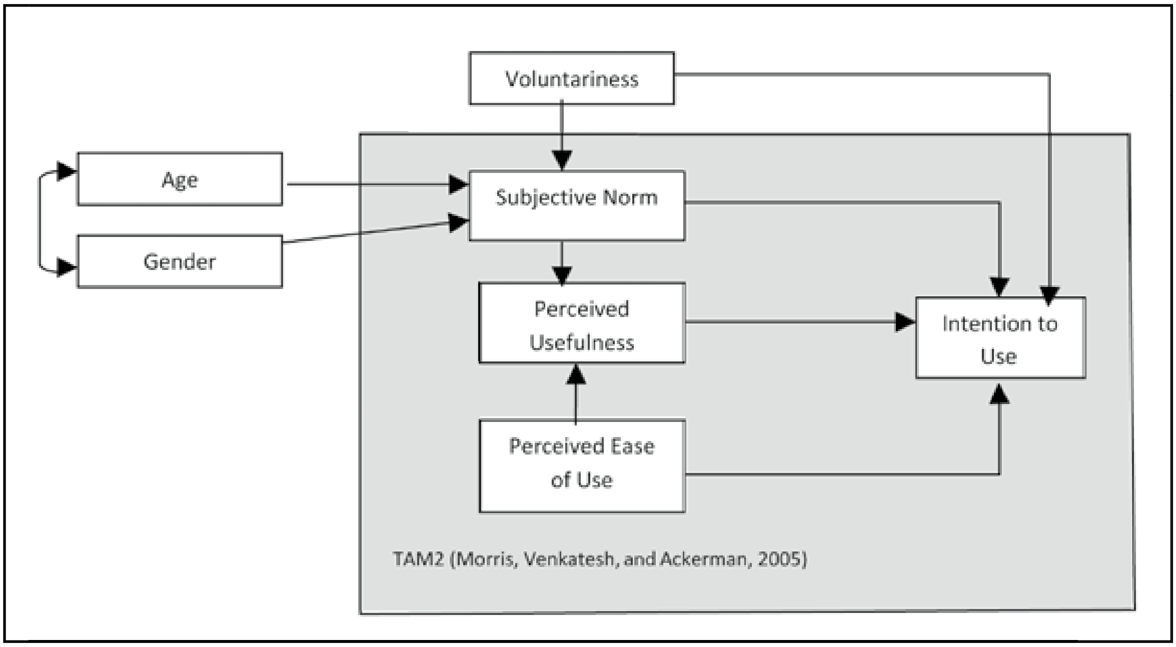

Figure 1. *Modified TAM2 theoretical model. Variables outside the gray box denote modifications to the TAM2 model.*

- User participation.

The first section of the questionnaire consisted of items adapted from TAM and TAM2.[6,15,17,19] The second section of the questionnaire pertained to 2 gender- and age-related demographics. In previous studies, these characteristics were shown to have moderating influences on the intention to use technology.[3,6,9] To obtain information regarding the subject's level of voluntariness, the third section of the questionnaire related to the individual's role in selecting and implementing the digital imaging system.

The instrument was field tested to ensure the measurement scales were adapted appropriately to the digital imaging context and the data was analyzed to determine the instrument reliability using Cronbach alpha for each subset of questions. The resulting alpha values were:

- Perceived usefulness (0.930).
- Perceived ease of use (0.946).
- Perceived behavioral control (0.967).
- Subjective norm (0.938).
- Voluntariness (0.862).

All alpha values indicated high internal reliability of the survey instrument. Survey responses were used to test the modified TAM2 model (see Figure 1), including:

- Age – chronologic age based on self-reported years of age.
- Gender – male or female based on self-reported identification.
- Intention to use – an individual's belief about his or her expected or anticipated use of the digital imaging system.
- Perceived ease of use – the extent to which a person believes using the digital imaging system will be free of effort.
- Perceived usefulness – the extent to which a person believes the digital imaging system will improve his or her job performance.
- Subjective norm – an individual's perception of what others feel about adopting an innovation, and the belief that others of perceived importance think he or she should perform the behavior.
- Voluntariness – the extent to which potential adopters perceive technology use to be a free choice.

Data Analysis

A data analysis was performed using a structural equation modeling component of SPSS software (Analysis of Moment Structures [IBM, Armonk, New York]) to determine if the data supported the implied

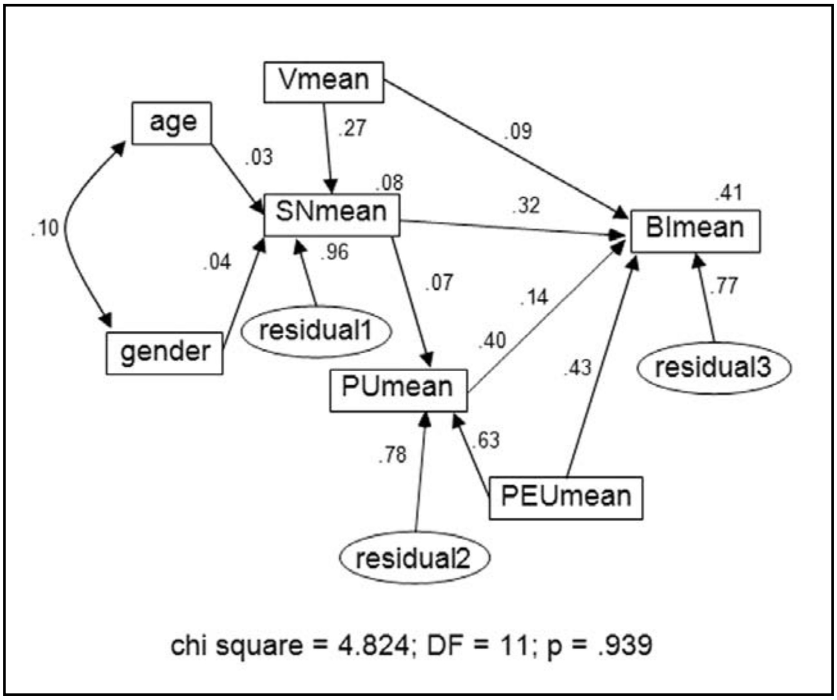

Figure 2. *Standardized structural equation model results* ***including*** *age and gender variables. Path coefficients indicate amount of variance explained between each variable tested.*

theoretical model (see Figure 2). A model fit criterion is based on a comparison of the model-implied covariance matrix to the sample covariance matrix. A confirmatory approach was used to accept or reject the theoretical model based on a chi-square test of statistical significance. A nonstatistically significant chi-square value indicates that the sample covariance matrix and the reproduced model-implied covariance are similar, demonstrating the theoretical model fits the data sample.

Path analysis was used to examine a series of dependence relationships between variables as denoted by standardized regression coefficients (β). In this model, exogenous variables (similar to independent variables) included age, gender, voluntariness, and perceived ease of use. Endogenous variables (similar to dependent variables) in this model included subjective norm, perceived usefulness, and intention to use. Path models are extensions of multiple regression models that establish causal relationships among 2 variables. Standardized regression coefficients are computed on the particular set of independent variables that lead to a particular dependent variable as designated in the path model.

Results

Demographic Description

A total of 120 surveys were distributed and 111 surveys were returned for a response rate of 92.5%. Surveys less than 75% complete were excluded from final analysis. Based on this exclusion criterion, 110 surveys were included for final data analysis for all areas with the exception of social norm. Only 75 respondents completed the entire subjective norm section, so analysis of the subjective normative variable is based on responses from those 75 surveys. Demographic data indicated that the majority of the respondents (83.6%) were women (see Table 1), which is consistent with the national population of radiographers. However, the low number of males does limit gender analysis. The respondents' ages ranged from 20 to 41 years and older, with fairly equal distribution by age range (see Table 2).

All respondents completed the questions regarding intention to use the digital imaging equipment (Definium 8000, GE Healthcare, Waukesha, Wisconsin), for which all of the respondents attended the same orientation and training program. The majority of respondents reported very little input in the selection and implementation of the digital imaging system. Only 6 individuals (5.5%) indicated they served in a leadership role regarding the adoption and selection of the digital imaging system. Sixteen respondents (14.5%) reported assisting in the implementation phase. However, almost half of the respondents (42.7%) reported having responsibility for user training of the digital imaging system. These results suggest that for the majority of respondents, the selection, adoption, and implementation of the digital imaging system was mandated by personnel at a higher organizational level.

Path Analysis

The squared multiple correlation value (R^2) indicates the amount of variance explained, predicted, or accounted for a particular endogenous variable by the set of exogenous predictor variables. Path analysis in this study specified the R^2 value for subjective norm (the endogenous variable) was 0.08, estimating that voluntariness, age, and gender accounted for or explained only 8% of subjective norm. The R^2 value for perceived usefulness was 0.40, estimating that subjective norm and perceived ease of use accounted for 40% of perceived usefulness. The R^2 value for intention to use technology was 0.41, indicating that the 4 variables — voluntariness, subjective norm, perceived usefulness, and perceived ease of use — accounted for or explained 41% of the radiographers' intention to use the digital imaging system.

Research Questions

- Does a relationship exist between age and subjective norm in a mandated health care environment?

The path model demonstrated a relationship between subjective norm and age ($\beta = 0.03$). This indicates that age did not significantly affect subjective norm.

- Does a relationship exist between gender and subjective norm in a mandated health care environment?

The path model demonstrated a relationship between subjective norm and gender with $\beta = 0.04$. This indicates that gender did not significantly affect subjective norm. However, the low number of men (15.5%) who participated in this study limited analysis of gender effects.

- Does a relationship exist between voluntariness and subjective norm in a mandated health care environment?

The path model demonstrated a relationship between subjective norm and voluntariness ($\beta = 0.27$). This indicates that voluntariness explained or predicted a small percentage of subjective norm.

Table 1
Self-Reported Gender of Respondents

Gender	n (%)
Male	17 (15.5)
Female	92 (83.6)
Missing	1 (0.9)

Table 2
Self-Reported Age of Respondents

Age Range in Years	n (%)
20-30	39 (35.5)
31-40	42 (38.2)
≥ 41	27 (24.5)
Missing	2 (1.8)

- Does a relationship exist between subjective norm and intention to use the technology in a mandated health care environment?

The standardized path relationship between subjective norm and intention to use the technology was $\beta = 0.32$. This indicates that subjective norm explained or predicted approximately one-third of behavioral intention to use the technology.

- Does a relationship exist between subjective norm and perceived usefulness in a mandated health care environment?

The standardized regression coefficient assessing a relationship between perceived usefulness and subjective norm was $\beta = 0.07$. This indicates that subjective norm did not significantly affect perceived usefulness.

- Does a relationship exist between voluntariness and intention to use the technology in a mandated health care environment?

The standardized path relationship between intention to use the technology and voluntariness is $\beta = 0.09$. This indicates that voluntariness does not significantly affect behavioral intention to use the technology.

Consistent with previous studies, perceived ease of use was the largest predictor of perceived usefulness and behavioral intention (see Table 3).

Limitations

Several limitations were acknowledged in this study. First, the study population may not be representative of all radiographers certified by the American Registry of Radiologic Technologists who use digital imaging equipment. Although a variety of imaging locations — including both inpatient and outpatient facilities — were included in the study, the generalizability of the results is limited to the study population.

Another limitation of this study is the variety of additional independent or exogenous variables affecting subjective norm that were not incorporated into this theoretical model. A review of the literature suggests that attitude, behavioral control, managerial and environmental resources, and training could be important factors relative to subjective norm. Unfortunately, a current model does not exist to account for all confounding variables.

Additionally, the low number of male respondents limited the analysis of the impact of gender pattern-related relationships.

Discussion

Although the data supports the modified versions of TAM2, the relationship between age and gender was very low with $\beta = 0.10$. Therefore, one can conclude that radiographers are equally likely to use digital imaging equipment regardless of their age. Secondly, gender patterns did not apply to the adoption of technology for this population, men and women appear to be equally likely to use digital imaging equipment. It must be noted, however, that gender limitations were encountered because of the low number of men participating in this study. These results are contrary to previous research that suggests gender differences should be expected to vary based on age and that gender-based attitudes are more salient for older individuals (ie, older women would be less likely to adopt the technology). In this study, however, gender and age had no effect on the influence of perceived social pressure to use digital imaging equipment.[11,19]

The majority of previous TAM2 studies were conducted in the business sector (eg, insurance and banking), including samples with a wide range of organizational positions and functions. This is the first study to examine radiographers' acceptance of technology using a standardized adoption model. It is important to note these results indicate that radiographers react differently to technology adoption in a mandated environment than do other populations.

Based on these findings, age and gender were removed from the acceptance model, leaving voluntariness as the only exogenous variable measured in terms of subjective norm (see Figure 3). In this scenario, voluntariness had a weak mediating effect, suggesting that other environmental factors play a larger role in explaining subjective norm in a radiologic environment. Therefore, one can conclude that additional contextual variables play a role in the radiographers' intention to use the technology in a nonvoluntary environment.

One factor for this unexplained variance may relate to the occupational differences in this population compared to those populations previously studied.[6] Earlier studies included individuals with various hierarchical positions within an organization. Sociocultural factors shown to influence technology adoption in the business sector include differences in income, education, and previous computer use. However, the population in this study was homogeneous; they were all staff radiographers holding similar positions within the organization and had similar incomes, education, and computer skills. They self-selected to enter a health care profession driven by technology and were accustomed to working in an environment in which technologic changes are mandated frequently. All participants in this study also chose to pursue a career in a technical field that requires continual development of new skills to function in a modern imaging department.

This implies that in a homogeneous population, the context in which the knowledge is developed and

Table 3
Standardized Regression Coefficients

Dependent/Independent Variables	β Coefficient
SN mean ← age	0.030
SN mean ← gender	0.040
SN mean ← V mean	0.270
SN mean ← residual 1	0.961
PU mean ← SN mean	0.034
PU mean ← PEU mean	0.630
PU mean ← residual 2	0.771
BI mean ← V mean	0.113
BI mean ← SN mean	0.187
BI mean ← PU mean	0.155
BI mean ← PEU mean	0.487
BI mean ← residual 3	0.866

applied (ie, the culture of the community of practice) may have a greater influence on subjective norm and intention to use a technology than an individual's choice to use the technologic innovation does. Results of this study support the concept that the learner's experiences cannot be separated from learning and cognition.[20,21] Adopting the belief system of the community in which the new technology is used is an integral and inseparable aspect of the social practice of radiography, suggesting that meaningful learning is connected to the social norm or the social and physical context within which the knowledge is used. Therefore, one can conclude that the community of practice must be considered when identifying those exogenous variables affecting subjective norm and intention to use the technology.

Because radiographers are connected both by their professional practice and through socially constructed beliefs essential to understanding their activities, the contextual factors within a particular organization will affect the use of the new knowledge. Therefore, one can conclude that technology acceptance models must be adapted to the particular culture of the population under study. Technology acceptance models must be specific to the context in which the learning and technology use take place. This suggests that a unified technology adoption model is not sufficient to explain intention to use technology and that each model must be adapted to the particular environment being tested to provide useful information.

Previous research suggested that attitude as an independent variable significantly affects subjective norm in a mandated environment because it represents the degree to which users are satisfied with the system.[5,22] Individual differences in personality, demographic, and situational variables — including intellectual abilities, domain-specific knowledge, experience, education, professional orientation, and organizational level — were identified to have a critical role in subjective norm.[23] The implementation context (ie, social influence, training, and facilitating conditions) also were shown to have a great influence on behavioral intention.[23,24] Given that age, gender, and voluntariness demonstrated little effect on social norm and behavioral intention in this population, pertinent variables to explore in future studies may be a measurement of attitude, domain-specific knowledge learned within the community of practice, shared professional orientation, participants' experience, and training/facilitating conditions.

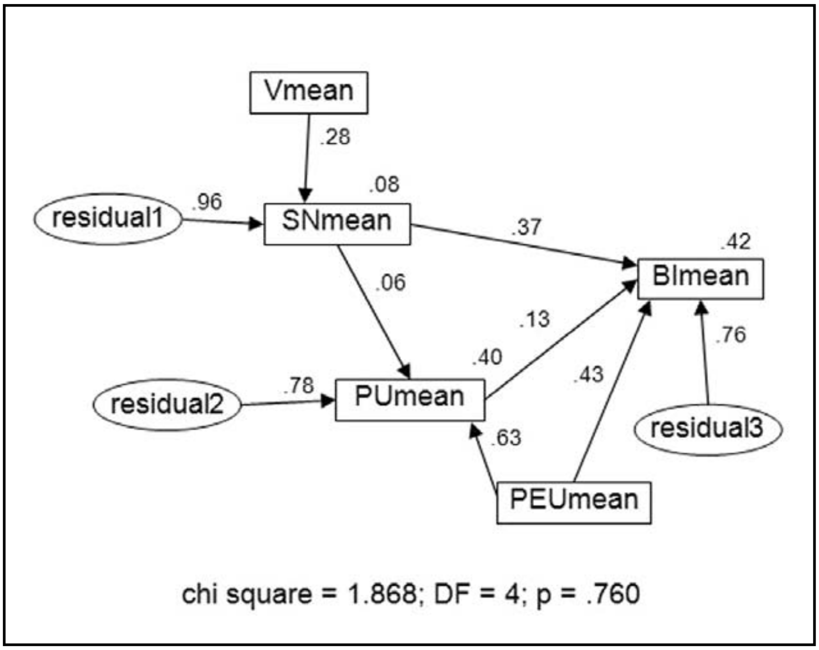

Figure 3. *Standardized structural equation model results* ***excluding*** *age and gender variables. Path coefficients indicate amount of variance explained between each variable tested.*

Conclusion

Multiple implications and recommendations are identified consequential to this study. The adoption of a digital imaging system is a critical investment decision. Simply acquiring the technology is not a sufficient condition for effective use of the system. This study demonstrated that choosing a system with low perceived ease of use may have a dramatic effect on the perceived usefulness of the equipment, as well as the radiographers' behavioral intention to use the equipment.

Second, attention must be given to managing change within the imaging department. To realize the expected benefits from digital imaging investments, the effect of social dynamics in the workplace on the adoption and use of innovative products is of paramount importance. Purchasing digital imaging equipment without consideration of the community of practice and the organizational environment will not solve existing problems or create a competitive advantage. This study indicated that a relationship exists between subjective normative factors in an environment where the use of digital imaging is mandatory. In turn, subjective normative factors also were shown to have a relationship to the radiographers' behavioral intention. This suggests that an administrator's ability to identify, predict, and manage employee acceptance of technology will facilitate implementation efforts and improve the ultimate success of the capital investment. Additional studies should be conducted to identify other exogenous variables affecting subjective norm. This knowledge may enable administrators to develop a medical imaging workforce that can respond to rapid technologic changes and to assess the importance of careful employee selection and training and support of leadership, which is critical to maintain a change-oriented culture.

This study supports the concept that radiographers' intention to use digital imaging equipment depends on social processes, as evidenced by the relationship between subjective norm and intention to use the technology. Thus, understanding the environment, resources, and culture are critical to successful adoption of digital imaging systems. Implementation of a new technology directly affects employees; therefore, vendors must place equal focus on humanistic and organizational issues and technological aspects of the project for a successful implementation. If the innovation creates a high degree of change or if employees have not been consulted prior to the adoption of the technology, they may resist the technologic change. Resistance also can increase in the postadoption stage if the system does not perform as expected or if it creates a disruptive conflict in the workplace.[1]

Implications also are warranted for educators and trainers. Situated cognition theory states that moving from a novice user to a master user requires full participation within a community.[20,21] From an educator's perspective, it is important to note that a novice does not lack the ability to perform a task or skill; they lack the knowledge only accessible through experience within the community and the situation that permits conceptualization of the knowledge. Adult learning is a social, interactive process in which the learner interacts with the learning environment. This theory is supported by the results of this study, which demonstrated that social norm accounts for approximately one-third of the variance explained in the intention to use new technology. Therefore, it is critical to understand the learners and the context in which the learning will occur most effectively. However, age and gender are demonstrated to have little effect on social norm in this population, suggesting that variables outside the scope of the modified TAM2 model play a significant role in social normative factors.

Although voluntariness, age, and gender have shown to have little to no affect on subjective norm — suggesting the models tested do not adequately identify variables pertinent to subjective norm in this population — this study does support the concept that social influence is an integral part of behavioral intention. Previous research suggests that attitude, training, and facilitating conditions have a significant influence on behavioral intention.[23,24] In addition, the implementation context and self-efficacy were identified as primary factors in reducing anxiety in previous research. Therefore, providing a safe, interactive, context-based learning environment that acknowledges the unique adult population may positively affect radiographers' intention to use new technology.[23,24]

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Erratum

An error occurred in the Directed Reading, "Solid Organ Donation and Transplantation," which appeared in the March/April 2012 issue. The liver and lung labels in Figure 2 were transposed. The error did not affect the post-test.

Thank you to the readers who brought this error to our attention.

Radiation Safety for Radiologic Technologists

LEE A BRADLEY, MSRIS, R.T.(R)(CT)(QM)

Radiologic technologists and ancillary staff who work with or near ionizing radiation face possible short- and long-term effects of occupational radiation exposure. Further, radiologic technologists must minimize unnecessary exposure that risks the patient's safety, while achieving the best possible image or outcome. This article reviews occupational dose limits, dose calculation, devices used to measure exposure, and safety best practices that can help technologists keep radiation exposure "as low as reasonably achievable" for them and their patients. The article also discusses the appropriate use of mounted and mobile equipment, personal protective equipment, and safety features on imaging equipment to minimize unnecessary radiation exposure.

This article is a Directed Reading. Your access to Directed Reading quizzes for continuing education credit is determined by your CE preference. For access to other quizzes, go to www.asrt.org/store.

After completing this article, readers should be able to:

- *List the basic principles of radiation production.*
- *Describe dose limits and measurement.*
- *Explain safety measures, including inherent protection and personal protective devices.*
- *Identify safety best practices for radiologic technologists.*
- *Discuss the risks of radiation exposure.*

For the radiologic technologist, medical imaging often is a balancing act: What combination of milliamperage (mA) and kilovoltage (kV) is needed to ensure the best image? When should the patient wear lead shielding, and how can unnecessary anatomy be excluded to save the patient from unnecessary exposure? Occupational radiation safety is also a concern because a high cumulative dose of radiation can be dangerous. Currently, the National Council on Radiation Protection & Measurements (NCRP) has 124 reports regarding radiation safety for public and occupational sectors, including recommendations for dose limits.[1] The United States Nuclear Regulatory Commission (NRC) has adopted those limits and, in conjunction with state and federal laws, mandates construction specifications of exam rooms and adjacent areas and dose monitoring procedures to protect those who work with radiation.[2,3]

History of Radiation Protection

There have been many advances in the radiologic sciences and in radiation protection theories and practices since x-rays were discovered (see Table 1). Although Wilhelm Roentgen is credited with discovering the properties of x-rays in 1895, he was not the only scientist working with radiation.[3] Thomas Edison realized the potential of x-rays and constructed his first fluoroscope in 1896.[4] Over the course of a few years, his lab assistant Clarence Dally was exposed to enough radiation to cause severe burns, which led to the amputation of his fingers and arms, and finally to his death in 1904. Dally's death was the first recorded fatality in the United States caused by cumulative radiation exposure from x-rays, just 9 years after they were discovered.[5]

Dr William Rollins, a dentist in Boston, used x-rays in his practice and experienced a radiation burn on his hand, which led to experiments with radiation on guinea pigs. In 1901, Rollins published a paper cautioning against using x-rays without some type of lead shielding for the tube, patient, and radiographer.[6]

In 1915, the British Roentgen Society took Rollins' advice and made the first formal advances to protect patients and

Table 1
Timeline of Radiation Discovery and Safety Measures

Date	Event
1895	Wilhelm Roentgen discovers x-rays.
1896	Thomas Edison develops first fluoroscope.
1901	William Rollins recommends lead shielding.
1904	Clarence Dally dies from cumulative radiation exposure from x-rays (first recorded radiation-related death in the United States).
1913	Niels Bohr publishes theory of atom design.
1915	The British Roentgen Society adopts resolution to use lead shielding.
1934	U.S. Advisory Committee on X-ray and Radium Protection issues first recommendation for dose limits.
1952	American Society of Radiologic Technologists (ASRT) issues first radiography program curriculum recommendation.
1993	National Council on Radiation Protection & Measurements issues dose limits used today.
2012	ASRT introduces latest radiography program curriculum recommendation.

medical radiation workers by adopting a resolution recommending that x-ray tubes be shielded with lead.[5,7] In 1934, the U.S. Advisory Committee on X-ray and Radium Protection, now known as the NCRP, issued the first report of recommended maximum exposures. NCRP Report 116, published in 1993, set the current public and occupational dose limits for exposure to ionizing radiation.[1]

ALARA, or "as low as reasonably achievable," is the principle used today to help manage both patient and occupational radiation exposure. To help radiologic technologists adhere to the ALARA principle, the American Society of Radiologic Technologists (ASRT) maintains a recommended radiography program curriculum that focuses on radiation production and safety. The ASRT published its first recommended radiography curriculum in 1952 and has continually modified it to keep up with advances in knowledge and technology.[8] The current curriculum, adopted for use beginning in 2012, includes an introduction to radiologic science and health care, radiation production and characteristics, radiation biology, and radiation protection.[9]

Basic Radiation Principles

Radiation is the act of emitting energy in the form of photons or particles.[10] It is considered "ionizing" when the energy can produce changes in atomic structure by creating positively or negatively charged atoms. The types of ionizing radiation used in a diagnostic imaging department are x-rays, gamma rays, and beta particles. The nature of the images sought determines the type of radiation used.

The Atom

When most people picture an atom, they think of the structure described by Niels Bohr in 1913 — a dense nucleus housing protons and neutrons, surrounded by electrons moving in elliptical paths. These ellipses are called shells; the shell closest to the nucleus is the K-shell, with successive shells L through Q available depending upon the element. Each shell has a predetermined maximum number of electrons that can be calculated by using the quantity $2n^2$, where n equals the shell position from the nucleus; the outermost shell always has a maximum of 8 allowable electrons. As an example, an oxygen atom contains 8 electrons. If the K-shell is allowed only 2 electrons ($2[1]^2$), the atom must have at least an L-shell to house the other 6 electrons. In a stable atom there are enough shells containing negatively charged electrons to balance out the number of positively charged protons in the nucleus. A neutron has no charge.[5]

Electrons are held within their orbit by "binding energy." An atom is termed an ion if the number of electrons in the atom changes from its stable configuration. Ionizing radiation is any radiation capable of overcoming the binding energy and knocking an electron from its shell.[5]

Types of Radiation

Radiology modalities use different types of ionizing radiation. X-rays are created when an outside source bombards a target with an artificially created stream of electrons. The transfer of energy from the electron stream to the innermost electrons of the target's atoms creates x-ray photons with characteristics that identify the target material used. The resulting photons are known as characteristic x-ray photons. However, if the electron stream interacts with the nucleus of a target atom instead of the electrons, it produces bremsstrahlung radiation. A bremsstrahlung photon is created when an electron from the stream passes close enough to the target nucleus to be affected by its electrical field, or when it collides with the nucleus. Either interaction will result in a loss of energy by the incoming electron. This loss of energy becomes the new photon.[5]

Nuclear medicine uses beta particles and gamma rays rather than x-rays. A beta particle is created when an unstable isotope with too many neutrons emits an electron from its nucleus in an attempt to reach a state of stability. Gamma rays carry the same properties as x-rays, including ionization; however, they originate from the nucleus of an atom after either an electron or a positron (a positively charged electron) is emitted from it. The creation of both gamma rays and beta particles is considered radioactive decay or disintegration.[5]

Effects of X-rays on Matter

The x-ray tube used in diagnostic radiography consists of a negatively charged cathode that emits a high-powered stream of electrons toward a rotating, positively charged anode. The electrons react with the atoms of the anode, creating x-ray photons that are directed by the rotation of the anode through a glass window toward the subject to be imaged. The original stream of photons produced is called the incident x-ray or primary beam.

Within the diagnostic radiography range of kilovolts (kV), x-ray photons can interact with human tissue in 3 ways:

- Coherent scattering.
- Compton effect.
- Photoelectric effect.

Coherent scatter (ie, Thomson, classical, or unmodified scatter) results when a low-energy incident photon causes tissue atoms to vibrate. An atom may absorb the incident photon and then expel a scattered photon with a change in direction but no change in energy. The scattered x-ray — at such low kV — does not change the composition of tissue atoms, so it is not considered ionizing radiation. Coherent scatter does not increase patient or technologist dose and does not provide any useful diagnostic information, but it can cause fogging on film or an image receptor.[11]

Scatter radiation produced by the Compton effect presents the greatest danger to technologists. The Compton effect occurs when an incident photon interacts with an outer-shell electron from the patient (or other human tissue) and knocks it from its orbit. The result is a scattered x-ray and a Compton electron (a Compton pair) with a combined energy equaling that of the incident photon. Either one also can interact with more tissue. The Compton effect could happen with any x-ray photon, but it is more likely to occur as the energy of the incident photon increases. The scatter produced by the Compton effect is considered isotropic, meaning it can travel in any direction from its point of origin. For example, if a patient is positioned for a posteroanterior chest radiograph, a Compton pair may scatter forward, backward, or to the side.[3] Technologists can avoid Compton effect scatter from a single radiograph if they are in a control booth with shielding or stand at a sufficient distance from potentially dangerous scatter. However, large amounts of scatter produced by patients during fluoroscopy can contribute to occupational radiation dose.

The photoelectric effect occurs when an incident photon interacts with a K-shell electron. The photon knocks the electron from its orbit and releases all of its energy; the new "photoelectron" has energy equal to the incident photon minus the binding energy of the original electron. The binding energy of the K-shell of human tissue is relatively low. Therefore, the photoelectron created during the photoelectric effect can continue to interact with other atoms within the patient, causing an increase in patient dose. Because of the vacancy in the K-shell created by the expulsion of the photoelectron, the original atom is now unstable. Electrons in successive shells now drop into the open spots, creating what is called characteristic radiation.[3] It is this characteristic radiation that contributes useful information to a radiographic image.

Measuring Radiation Exposure

Radiation exposure is measured in a variety of ways, depending on the nature of the radiation and the reason behind the measurement. Two different tables are in use: conventional (British) units and the International System of Units (SI). These 2 systems are not directly equivalent (see Table 2).

In diagnostic radiography and computed tomography (CT), the basic measurement of radiation intensity is the roentgen (R), or coulomb/kilogram (C/kg [SI unit]). The measurement represents the amount of radiation produced before it interacts with an object and is based upon the potential damage of any particular dose of radiation to human tissue. The radiation intensity of diagnostic x-rays is generally measured in milliroentgens (mR).[5]

Table 2
Measuring Radiation

Conventional Unit	SI Unit	Conversion Factor	Application
roentgen (R)	coulomb/kilogram (C/kg)	1 R = 2.58 × 10^{-4} C/kg	Primary beam intensity
radiation absorbed dose (rad)	gray (Gy)	1 rad = 0.01 Gy 1 Gy = 100 rad	Patient dose
radiation equivalent man (rem)	sievert (Sv)	1 Sv = 100 rem	Occupational dose
curie (Ci)	becquerel (Bq)	3.7 × 10^{10} Bq	Radioactivity

Within the diagnostic department, patient dose is measured in radiation absorbed dose (rad) or grays (Gy [SI unit]), and occupational dose is measured in radiation equivalent man (rem) or sieverts (Sv [SI unit]). Radiation absorbed dose reflects the amount of radiation a person or body part absorbs as the x-ray photon passes through the body. The rem is based on the expected biologic effect of a specific type of radiation exposure. Within the diagnostic radiography spectrum, 1R = 1 rad = 1 rem. However, this is not true for all types of radiation.[5]

An isotope is an atom that has the same number of protons and electrons as an element, but differs in the number of neutrons; for some isotopes the change in neutrons makes them automatically attempt to compensate. "Disintegration" describes when the nucleus of an unstable isotope emits a particle to approach stability. Radioactive isotopes such as those used in nuclear medicine are discussed in terms of curie (Ci) or becquerel (Bq [SI unit]). The curie and becquerel are measurements of the quantity of material — not the amount of radiation it may produce — which defines its radioactivity. A curie is the amount of a particular isotope needed to produce 3.7 × 1010 disintegrations per second. A becquerel is only 1 disintegration; so, 1 Ci equals 3.7 × 1010 Bq. One curie is not equal to 1 R or 1 rad or 1 rem. Patient doses in nuclear medicine are in the millicurie (mCi) range.[11]

Relative Biologic Effectiveness

The potential damage of any type of ionizing radiation on human tissue is expressed as relative biologic effectiveness (RBE). Diagnostic x-rays, gamma rays, and beta particles are each assigned an RBE of 1. Although radioactive material used in nuclear medicine is measured in millicuries, the damage potential equals that of x-rays. So, the equivalent dose potential of radioactive isotopes is expressed in roentgen or radiation equivalent man (see Table 2).[5,12,13]

Measurement Devices

The NRC mandates that all workers who are routinely exposed to radiation be monitored so they do not exceed the annual dose limits set forth by the NCRP.[2,14] The most common way to measure occupational exposure in a radiology department is through personal dosimeters such as a film badge, thermoluminescent dosimeter (TLD) or an optically stimulated luminescence whole-body dosimeter (OSL).

A typical film badge is a small piece of plastic that contains metal filters and film. The filters interact with radiation received by the wearer and leave an impression on the film. Film badges are a reliable way to track dose for all types of radiation used in a hospital setting and begin detecting radiation exposure at 10 mR and higher. They are relatively inexpensive, but inadvertent exposure to humidity or temperature can damage the film.[5]

A TLD is similar in size and shape to a film badge but works in an entirely different way. Instead of film, a TLD uses lithium fluoride crystals that react with radiation by exciting electrons and keeping them within a framework. When heated, the electrons drop from their frame and emit light. This light is measured to estimate the amount of radiation exposure. TLDs are more sensitive and more accurate than film badges — down to 5 mR — but they can cost up to twice as much as film badges.[3]

An OSL dosimeter is similar in function to a TLD with the exception that, when read, the crystals within are stimulated by the light of a laser instead of by heat. OSLs also can be read more than once, if a reading needs to be verified, and are capable of measuring x-ray exposure to 1 mrem.[15,16]

The technologist is responsible for wearing his or her dosimeter in the proper place at all times during work hours and only when working. Any dose absorbed outside of work is considered nonoccupational radiation and should not be included in occupational monitoring. Badges should be worn at waist or chest level under normal circumstances. If the technologist is wearing a lead apron, he or she should wear the badge at neck level to get an accurate reading for exposed anatomy, such as the eyes. Pregnant technologists should wear a second dosimeter at waist level. When wearing lead, the technologist should place the abdominal dosimeter under the shield.[3] There are also extremity dosimeters, or ring badges, that generally are worn by nuclear medicine technologists because their hands may be subjected to direct radiation exposure (see Figure 1).

Film badges or TLDs are collected monthly or quarterly by 1 designated person within the radiology department, usually the radiation safety officer or quality manager. The dosimeters are sent to an outside company that processes them and prepares a report for the radiation safety officer.[3] Per NRC regulations, all employees are allowed to see their reports.[17] If there are any suspicious spikes in radiation, the radiation safety officer will try to determine a specific cause and counsel the employee.

Dose Limits

Occupational dosimetry is mandated by the NRC to keep radiation exposure within the limits recommended by NCRP Report 116.[1] The general public should be limited to a yearly whole-body dose of 500 mrem (5 mSv). Radiation workers are allowed 10 times more radiation, for a total body dose of 5000 mrem (50 mSv). However, there is also a cumulative occupational dose limit in effect of 1000 mrem (10 mSv) times age in years.[1] For example, if a radiologic technologist is 35 years old, his or her total exposure should not be more than 35 000 mrem (350 mSv). The radiation safety officer must make available a cumulative occupational dose history form if requested by a technologist.[12,18]

Yearly dose limits for specific body parts are based on their radiosensitivity and susceptibility to damage from ionizing radiation. These limits are based on the work of 2 scientists who described the phenomenon. The Law of Bergonie and Tribondeau states that radiosensitivity of a cell is determined by 4 factors: differentiation, age, activity rate, and rate of mitosis. Stem cells, younger cells, very active cells, and rapidly dividing cells are more radiosensitive than differentiated, older, dormant, or dead cells.[5] The dose limits for adults who work in any field containing a regular and continuous chance of exposure to radiation are 15 rem (0.15 Sv) to the lens of the eye and 50 rem (0.5 Sv) to the extremities or skin of the entire body.[2]

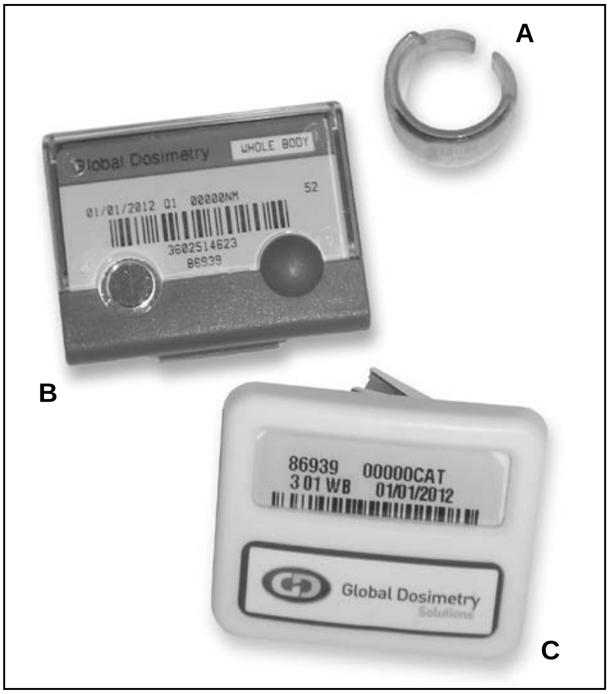

Figure 1. *Ring badge (A), thermoluminescent dosimeter (B), and film badge (C).*

Embryo exposure is not differentiated between radiation workers and the general public. The total gestational dose limit is 500 mrem (5 mSv). Dose limit for each month of the pregnancy is 50 mrem (0.5 mSv).[2,19]

The U.S. Department of Energy maintains a chart of dose comparisons compiled from research by Noelle Metting, ScD, that puts these doses into perspective. According to the chart, a chest radiograph delivers a dose of approximately 10 mrem to 20 mrem, and a dental exam delivers 160 mrem. Natural background radiation in the United States is listed at 300 mrem (this total includes radon) and the typical airliner crew is exposed to an average yearly dose of 200 mrem to 400 mrem out of the yearly 1000-mrem limit (see Tables 3 and 4).[20]

Potential Effects of Ionizing Radiation

When discussing the deleterious effects of radiation, the accepted theory is a linear nonthreshold model: the higher the radiation exposure, the more damage it can produce.[21] When using this model, any dose of radiation can be harmful. Generally, potential effects of radiation are discussed in terms of acute vs chronic exposure and whole-body vs localized exposure.

Table 3
Occupational Dose Limits[1]

Occupational Dose Limits	mrems
Yearly	5000
Cumulative	1000 × age in years
Lens of the eye	15 000
Extremities/whole skin	50 000

Table 4
Approximate Radiation Dose[20]

Radiation Exposure	mrem
Chest radiograph	10-20
Dental exam	160
Natural background radiation	300
Airline crew (yearly dose)	200-400

Severe Effects

Severe effects of radiation exposure can manifest for either a specific body part or system, or for the entire body. No damage occurring below a dose of 5 rad has been documented.[5] For acute exposure, the smaller the area exposed, the more radiation needed to cause measurable damage. Whole-body radiation exposure of 5 rad or more can cause chromosomal changes, whereas 10 rad are needed to affect gonadal function. Reddening of the skin (erythema) can occur in a small area exposed to 200 rad, and hair loss (epilation) to a comparably sized area can occur at 300 rad. The entire body can be exposed to lower doses with localized effect (eg, cell counts), but if left untreated, a whole-body exposure of 600 rad or more will result in death.[5]

The severity of the effects of acute radiation exposure follows a documented pattern of symptoms based upon the dose received. The prodromal period, directly after exposure of 100 rad or more, is characterized by nausea, vomiting, and diarrhea. This period may be followed by a latent period in which the exposed person does not show any outward symptoms. If the dose received is between 200 rad and 1000 rad, manifest illness begins with a return of the nausea, vomiting, and diarrhea, and includes cell count changes in the blood. Exposures of 1000 rad to 5000 rad lead to lethargy and shock, followed by symptoms of damage to the central nervous system at exposures greater than 5000 rad.[5] The progression of exposure to death can take anywhere from approximately 3 to 60 days, depending upon the whole-body dose.

Long-term Effects of Acute Exposure

Atomic bomb survivors are a unique population that scientists observe to determine the effects of short-term exposure over an extended period of time. The Radiation Effects Research Foundation (RERF) is a cooperative effort between Japan and the United States to track statistical evidence of cancer and other diseases in the survivor population. According to RERF, incidence of radiation-induced cancer coincides with the age at exposure and the time elapsed since exposure. RERF statistics indicate that the younger the age at exposure, the higher the incidence of cancer, which follows the Law of Bergonie and Tribondeau. However, for those victims who lived more than 20 years past the bomb, risk of leukemia became equal to that of the nonirradiated population.[3,5,22]

Chronic Medical Exposure

Chronic exposure to ionizing radiation, even at low doses, has been shown to lead to several health conditions. Cataracts, leukemia, and several types of cancer have been linked to radiation exposure in certain populations, including radiation physicists and early radiologists who practiced before modern safeguards were in use. Clusters of thyroid, bone, and breast cancers have been attributed to the overzealous use of radiation treatment for thymus enlargement, ankolysing spondylitis, and postpartum mastitis.[5]

Acute Medical Exposure

It is an unfortunate truth that some patients are over-radiated in the name of diagnostic imaging. Although the benefits generally far outweigh the risks, there are documented cases of patients suffering erythema, epilation, or worse because of fluoroscopy or similar imaging procedures.[23]

Protection for Technologists

The National Institutes of Health is conducting research on the risks of developing cancer from occupational radiation. With the exception of a possible but still unproven link to breast cancer, modern radiologic technologists (as of 1983) are at no greater risk for cancer than nonradiation workers.[24] However, following radiation safety guidelines is crucial.

The working technologist has 3 types of protection from radiation exposure:

- Inherent protection provided in equipment construction and workspace design.
- Personal protective equipment.
- Understanding the nature of radiation and the inverse square law.

Inherent Protection

The construction of diagnostic imaging equipment includes several elements designed to help keep a technologist's annual dose under the 5000-mrem (50 mSv) limit set by the NRC.[2] The housing of an x-ray tube must be sufficient to absorb any radiation not included in the primary beam so the leakage from the housing at a distance of 1 m does not exceed 100 mR/hr (1 mGy/hr). If initial construction material is not sufficient, extra filtration can be added. The entire filtration for any x-ray tube above 70 kVp (which most multipurpose tubes are) must be equivalent to 2.5 mm of aluminum.[5] The x-ray tube also has a set of collimators, or shutters, which not only helps direct the primary beam, but also absorbs any radiation not acutely focused on the patient.

Radiation protection is a construction component of any room designated for use with radiation equipment. Two types of barriers, primary and secondary, coincide with protection from either the primary beam or secondary scatter. The primary beam is the photon energy directed from the x-ray tube through a patient to an image receptor. The beam is given the most consideration because it contains the highest amount of radiation. Any wall (including floors and ceilings where applicable) perpendicular to the path of the x-ray beam must have at least the equivalent filtration of 1/16 in of lead; this is considered a primary barrier. Secondary barriers are used to protect technologists and incidental personnel from scatter radiation coming from the tube, beam, or patient. Secondary barriers can be equal to half that of a primary barrier, or the equivalent of 1/32 in of lead.[3] Both primary and secondary barriers can be constructed of any material, as long as the thickness used provides the needed filtration.

Workload and Occupancy Factors

Several factors are considered when deciding how much protection is built into a particular room. The workload factor relates to how often the room is used for radiation work and general kilovolt levels used. The occupancy factor refers to the use of rooms adjacent to a radiation workspace, who is using them (radiation worker, nonradiation worker, or the public), and possibility of exposure. The calculations for these and recommended construction information are included in reports 49 and 102 from the NCRP.[25,26]

Personal Protection

Radiologic technologists do not have to think about inherent protection because it is a built-in safety feature in all radiology departments. However, technologists can take steps to further protect themselves from primary and secondary radiation.

Mobile Shielding

A mobile shield is a vertical piece of Plexiglass or metal on wheels. It can be positioned so that a technologist or other personnel can step behind it during a fluoroscopic procedure or radiographic exposure when a lead apron is not available or practical. These devices should contain between 0.5 mm and 1.0 mm of lead equivalent to absorb scatter radiation sufficiently. Mobile shields are particularly useful in the operating room when 1 diagnostic image is being taken, but they are not practical for use with a C-arm.[3]

Personal Shielding

The term "lead shield" can be misleading because many shields are no longer made of lead, but instead a lighter weight composite of other metals (eg, tungsten or tin) at a thickness to be equivalent to the properties of lead.[27] The term is used in this article with the understanding that, in some cases, it may refer to shielding that comprises lead equivalent composites rather than lead.

Lead shields come in different shapes and sizes to protect certain body parts. The most frequently used shield is the body apron, which must be at least a lead equivalent of 0.25 mm.[3,5] The apron is used to protect the bulk of the chest area down through the gonads on the anterior side. Aprons generally have straps with buckles or Velcro to secure the sides, but some have wrap-around straps that place less stress on the shoulders and back. Because aprons only protect the wearer from the front, a technologist should never turn his or her back to the primary beam or patient, who may emit scatter.

The same lead equivalents apply to vest and skirt shielding, which can be used during fluoroscopy (see Figure 2). This pairing provides full protection for the chest to the gonads, both front and back, and sides. Compared with an apron alone, the extra protection of

Figure 2. *Wrap-around skirt and vest shielding.*

the vest-skirt combination increases the weight of shielding and might be a consideration for the technologist.

Because of the "one size fits all" approach, lead aprons and vests may fit loosely and generally do not fully protect the thyroid, a butterfly-shaped gland that sits above the sternal notch in the anterior neck and chest. This gland is sensitive to radiation and should be shielded whenever possible with a thyroid shield with 0.5 mm lead equivalent or greater (see Figure 3).[3] A thyroid shield is fairly lightweight, wraps around the neck, and is secured in the back with Velcro.

Although radiologic technologists should avoid intersecting the primary beam if possible, sometimes it is unavoidable, especially during fluoroscopy. During upper gastrointestinal exams, for example, a technologist may need to help patients turn over or hand them barium to drink during the test. In these cases, the technologist should wear lead-lined gloves to protect his or her hands and wrists. These gloves must have at least a 0.25 mm lead equivalent.[3]

Additionally, protective eyewear should be worn during fluoroscopic procedures or when intersecting the primary beam. Slightly heavier than regular glasses, protective eyeglasses should have side panels of leaded glass and must have 0.5 mm of lead equivalent (see Figure 4).[3]

Inverse Square Law

Time, shielding, and distance are cardinal rules of radiation protection. Understandably, limiting exposure time helps minimize dose, and shielding protects the technologist from low-dose scatter radiation. However, maintaining distance from the source of the scatter is the easiest way for technologists to protect themselves.

A technologist's radiation exposure can be calculated using the inverse square law:

$$I_1/I_2 = (D_2/D_1)^2$$

where I = *intensity of the beam* and D = *distance from the source*. By doubling their distance from the source, technologists can reduce their exposure to one-fourth the original dose (see Box).[11]

Considerations by Modality

During their initial education, radiologic technologists are taught that time, distance, and shielding are the best ways to protect themselves from radiation exposure and adhere to the ALARA principle. If technologists spend as little time as possible near radiation, stand as far as possible from the source, and use shielding, their occupational dose should stay relatively low. However, special considerations should be taken into account, depending upon the modality.

Diagnostic Radiography

Modern radiography departments may use computed radiography (CR), digital radiography (DR), or film cassettes, and often some combination of the 3. Regardless of how the image is captured, the radiation

Box
Calculating Radiation Exposure[11]

Technologists can reduce their exposure to one-fourth the original dose by doubling their distance from the source. For example, if a technologist stands 1 ft from the source of radiation, where the intensity is 10 mR, and then moves back another foot from the source, the equation to find the new intensity of the beam can be calculated using the inverse square law:

$$\frac{I_1}{I_2} = \frac{d_2^2}{d_1^2} \rightarrow \frac{10\text{mR}}{x} = \frac{2^2}{1^2}$$

Square the right side and multiply both sides by *x*:

$$10\text{ mR} = 4x$$

and divide both sides by 4 to get the new intensity of the beam:

$$2.5\text{ mR} = x$$

Figure 3. *Marilyn Rivera, R.T.(R)(CT), wearing a lead apron, thyroid shield, and dosimeter.*

Figure 4. *Thyroid shield and leaded eyewear.*

used for any type of radiography is the same. Although the chosen imaging method may affect patient dose, the same types of protection apply for radiologic technologists regardless of the imaging method.

The control booth is a safe area behind secondary barriers; if the construction of the room is up to code, any radiation in this area will be held to a maximum of 100 mrem (1 mSv) per week.[3] The control panel for the x-ray tube contains exposure controls and an exposure button that may be connected by a cord so the technologist can hold it in his or her hand. The cord should not be long enough to allow the technologist to enter the imaging room while making an exposure. For the safety of both technologist and patient, there should be a leaded glass window that allows the technologist to watch the patient without being exposed to radiation.

Basic radiography rooms are used for many types of examinations, and generally the x-ray tubes can be pointed in any direction. The technologist is responsible for ensuring the tube is never pointed at an open doorway, the control booth wall or window, or anything other than the image receptor. Also, focusing the beam collimators and using the smallest field of view necessary ensures that the patient and technologist are exposed to the least amount of radiation possible.

If a patient needs help remaining still during an exam, patient restraint devices can be used instead of having a staff member hold the patient in place. Some exam tables have safety straps, and wall units may have stabilization bars. Most diagnostic radiography departments also have sandbags that can be used for several purposes, including:

- Weighing down a patient's arms for a cervical spine study.
- Securing a pole the patient is holding for stabilization.
- Keeping an extremity in a particular position.

Adhesive tape only should be used as a last resort to keep a patient or body part still, and only if the patient gives consent.

If personal assistance is necessary, a member of the patient's family should be the first choice to remain in the room with the patient during an exam, provided the relative is not pregnant and does not suspect she may be. If family is unavailable, a hospital employee who generally is not exposed to occupational radiation (eg, a nurse) can help. Radiologic technologists should be the last choice to help a patient stay still during an examination. Finally, whoever remains with the patient in the exam room for this purpose — hospital staff member or not — should be advised of possible radiation exposure and should be given a minimum of a lead apron and a thyroid shield, with leaded eyewear if needed.

Portable Radiography

If a patient is not able to come to the imaging department, basic radiographs can be taken using portable radiography equipment. The technical factors used in portable imaging may be slightly lower than on a fixed machine (eg, using 95 kV without a reciprocating grid compared to 120 kV with a reciprocating grid), but the technologist generally does not have the opportunity to leave the room and take the exposure remotely. To ensure the technologist's safety, the cord to the exposure button on a portable machine must be at least 6 ft (approximately 2 m) long. Each portable x-ray machine should have a hook or storage place for a lead apron, which technologists always should wear when performing portable exams. Additionally, the technologist should stand at least 6 ft from the patient and at a 90° angle from the primary beam, where there is the least amount of scatter (see Figure 5).[3]

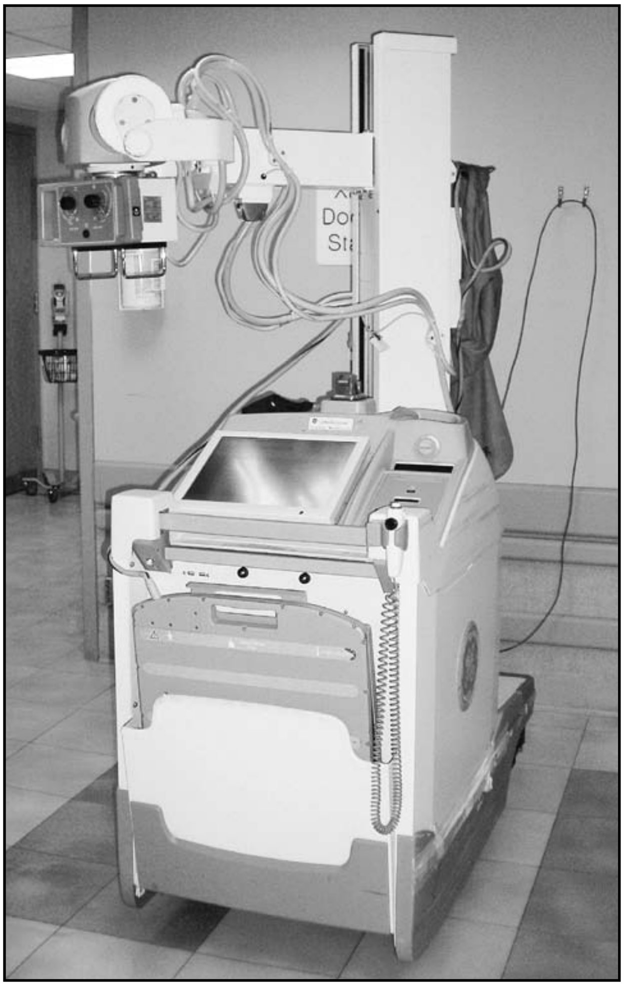

Figure 5. *Portable x-ray machine with 6-ft exposure cord and hook for lead apron.*

Fluoroscopy

Fluoroscopic units are located in diagnostic imaging departments and generally are used for studies involving ingested or inserted barium, or for needle placement such as a myelogram. The table can be positioned horizontally so that the patient lies prone or supine, or it can be tilted vertically to allow the patient to be examined in an upright position. Whereas radiography is static, fluoroscopy is dynamic because it uses x-rays to show real-time images during a procedure. A general fluoroscopic study uses the same x-rays as a regular tube, but it involves a continuous projection of the primary beam instead of 1 exposure. Per NCRP Report 102 requirements, the maximum allowable rate of radiation exposure at a fluoroscopy unit's tabletop is 10 mR/minute. This can raise the patient's dose significantly, which can ultimately raise the technologist's dose.[26]

Fluoroscopy equipment has built-in protection. Traditionally, the x-ray tube is located within the table. Although some models have the x-ray tube over the table, both types have the requisite housing to prevent radiation leakage. There must be at least 2 mm of aluminum equivalent between the tube and the patient to absorb low-dose x-rays, which can increase patient dose without providing additional diagnostic value.

If the tube is located within the table, the tower is situated above the patient — or in front of the patient if the table is positioned vertically — and contains the image intensifier or receptor. Considered a primary barrier, the tower requires at least 2 mm of lead equivalent shielding. The table contains a Bucky tray to hold a cassette for a single image; when fluoroscopy is used, the tray is moved to the patient's feet so the opening in the side of the table is shielded by the tray's slot cover, which contains at least 0.25 mm lead equivalent. A curtain of at least 0.25 mm lead equivalent should be connected to the tower when the table is positioned horizontally.[5] If the x-ray tube is above the patient, then corresponding safety precautions would be taken to satisfy recommendations made in NCRP report 102.[26]

During fluoroscopic procedures, a radiologist, a technologist, and occasionally other personnel are usually in the exam room with the patient. It is especially important for all personnel to adhere to the rules of time, distance, and shielding during fluoroscopy. The pedal, pulse mode, and timer can help with limiting the exposure time. The main exposure button for fluoroscopy is a foot pedal, which may be a rounded piece of rubber that lies flat on the floor or a metal pedal. The foot pedal is attached to the fluoroscopy unit by a long cord and is generally positioned so the radiologist can stand on the pedal while manipulating the fluoroscopy tower. The pedal is called a "dead man's switch" because the beam will stop if pressure on the pedal is removed for any reason.[5] There also will be an exposure button on the tower or the table console of the fluoroscope that the radiologist may prefer to use, and it must be continuously pushed.

The fluoroscopic tube also has the option of a pulsed beam for fewer frames per second. For general fluoroscopy work, this will not interfere significantly with the diagnostic quality of the test. However, it will reduce patient dose and scatter production as a result.

Fluoroscopy units are equipped with timers that sound an alarm after 5 minutes of fluoroscopy time, forcing the technologist or radiologist to acknowledge the cumulative exposure time and silence the alarm. Even before the alarm sounds, it is within the scope of practice for the technologist to remind the radiologist of exposure time for the safety of everyone in the room. Alarms will continue to sound at each 5-minute interval of fluoroscopy exposure.[5]

Keeping a sufficient distance from primary and secondary sources of radiation during fluoroscopy can be a challenge. The technologist often is called upon to help move the patient or manipulate equipment during an exam. According to the inverse square law, the technologist should stand as far away from the patient as possible while still being able to perform his or her duties.

Shielding is essential for technologists and any other personnel present during fluoroscopy procedures. Often technologists must stand near the primary beam and the patient, whose body generates scatter, to assist the radiologist with the exam. Personnel should wear a full lead vest and skirt, thyroid shield, and leaded glasses. If full vests and skirts are not available, technologists should wear aprons and pay special attention not to turn their backs toward the primary beam or patient because the physician could initiate the primary beam at any time. Although lead gloves may not be practical for tasks that require dexterity, they should be worn if a technologist's hands will make contact with the primary beam or the patient (ie, holding the barium for the patient to drink during the exam).

Operating Room

Several routine procedures in the operating room (OR) require a radiologic technologist's assistance. Plain radiographs often are used to check the location of a needle in spinal surgery or to perform a quick cholangiogram after stent placement. The biggest adjustment when using a portable machine in the OR is beam intensity. Because of the sterile surgical site and surrounding area, the intensity of the beam may need to be increased or decreased to compensate for changes in source-to-image distance or object-to-image distance. The technologist always should use a mobile shield or wear a lead apron and extend the full length of the 6-ft cord on the exposure button to ensure the lowest occupational dose.

Similar to a portable fluoroscopy machine, a mobile C-arm also is used in the OR. It is shaped like a "C," with the x-ray tube mounted on the bottom curve and the image intensifier/receptor on the top curve.[11] This unit can be useful in the OR for both static and real-time imaging of fixation screws, pacemaker lead placement, or angiographic work. A C-arm can be draped for sterility and moved over or under the patient, rather than moving the patient. The challenge for technologists is keeping track of the x-ray tube — and therefore the direction of the primary beam — as its mobility means it can irradiate the patient and surrounding personnel from almost any direction.

A C-arm generally has 2 basic exposure buttons: 1 on a cord similar to a portable x-ray machine, and 1 on a foot pedal that may be by itself or included on a panel of several pedals. C-arms generally have the same capabilities as fixed fluoroscopic equipment, and can be operated in pulse or angiographic mode using other pedals on the foot panel. When in an OR with a C-arm, the technologist is within his or her scope of practice to remind the physician or other personnel of radiation safety guidelines and to ensure his or her own safety by wearing wrap-around lead and a thyroid shield.[28]

Computed Tomography

Modern helical (or spiral) CT units are constructed using slip-ring technology that allows the x-ray tube to rotate 360° around the patient as the table moves through the gantry (see Figure 6).[5] A helical unit can complete an entire dynamic study in less than 1 minute, but the primary beam is on the entire time. There are some CT exams performed where the beam is only on for a partial rotation, but in terms of real time, it would be impossible to distinguish with respect to radiation protection. Because of the continuous exposure of the beam, patient dose in CT can be significantly higher than in radiography. For occupational dose, however, it is generally the opposite. Most CT technologists receive little to no radiation exposure because they are usually safely behind the secondary barrier of the control room wall when the beam is on.

Figure 6. *Computed tomography gantry, rear.*

Helical units are used for special procedures performed by a radiologist or other physician using the guidance of CT images to place a needle for tissue biopsy or a drainage tube for an abscess. All units can image the same 20 mm of tissue at given intervals to check for needle placement. Some CT units also are capable of fluoroscopy, which can reduce the length of the procedure because it provides real-time imaging. However, CT fluoroscopy also can raise the patient's exposure if the radiologist or other physician does not use the fluoroscopy pedal judiciously. As in radiography, raising patient exposure produces a greater amount of scatter, which increases occupational exposure for technologists and other personnel who may be assisting in the exam room. Wrap-around lead and thyroid shields should be worn, with leaded glasses if needed, by any technologist or other personnel who must assist the patient during the exam. As always, the technologist should avoid holding the patient if any other staff or family member is available to do so.

Interventional Radiology

Interventional radiology is performed by specialized radiologists using invasive procedures under fluoroscopic guidance for diagnostic or therapeutic purposes. The equipment used in interventional radiology looks similar to a C-arm used in the OR, and although it differs in some aspects to regular diagnostic equipment, the x-ray beam and resultant scatter are the same. Interventional radiology procedures generally require more time — up to several hours more — than fluoroscopy procedures conducted in the diagnostic radiography department.[29] Because of the length of time the technologist is exposed to the beam, working in the interventional radiology suite generally carries the greatest risk for occupational radiation exposure. According to Bushberg et al, the average technologist working in diagnostic radiography receives approximately 100 mrem per year; for those who work in interventional radiology that number can be as high as 1500 mrem.[15] To minimize their exposure, technologists should follow all shielding guidelines and can be rotated between the exam room and the control room.

Nuclear Medicine

All members of a diagnostic radiology department may be called upon to assist with transferring a patient to an exam table or transporting a patient between modalities; therefore, all technologists should understand the differences in radiation safety requirements between radiography and nuclear medicine. The machinery used in nuclear medicine does not emit radiation and poses no risk to the patient or technologist. Any risk of exposure to a nuclear medicine technologist comes from radiopharmaceuticals (radioactive isotopes combined with particular drugs to pinpoint the body part of interest), either before or after they are administered to a patient.[30]

Radioactive isotopes are stored in special containers in a clearly marked room per NRC standards. The dosage of any particular isotope is based on its half-life, or the amount of time it will take for the radioactivity to be halved.[5] Once the correct patient dose (measured in millicuries) is calculated, the nuclear medicine technologist administers the radiopharmaceutical to the patient while following established department protocol. The radiopharmaceutical travels through the patient's body, where it is either diffused throughout or concentrated in a particular organ or disease process, depending on the tagging characteristic of the radiopharmaceutical used for the test. The patient emits gamma rays and beta particles that are used to produce the diagnostic image and can be a source of radiation exposure for others.[5]

Transport of the radiopharmaceutical to the patient also depends on the nature of the test. Some doses may need to be given to a patient at a certain time before the test. If a technologist needs to leave the nuclear medicine department to inject a patient, the syringe containing the isotope is transported in a lead-lined box. The syringe also may have a lead-equivalent shield to protect the hands of the nuclear medicine technologist.[30] No one other than a technologist should handle the box or the syringe.

Once the isotope is administered to the patient, the wait before the actual nuclear medicine test begins can be anywhere from 30 minutes to an entire day.[31] Patients (and caregivers if present) receive explicit instructions regarding radiation safety if there is any danger of radiation exposure to others. Although there are some isotopes used in medical imaging that may take days to completely decay, most do so within a few hours to a day. Generally, patient radiation exposure from a nuclear medicine test is equivalent to that of other modalities in diagnostic radiology.[32]

As with other modalities, time, distance, and shielding are the best way for nuclear medicine radiologic technologists to avoid radiation exposure from a patient injected with a radioactive isotope. One hour after injection of a radioactive isotope, exposure rates at a 1-m distance from the patient vary from 0.54 mrem to 1.5 mrem. A notable exception is any test that uses iodide 131, which can have a rate of up to 45 mrem per hour depending on the dose.[33] However, NRC regulations state that patients given radioactive iodine only may be released from isolation if they emit less than 5 mrem per hour at a distance of 1 m.[34] The nuclear medicine technologist is charged with keeping personnel aware of any danger from patient exposure.

The inverse square law also applies to the nuclear medicine department. Doubling the distance from a patient will decrease any possible exposure to one-fourth the original amount. Lead aprons or skirts are also available in a nuclear medicine suite for any technologist that wants to avoid even a small amount of exposure.

Considerations for Pregnant Technologists

A pregnant radiologic technologist is under no federal obligation to report her pregnancy to her manager, but full disclosure will make it easier to avoid any unnecessary exposure. Not exceeding the radiation dose limit for an embryo or fetus is easily achieved by following the time, distance, and shielding rules. A pregnant technologist should wear a wrap-around lead apron or skirt and vest when assisting during fluoroscopy or CT examinations, or when transporting a nuclear medicine patient. Also, a fetal dosimeter should be issued as soon as possible. The dosimeter should be worn at waist level and beneath any lead shielding the technologist wears.[5] Any questions regarding possible exposure to the fetus should be referred to the facility's radiation physicist.

The Future of Radiation Protection

Radiation protection is not a static field. In recent years there have been several studies worldwide concentrating on improving our understanding of how to keep radiation workers and the public safe from unwanted radiation exposure. The Multispecialty Occupational Health Group, whose membership includes several specialty organizations such as the Societies of Interventional Radiology and Neuro-Interventional Surgery, continues to meet and present recommendations for keeping radiation dose low in the interventional suite.[35]

Two studies were published in 2011 that discussed radiation exposure and protection during endoscopic retrograde cholangiopancreatography. A group from British Columbia conducted a retrospective analysis on fluoroscopy times to determine if specific patient and illness criteria could be used to anticipate and plan for longer exams.[36] At a similar time, a study of Korean radiation protection practices during endoscopic retrograde cholangiopancreatography highlighted the alarming statistic that only 52.5% of endoscopists regularly wear a thyroid shield, while 75% of those questioned do not monitor their radiation dose.[37]

Not all countries are as standardized as the United States when discussing radiation protection. A 2011 study of 18 public and private radiography facilities in Edo State, Nigeria, reported that only 7 (39%) had programs to monitor the radiation exposure of their workers.[38]

Conclusion

It has been more than 100 years since Wilhelm Roentgen deciphered most of the properties of x-rays. However, every advance in medical imaging technology since then has necessitated a reworking of radiation protection standards for occupational radiation workers. Educating radiologic technologists on the basics of radiation production, the damage potential for human tissue, and the ways in which technologists can protect themselves are minimum standards that should be enforced in hospital diagnostic imaging departments. In this dynamic field, ongoing research and education is necessary to assist all radiologic technologists in keeping their occupational radiation exposure as low as reasonably achievable.

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1. The _______ mandates construction specifications of exam rooms and adjacent areas and dose monitoring procedures to protect those who work with radiation.
   a. American Society of Radiologic Technologists
   b. Nuclear Regulatory Commission (NRC)
   c. Department of Environmental Protection
   d. National Council on Radiation Protection & Measurements

2. _______ was the first person to recommend lead shielding for x-ray tubes.
   a. Wilhelm Roentgen
   b. Thomas Edison
   c. Clarence Dally
   d. William Rollins

3. Ionizing radiation used in diagnostic imaging departments include:
   1. beta particles.
   2. x-rays.
   3. gamma rays.

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

4. Scatter radiation produced by _______ presents the greatest danger to radiologic technologists.
   a. the Compton effect
   b. coherent scatter
   c. the photoelectric effect
   d. Bremsstrahlung photons

5. The radiation intensity of diagnostic x-rays typically is measured in:
   a. millirads.
   b. milligrays.
   c. milliroentgens.
   d. millisieverts.

6. Ring badges are generally worn by _______ technologists.
   a. computed tomography (CT)
   b. nuclear medicine
   c. diagnostic radiography
   d. fluoroscopy

Continued on next page

Directed Reading Continuing Education Quiz

7. According to NRC occupational dosimetry regulations, the cumulative dose limit for a 35-year-old technologist is _______ mrem.
   a. 350
   b. 3500
   c. 35 000
   d. 350 000

8. Hair loss, or epilation, to a particular part of the body can occur at an exposure of _______ rad.
   a. 150
   b. 300
   c. 600
   d. 1200

9. Clusters of thyroid, bone, and breast cancers have been attributed to overzealous use of radiation treatment for all of the following ***except***:
   a. thymus enlargement.
   b. leukemia.
   c. postpartum mastitis.
   d. ankolysing spondylitis.

10. Which of the following materials can be used to construct a secondary barrier against scatter radiation from x-ray tubes, beams, or patients?
    1. lead
    2. glass
    3. concrete

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

11. Lead aprons and vests do not fully protect the _______, which require(s) separate shielding.
    a. thyroid gland
    b. gonads
    c. abdomen
    d. chest

12. According to the _______, radiologic technologists can reduce their dose by one-fourth when they double their distance from the radiation source.
    a. ALARA principle
    b. inverse square law
    c. rules of time, distance, and shielding
    d. Law of Bergonie and Tribondeau

13. If personal assistance is needed to help a patient keep still during a diagnostic radiography exam, a _______ should be the first choice to remain in the room with the patient during an exam, unless that individual is pregnant.
    a. radiologist
    b. radiologic technologist
    c. nurse
    d. member of the patient's family

14. When imaging with portable radiography equipment, the safest place for a technologist to stand is 3 feet from the patient at a 45° angle.
    a. true
    b. false

15. Fluoroscopy machines have a pulsed beam option that reduces all of the following ***except***:
    a. diagnostic quality.
    b. patient dose.
    c. radiation scatter.
    d. frames per second.

16. _______ are equipped with timers that sound an alarm every 5 minutes during exams to monitor cumulative exposure time.
    a. CT scanners
    b. Nuclear medicine cameras
    c. Portable radiograph machines
    d. Fluoroscopic machines

Continued on next page

Directed Reading Continuing Education Quiz

17. Resulting scatter produced by the x-ray tube of a fluoroscopy table is more likely to reach the _______ of anyone standing near the beam and patient.
    a. extremities
    b. lower body parts
    c. upper body parts
    d. midsection

18. During radiographic imaging in the operating room (OR), the technologist should use a mobile shield or wear a _______, at the very least.
    a. pair of leaded gloves
    b. thyroid shield
    c. full vest
    d. leaded apron

19. Keeping track of the _______ can be a challenge for technologists when using a C-arm for static or real-time imaging in the OR.
    a. 6-ft cord
    b. x-ray tube
    c. foot pedal
    d. beam intensity

20. Patient dose can be significantly _______ in CT compared to radiography, whereas occupational exposure tends to be _______.
    a. higher; lower
    b. lower; higher
    c. higher; the same
    d. lower; the same

21. _______ procedures generally require up to several hours more time than fluoroscopy procedures conducted in the diagnostic radiography department.
    a. CT fluoroscopy
    b. Nuclear medicine
    c. Interventional radiology
    d. Portable fluoroscopy

22. According to Bushberg et al, technologists who work in interventional radiology may receive as much as _______ mrem per year, whereas the average technologist working in diagnostic radiology receives approximately 100 mrem.
    a. 50
    b. 150
    c. 1500
    d. 15 000

23. In nuclear medicine, the dosage of a radioactive isotope is based on the amount of time it will take for the radioactivity to be:
    a. contained.
    b. inactive.
    c. effective.
    d. halved.

24. After a radioactive isotope is administered to the patient, the wait can be anywhere from 30 minutes to _______ day(s) before the nuclear medicine test can begin.
    a. 1
    b. 2
    c. 3
    d. 4

25. Pregnant technologists should wear fetal dosimeters at _______ level and _______ any lead garments they might be wearing.
    a. waist; on top of
    b. chest; on top of
    c. waist; underneath
    d. chest; underneath

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Directed Reading Evaluation

Radiation Safety for Radiologic Technologists

ASRT DIRECTED reading

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- ○ Computed Tomography
- ○ Education
- ○ Magnetic Resonance
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- ○ Nuclear Medicine
- ○ Quality Management
- ○ Radiation Therapy
- ○ Radiography
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- ○ RN
- ○ Sonography
- ○ Other ____________________

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- ○ Master's degree
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Radiation Safety for Radiologic Technologists

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7	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
8	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
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Stroke and CT Perfusion

MARLENE M JOHNSON, MEd, R.T.(R)

Stroke is one of the leading causes of long-term disability and the fourth leading cause of death in the United States, killing more than 137 000 people a year. Time is critical during a stroke because prompt diagnosis and subsequent treatment can prevent the potential loss of brain function. Radiologic technologists who work in computed tomography (CT) must know how to perform CT perfusion and understand stroke diagnosis. This article provides information regarding strokes and CT perfusion techniques, including data acquisition, postprocessing, and interpretation.

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After completing this article, readers should be able to:

- *Differentiate between ischemic and hemorrhagic stroke.*
- *Explain why rapid and effective imaging is critical for ischemic stroke patients.*
- *Describe the concept of "penumbra" as it relates to stroke imaging and treatment.*
- *Identify the parameters evaluated when performing brain CT perfusion examinations.*
- *Describe what the color-coded maps developed in CT perfusion demonstrate.*

Stroke is the leading cause of mortality and morbidity in the developed world.[1] Expeditious and effective imaging is critical for patients suspected of having strokes to increase the chances that physicians can salvage brain function before permanent damage has occurred.[2] Restoring blood flow is a principal goal when treating patients who have had ischemic strokes, and computed tomography (CT) is the most commonly used technique for diagnosing strokes.[2] CT can display evidence of bleeding into the brain nearly immediately, a critical finding that will differentiate between hemorrhagic and ischemic stroke and permit faster treatment.[2]

A recent development in CT, known as dynamic CT perfusion, has resulted in higher resolution images and the ability to create graphs charting blood flow and blood volume over a fixed period.[3] This ability to observe and quantify perfusion in the brain has been an invaluable step in enabling physicians to make rapid and accurate treatment decisions.[3] The value of CT perfusion comes at the cost of radiation exposures that are higher than normal, so the studies are ordered only as needed.

In 2009, the U.S. Food and Drug Administration (FDA) investigated several cases of radiation overexposure during CT perfusion studies. The agency found that patients experienced epilation and erythema because of exposure from the CT examinations. The resulting 2010 FDA report concluded that the radiation overexposures were attributed to a number of reasons, such as the use of high-radiation exposure protocols, lack of operator resources and training, and a lack of safety equipment on CT scanners.

Combining noncontrast CT, CT perfusion, and CT angiography (CTA) provides a comprehensive imaging evaluation of acute stroke that can display the arterial blood supply to the brain and assist in prompt assessment of vascular anatomy and regional hemodynamics.[4] CT perfusion also can be used to evaluate other cerebrovascular conditions and to grade tumors.[2]

Stroke Statistics

Stroke is a leading cause of death in developed countries and the fourth leading cause of death in the United States.[1] Of the approximately 795 000 people in the United States older than 20 years of age who have a new or recurrent stroke each year, approximately 137 000 die.[1] In addition to high morbidity and mortality rates, stroke is one of the most common causes of long-term disability.[2] Between 20% and 30% of stroke victims do not survive, and 55% of survivors have disabilities.[1]

Women have a higher lifetime risk of stroke than men. Lifetime risk of stroke for women aged 55 to 75 years is 1 in 5 (20% to 21%) and approximately 1 in 6 (14% to 17%) for men.[1] On average, women are older at stroke onset (75 years) than men (71 years), and more women than men die of stroke each year. The difference is attributed to the higher number of elderly women. Women accounted for 60.1% of U.S. stroke deaths in 2008.[1] Blacks have about twice the risk of first stroke that whites do.[1] This difference is due to the higher incidence of risk factors in African Americans and the higher incidence and prevalence of some genetic diseases related to stroke.[2] Although the lifetime risk for stroke at age 65 decreased significantly for whites from the 1990s to 2005, a similar decline was not observed in blacks.[1] Hispanics, Native Americans, and Asian Americans have stroke incidence and mortality rates similar to those of white Americans.[2]

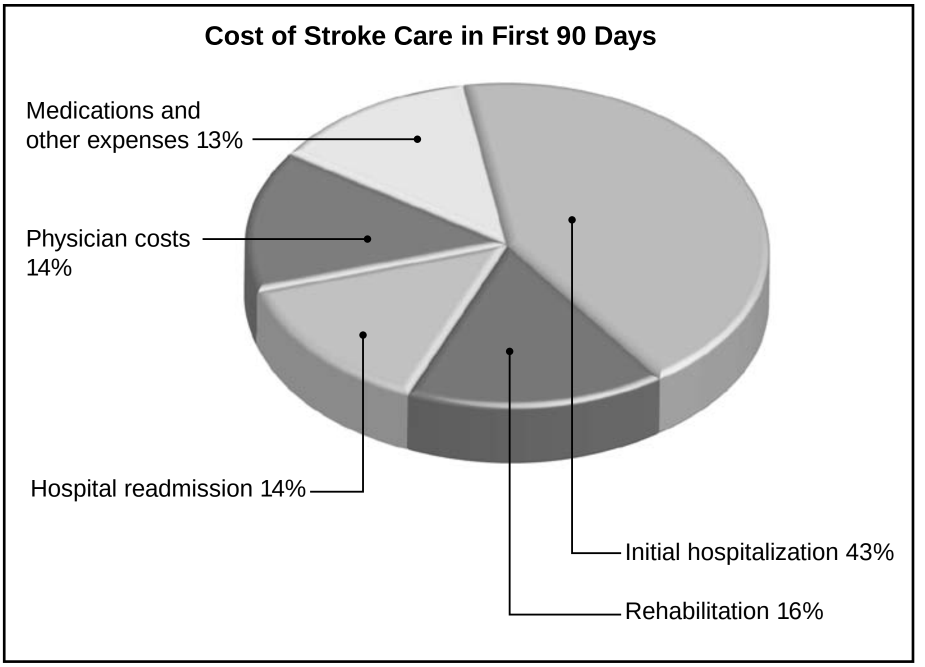

Figure 1. *The average cost of caring for a patient in the first 90 days following a stroke is between $15 000 and $35 000 for 10% of patients. National Institute of Neurological Disorders and Stroke. Stroke: hope through research. www.ninds.nih.gov/disorders/stroke/detail_stroke.htm. Accessed January 8, 2012.*

In 2008, approximately 54% of stroke deaths occurred outside of hospitals.[1] A review of published studies and data from clinical trials found that hospital admissions for intracerebral hemorrhage has increased 18% in the past 10 years, mainly because of a proportionately higher elderly population, many of whom lack adequate blood pressure control, along with increased use of anticoagulants, thrombolytics, and antiplatelet agents.[5] Stroke accounted for 1 of every 18 U.S. deaths in 2008.[1] Still, the statistical outcomes for stroke improved from 1998 to 2008, with the annual stroke death rate decreasing 34.8% and the actual number of stroke deaths declining 19.4%.[1,2]

Recurrent stroke is a frequent and major contributor to stroke disability and death.[2,5] Approximately 25% of people who recover from their first stroke will have another stroke within 5 years, and the risk of severe disability or death from stroke increases with each stroke recurrence.[2,5] The risk of recurrence is greatest immediately following a stroke, and the risk decreases with time. About 3% of stroke patients have a stroke within 30 days of their first stroke and one-third of recurrent strokes take place within 2 years of the first stroke.[2]

The total annual cost of strokes to the U.S. health care system is estimated to be about $43 billion.[2] Indirect costs from lost productivity and other factors could be as high as $15 million per year.[2] The greatest portion of the direct cost of care of stroke patients during the first 90 days is the initial hospitalization (43%), followed by rehabilitation, physician costs, hospital readmission, and medications and other expenses (see Figure 1).[2]

Stroke Categories

The carotid artery and the basilar artery, formed by the vertebral arteries, are the 2 main vascular structures that provide a continuous supply of oxygen to the brain.[5] Stroke can be classified into 2 broad categories: ischemic and hemorrhagic.[2,3,5] Ischemic stroke occurs when a blood vessel supplying the brain is blocked. Hemorrhagic stroke occurs when a blood vessel ruptures and bleeds into or around the brain. Ischemic strokes account for an estimated 80% to 85% of all strokes, and hemorrhagic strokes make up the remaining 15% to 20%.[2,3,5] Strokes also can be categorized as completed or progressive. In completed strokes, the infarction of brain tissue has ceased to occur. Progressive strokes are those that are still evolving, meaning the patient's condition is continuing to deteriorate. When progressive strokes affect the carotid arteries' ability to carry oxygen, there is little chance the effects will last longer than 24 hours.[5] The disruption of oxygen flow involving the vertebrobasilar blood supply can continue progressing for up to 72 hours.[6]

Ischemic Stroke

An ischemic stroke, also called cerebral ischemia, occurs when an artery supplying blood to the brain becomes blocked, suddenly decreasing or halting blood flow and ultimately causing a brain infarction.[2] The 3 divisions of ischemic stroke are thrombotic, embolic, and lacunar.[2,3,5] Blood clots are the most common cause of blocked arteries and brain infarction. The clots cause ischemia and infarction in 2 ways:

- A travelling, free-roaming blood clot called an embolus becomes wedged in a brain artery, blocking blood flow and causing an embolic stroke.
- A blood clot called a thrombus forms in 1 of the cerebral arteries and eventually grows large enough to block blood flow and cause a thrombotic stroke.[2,3,5]

Ischemic strokes also can be caused by stenosis, the narrowing of an artery due to the buildup of plaque and blood clots along the artery wall.[2,5] The stenosis most often is caused by atherosclerosis, in which plaque buildup causes the arteries to narrow and lose flexibility.[2,3,5] Plaque is a mixture of fatty substances, including cholesterol and other lipids. Plaque in the carotid arteries reduces the amount of blood and oxygen delivered to the brain and can occlude the artery, causing an ischemic stroke.[2,5] Atherosclerosis of the carotid arteries is by far the most common predisposing condition for stroke.[2,3,5]

Stenosis can occur in large or small arteries and might be referred to as large vessel disease or small vessel disease.[2,5] Stroke from small vessel disease results in a very small infarction, called a lacunar stroke or infarction, from the French word *lacune*, meaning gap or cavity.[2,5]

Hemorrhagic Stroke

The healthy brain's neurons require a delicate balance to function.[2] Neurons receive oxygen and nutrients through the thin walls of the cerebral capillaries and normally do not come into direct contact with blood.[2] A blood-brain barrier is formed by the glia, nervous system cells that support and protect the neurons. This barrier is an elaborate meshwork that surrounds blood vessels and capillaries and regulates which elements within the blood can pass through the neurons.[2] When an artery in the brain bursts, blood spills into the encircling tissue, upsetting the blood supply and chemical balance, and resulting in a hemorrhagic stroke (see Figure 2).[2,3,5]

Hemorrhagic strokes are classified based on how and where they occur.[5] Blood from ruptured brain arteries can enter the brain's tissues or the various spaces surrounding the brain.[2] Subdivisions of hemorrhagic stroke are intracerebral, subarachnoid, arteriovenous malformations (AVMs), and hypotensive.[2,5]

Intracerebral is the most common type of hemorrhagic stroke, occurring when a vessel in the brain leaks blood into the brain.[5] This type, which accounts for approximately 50% of all hemorrhagic strokes, usually results from hypertension, which exerts pressure on arterial walls already weakened by atherosclerosis.[5] The hemorrhage produces a hematoma, generally in the brain's parenchyma. Patients with heart attack histories have slightly higher risks for intracerebral strokes if they have received blood thinners or drugs to break up clots.[5]

Subarachnoid hemorrhage is bleeding under the meninges, or outer membranes of the brain, into the thin fluid-filled space that surrounds the brain. Subarachnoid hemorrhages comprise 1% to 7% of all strokes and usually are caused when an aneurysm ruptures.[5] In 85% of subarachnoid hemorrhage cases, the cause is a ruptured cerebral aneurysm that occurs spontaneously or from a head injury.[5] Approximately one-half of all subarachnoid hemorrhages are fatal and 10% to 15% of people who have this type of stroke die before they reach a hospital.[5] Neurological or cognitive impairment is common in patients who survive subarachnoid hemorrhages. Traumatic subarachnoid hemorrhage usually occurs near the site of a skull fracture or intracerebral contusion.[5]

A person with an AVM has an increased risk of a hemorrhagic stroke.[2,5] AVMs are tangles of defective blood vessels and capillaries within the brain with thin walls that can rupture.[2] Brain tissue is interposed between the vessels and usually is scarred from previous tiny hemorrhages. The patient with an AVM often is unaware of the condition or only experiences bad headaches.[2,5] An AVM shunts blood from the arterial system directly to the venous system, bypassing the capillary beds where oxygen and glucose normally are exchanged in brain cells. AVMs prevent the normal drop in pressure that should occur as the blood travels from arteries to veins, resulting in oxygenated blood with pressure that is above normal when the blood enters the veins. This increase in pressure can cause the vessels to rupture and result in a hemorrhagic stroke.[2,5]

A rare type of hemorrhagic stroke called hypotensive stroke occurs when blood pressure is too low, resulting in reduced oxygen supply to the brain.[5] In a hypotensive stroke, the blood flow is so low that cerebral autoregulation mechanisms cannot compensate, and the stroke episode occurs.[5]

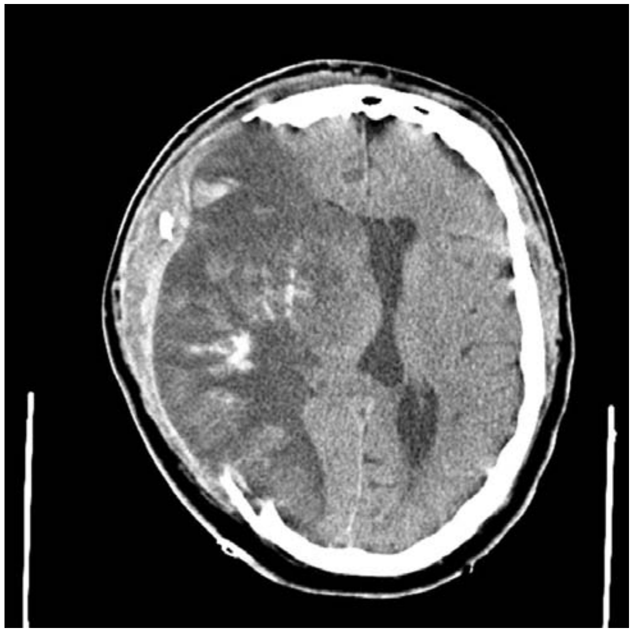

Figure 2. *Noncontrast computed tomography (CT) scan of the head. A portion of the cranium was removed to relieve the pressure from a subarachnoid or other type of hemorrhage. Once the swelling subsided, the removed piece of the cranium was surgically put back into place. Image courtesy of Ulrich Rassner, MD, University of Utah Health Care, Salt Lake City.*

Stroke Symptoms

Even though stroke episodes occur deep within the brain, the symptoms they cause are obvious. A stroke usually can be distinguished from other causes of headache or dizziness by the presence of more than 1 symptom.[2,5] For all types of stroke, symptom onset is sudden: The person having a stroke might experience sudden numbness or weakness, especially on 1 side of the body; sudden confusion; trouble speaking or understanding speech; difficulty seeing in 1 or both eyes; difficulty walking; dizziness, or loss of balance or coordination; or a severe headache with no known cause.[2,5] These symptoms indicate a need for immediate medical attention.[2,5]

Transient Ischemic Attack

A transient ischemic attack (TIA), sometimes called a mini stroke, is an episode of cerebrovascular insufficiency usually associated with partial occlusion of the cerebral artery by an atherosclerotic plaque or an embolus.[2,3,5,6] A TIA is a significant indicator that a more serious stroke is to come; however, there is virtually no way to distinguish between most of the signs and symptoms in a person experiencing a TIA or full stroke at onset.[2,5] The main distinguishing feature between a stroke and a TIA is that signs diminish or disappear with a TIA, which does not occur with stroke. Frequently, a small emboli lodges in an artery, much like with a stroke, and then quickly breaks and dissolves, resulting in no damage.[2,5]

TIAs are considered reversible episodes of localized neurologic dysfunction that usually last a few minutes and disappear within an hour.[2,5,6] Approximately 5% of patients who experience TIAs have a stroke within a month of the TIA and, without intervention, one-third of the 50 000 Americans who have a TIA each year have a stroke within 5 years.[5] Having a TIA is also a warning sign of a possible heart attack.[2,5]

Strokes and TIAs have the same general symptoms, although symptoms can vary depending on where the stroke or TIA is occurring.[3] For example, symptoms of a TIA in the carotid arteries differ from symptoms of TIAs in the basilar artery.[3] Because the carotid arteries supply blood to the retinal artery in the eye, emboli originating in carotid arteries cause symptoms in the retina or cerebral hemisphere.[3] Decreased oxygen to the eye causes a visual effect often described as "a shade being pulled down."[3] Poor night vision can be a result of a carotid TIA. When the cerebral hemisphere is affected with a TIA, the patient might experience problems with speech, partial and temporary paralysis, tingling, and numbness, typically on 1 side of the body.

The major difference in symptoms resulting from TIAs in the basilar artery compared with the carotid arteries is that both hemispheres of the brain might be affected with symptoms occurring on both sides of the body.[3] The patient might indicate temporary dim, gray, blurry, or lost vision in both eyes; tingling or numbness in the mouth, cheek, or gums; headache in the back of the head; dizziness; nausea; vomiting; difficulty swallowing; difficulty with speech; and weakness in the arms and legs, sometimes causing a sudden fall.[3,6]

Ischemic Stroke

Symptoms of a major ischemic stroke can vary, depending on the source, and can be identical to those of a TIA.[3,5] If the stroke is caused by a large embolus that has traveled to the brain and lodged there, the onset is sudden. If the stroke results from a thrombosis that has formed in a narrowed artery, symptoms occur more gradually, manifesting to full onset within minutes to hours, and on some rare occasions, from days to weeks.[3,5] Headache and dizziness occur within seconds of the blockage. A thrombosis on 1 side of the brain usually affects the opposite side of the body, with possible unilateral weakness, loss of feeling on 1 side of the face or in 1 arm or leg, or blindness in 1 eye. If the left hemisphere is involved, speech generally is affected. The patient might have difficulty expressing his or her thoughts or understanding spoken words. Patients might experience major seizures and coma from ischemic strokes.[3,5]

Hemorrhagic Stroke

Hemorrhagic stroke symptoms depend on how and where the hemorrhage occurs.[2] They tend to begin suddenly and evolve over the course of several hours. Symptoms include headache, nausea, vomiting, and an altered mental state. Sensitivity to light can be an early sign of a subarachnoid hemorrhage caused by the leaking of a blood vessel a few days to a month before an aneurysm in the vessel fully develops and ruptures.[2] When an aneurysm ruptures, the patient might experience a terrible headache, neck stiffness, an altered state of consciousness, or loss of vision; his or her eyes also might become fixed in 1 direction.[3,5]

Hypertensive Stroke

Symptoms of hypertensive stroke are loss of vision, decreased alertness, and weakness that mostly affects the shoulder, hand, and thigh. Silent brain infarctions are small strokes that cause no symptoms but affect mental status. Approximately 33% of patients older than 65 years of age experience silent brain infarctions, and the infarctions are a major contributor to decline in mental stability among the elderly.[3,6]

Stroke Risk Factors

Factors that put some people at higher risk for stroke than others can be divided into 2 categories: modifiable and unmodifiable.[2]

Unmodifiable Risk Factors

Unmodifiable risk factors include:

- Age.
- Gender.
- Race/ethnicity.
- Family history of stroke.
- Heart disease such as atrial fibrillation.
- Diabetes mellitus not related to obesity.
- Migraines.[2,5]

Although stroke can occur in all age groups, including fetuses, risk increases with age, doubling every 10 years after age 55.[2,5] People older than 65 years of age have a 7 times greater risk of dying from stroke than the general population, and two-thirds of all strokes occur in people older than 65 years of age.[2] An individual's genetic makeup might be responsible for many of the processes leading to stroke.[2] Studies show that a family history of stroke, particularly on the paternal side, is a strong risk factor.[2,5] The risk of stroke varies among different ethnic and racial groups.[2] In particular, the risk of stroke is higher among black Americans than other groups because stroke risk factors such as certain genetic diseases occur more often in that population.[2]

Heart disease, particularly atrial fibrillation, is a powerful risk factor for stroke and by age 70 years, 10% of adults have this disorder.[2,5] People who have atrial fibrillation have a 6-fold increase in stroke risk.[3] Atrial fibrillation is a disorder of the heart rate and rhythm in which the left atrium contracts in a rapid or disorganized manner.[5] The left atrium can beat up to 4 times faster than the rest of the heart in people with atrial fibrillation, resulting in irregular blood flow and occasional blood clot formation. The clots can leave the heart and travel to the brain, causing a stroke. Malformations of the heart valves or the heart muscle can increase the risk of stroke. Cardiac heart surgery to correct heart malformations or reverse the effects of heart disease can increase a person's risk for stroke by 1%.[2]

Diabetes is a strong risk factor for ischemic stroke, but not hemorrhagic stroke. People with diabetes have 3 times the risk of stroke compared with people who do not have the disease.[2] People with diabetes tend to have higher associated risk factors for stroke, such as obesity, high cholesterol levels, and hypertension.[5] People who have regular migraines have a slightly higher risk for stroke that is particularly significant before 50 years of age.[5]

Modifiable Risk Factors

Modifiable factors include:

- Hypertension.
- Smoking, alcohol, and drug abuse.
- High blood levels of homocysteine and vitamin B deficiencies.
- Unhealthy cholesterol balance.
- Obesity.[2,3,5]

Hypertension contributes to 70% of all strokes.[2,3,5] It is estimated that helping people control their blood pressure could prevent nearly one-half of all strokes.[2,5] People with hypertension have 4 to 6 times higher risk for stroke than those with normal blood pressure.[2] Recent studies suggest that treatment with antihypertensive medications can decrease stroke incidence by 38% and the stroke fatality rate by 40%.[2] Common hypertensive agents include adrenergic agents, beta-blockers, angiotensin-converting enzyme inhibitors, calcium channel blockers, diuretics, and vasodilators.[2]

Smoking increases the risk of stroke by promoting atherosclerosis and increasing the levels of blood clotting factors.[2] Of all the modifiable risk factors for stroke, cigarette smoking is the most powerful.[2] Smoking almost doubles the risk for ischemic stroke and is directly responsible for a greater percentage of total number of strokes in young adults.[2] The risk is proportional to the amount of tobacco smoked.[2,5] Because of a higher synergistic risk effect, women who smoke and take birth control pills have a significantly higher risk than women who smoke only (2 factors interact to increase the risk).[2] The relative risk of stroke decreases immediately after quitting smoking, and a major reduction can be seen 2 to 4 years later.[2]

High alcohol consumption is associated with a higher risk of both ischemic and hemorrhagic stroke.[2,5] Heavy alcohol consumption can seriously deplete platelet numbers and compromise blood clotting and blood viscosity, leading to hemorrhage.[2] Studies indicate that moderate use of alcohol does not increase risk and might even have a protective influence against ischemic stroke.[2,5] This could be because alcohol decreases platelets' clotting ability.[2]

The use of illegal drugs such as cocaine and methamphetamine increases the risk of stroke and stroke incidence in young adults.[2,5] Marijuana smoking also might be a risk factor for stroke because it decreases blood pressure to a critical low level and could interact with other risk factors, such as hypertension and cigarette smoking, to cause rapidly fluctuating blood pressure levels that can damage blood vessels.[2] Abuse of other drugs such as amphetamines, heroin, and anabolic steroids could increase stroke risk because the drugs increase heart rate and blood pressure.[2,5]

High cholesterol levels contribute to heart disease and stroke; however, the role cholesterol plays in stroke is less clear than is the role of heart disease.[3] Presumably, when too much cholesterol circulates in the blood, the body cannot handle the excessive low-density lipoprotein, which then builds up along the inside of the arterial walls.[2] The buildup hardens and becomes arterial plaque, leading to stenosis and atherosclerosis.[2] This plaque blocks blood vessels and contributes to the formation of blood clots.[2] Abnormally high blood levels of the amino acid homocysteine, which occur with deficiencies of vitamin B_6, B_{12}, and folic acid, also have been linked to an increased risk of coronary artery disease and stroke.[3]

Obesity is associated with stroke because being overweight increases the presence of other risk factors such as insulin resistance and diabetes, hypertension, and unhealthy cholesterol levels.[2] Weight that is centered around the abdomen has a greater association with stroke than weight carried around the hips.[5]

The Stroke Belt

People in the southeastern United States have the highest stroke mortality rates in the country and many scientists and statisticians have dubbed this region the "stroke belt."[2] Recent studies have demonstrated that there is a "stroke buckle" within the stroke belt that includes North Carolina, South Carolina, and

Georgia.[2,7,8] People living in these states have an extremely high stroke mortality rate that surpasses the rate of stroke in other stroke belt states and is up to 2 times the stroke mortality rate of the United States overall.[2,7,8] A comprehensive study analyzing factors that could explain the excessive stroke prevalence in the stroke belt concluded that three-fourths of the strokes were accounted for by differences in socioeconomic status (education and income), along with risk factors such as obesity and smoking, which contributed to chronic diseases (eg, hypertension, diabetes, and coronary artery disease) associated with strokes.[7,8]

Stroke Disabilities

An estimated 1 in 7 people who have a stroke require permanent institutional care.[9] Approximately one-half of people who have survived their first stroke after 30 days are likely to survive 5 years later, and one-third become disabled.[9] Stroke is a disease of the brain and can affect the entire body.[2] Disabilities that can result from stroke include paralysis, cognitive deficits, speech problems, emotional difficulties, daily living problems, and pain.[2,5] Paralysis on 1 side of the body (hemiplegia) and 1-sided weakness (hemiparesis) are common disabilities resulting from stroke that might be limited to 1 side of the face, an arm, or a leg, or could affect an entire side of the body.[2] The side affected is opposite the brain's hemisphere affected. For example, if a person has a stroke in the left hemisphere of the brain, he or she has effects on the right side of his or her body.[2] People who have had strokes might have difficulty performing basic daily activities such as walking, dressing, eating, and taking care of bodily functions.[2,5]

Stroke can affect thinking, awareness, attention, judgment, and memory functions.[2,5] People with stroke histories might present with "neglect" syndrome, a neuropsychological condition in which, after damage to 1 hemisphere of the brain, a deficit in attention to and awareness of 1 side of space is observed. This means they are unable to process and perceive stimuli on 1 side of their body or environment that is not due to a lack of sensation.[2] Patients often have problems understanding and forming speech following strokes and might have difficulty swallowing.[2] Stroke survivors also might have difficulty controlling emotions and be affected by depression.[2] Some people experience pain, uncomfortable numbness, or strange sensations following strokes.[2,5] People who survive stroke often face difficult rehabilitation and might have ongoing disabilities that affect them daily.

Stroke Pathophysiology

Stroke is a heterogenous syndrome caused by multiple mechanisms that result in a disruption of normal cerebral blood flow (CBF). The disrupted blood flow causes cerebral dysfunction.[10] Alternative descriptors of stroke are cerebrovascular accident, apoplexy, and "brain attack."[2,5] Brain cells require a constant supply of blood to maintain health and function. The brain is continually supplied with blood during systole and diastole and relies on this constant blood flow for its oxygen supply.[2,5] About 25% of the total cardiac output flows to the brain, and cerebral blood flows at approximately 800 mL per minute.[5,6] The high and continuous blood flow provides the glucose that the brain requires for energy metabolism.[5,6]

CBF has an autoregulatory mechanism that protects against hypoxia and low perfusion. The autoregulatory mechanism tries to maintain a mean arterial pressure of 60 mmHg to 100 mmHg and a CBF of 50 mL to 60 mL per 100 g of brain tissue per minute.[6] When the CBF decreases, the autoregulatory mechanism tries to compensate by increasing the blood pressure and inducing vasodilation.[6] If the blood flow falls below a critical level, cerebral blood volume (CBV) is reduced and infarction occurs. Occlusion, or blocked blood flow, results in ischemia, which causes immediate brain cell infarction. The lack of nutrients normally received from oxygenated blood and the damage caused by sudden bleeding into or around the brain lead to cell death.[2,5,11]

Cerebral ischemia initiates a number of damaging cellular events lasting from several hours to several days following the initial episode; this is called the ischemic cascade.[10-12] The events result in extensive cell death and tissue damage beyond the area originally affected by the lack of blood flow.[2,11] The events include:

- Acidosis, which is caused by a switch from aerobic to anaerobic metabolism.
- A release of the amino acid glutamate and consequent excitotoxicity, which is the exciting and poisoning of cells.
- Elevation of intracellular calcium.
- Production of toxic substances such as nitric oxide and free radicals.[7]

Reduced blood flow to the brain for even a short period of time can be disastrous to the patient and is the primary cause of stroke.[5] The current strategy in stroke management is to restore cerebral blood flow and perfusion as soon as possible to minimize irreversible tissue damage.[10-12] An acute episode of interrupted blood flow to the brain that lasts longer than 24 hours is called a complete or established stroke.[6] Most completed strokes cause a maximum neurological deficit within an hour of onset.[5,6]

An assessment of cerebral blood circulation is needed soon after stroke occurs to determine whether conservative or aggressive therapy is required. Understanding how to potentially salvage tissue is important to stroke diagnosis and treatment.[6,10,11] When blood flow to a particular area of the brain decreases, collateral supply from the vessels supplying the brain's arachnoid and pia mater layers and normal surrounding vessels try to compensate. This results in a central infarct (an area of necrosis), which receives little or no blood supply, and a larger peripheral area of autoregulatory compensations.

The peripheral area, which is the penumbra, is composed of tissue that is potentially salvageable using thrombolytic therapy.[10-12] Penumbra is not permanently injured and the tissue damage can be reversed if treated within a small window of time; however, fully infarcted tissue does not benefit from thrombolytic therapy and can be at increased risk of hemorrhage.[13] Regions of the brain with CBF lower than 10 mL per 100 g of tissue per minute are referred to collectively as the core, and these cells are presumed dead within minutes of stroke onset.[10] Zones of decreased or marginal perfusion (CBF < 25 mL/100 g of tissue/min) are collectively called the ischemic penumbra. Tissue in the penumbra can remain viable for several hours because of marginal tissue perfusion.[10] If reperfusion of the penumbra occurs quickly and effectively, the tissue recovers and the patient improves (see Figure 3).[13]

When blood flow to the brain is interrupted, some brain cells die immediately and others are damaged and remain at risk for death.[2,5] The ischemic penumbra refers to areas of damaged brain cells arranged in a patchwork pattern around areas of dead brain cells.[2,12] The concept of a penumbra in acute stroke was first advanced by Astrup et al in 1981.[14]

Stroke Treatment

Recombinant tissue plasminogen activator (tPA) is the only FDA-approved thrombolytic agent used to treat a progressive, acute ischemic stroke caused by artery blockage.[13,15,16] Use of tPA halts the stroke by dissolving the clot that is blocking blood flow to the brain. Recombinant tPA is a genetically engineered form of tPA, a thrombolytic substance made naturally by the body.[5,11,17]

When appropriately administered to patients who fall within narrow clinical guidelines, tPA can limit the

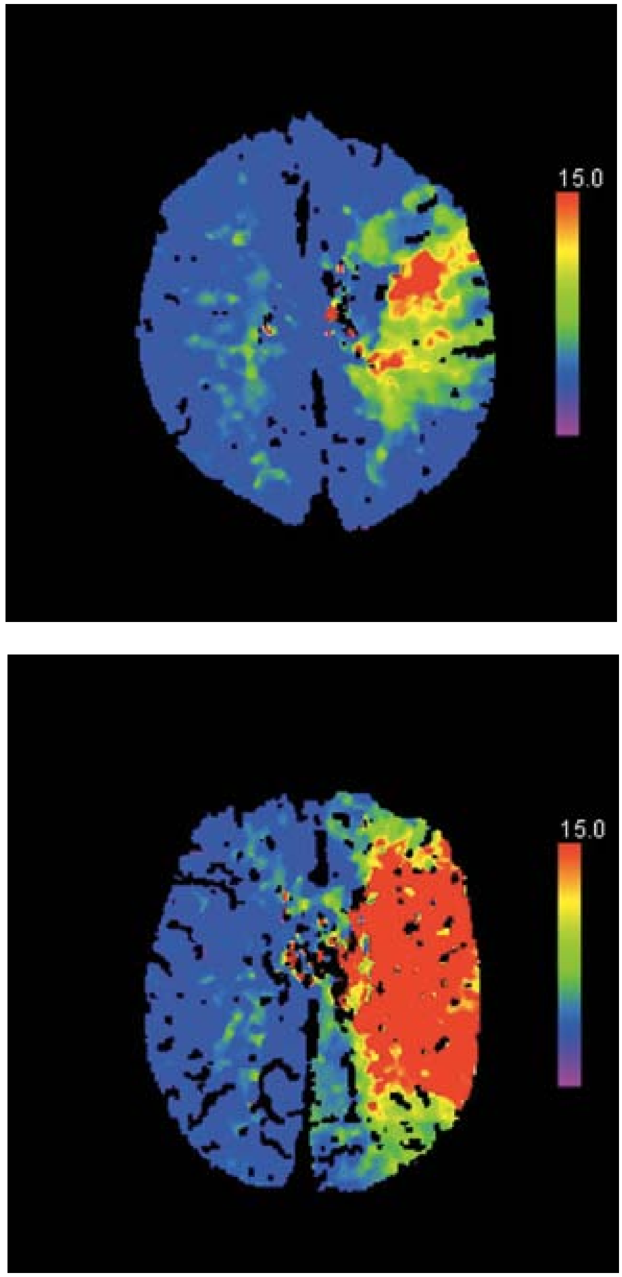

Figure 3. *Color-coded CT perfusion images demonstrating cerebral blood flow and cerebral blood volume within 15 seconds. The lower the color is on the bar graph, the faster the blood is reaching the region. Blue indicates normal blood flow, and red is the worst finding, indicating infarcted tissue. The yellow and green indicate the penumbra, or salvageable tissue. Images courtesy of Ulrich Rassner, MD, University of Utah Health Care, Salt Lake City.*

extent of brain injury and improve outcomes after stroke. The use of tPA for acute stroke therapy began in 1995 when the National Institute of Neurological Disorders and Stroke published a landmark multi-institution study on the intravenous injection of tPA.[15] The treatment was approved by the FDA in June 1996. The availability of tPA has revolutionized how the medical community responds to treating 80% of ischemic stroke patients.[15] Use of tPA has improved stroke outcomes, resulting in 30% lower likelihood of neurologic disability for stroke survivors 90 days following stroke compared with stroke survivors who received a placebo.[16] Unfortunately, only about 4% of acute stroke patients receive tPA, largely because of the strict clinical parameters that must be met before tPA administration.[11,13] Even more alarming is that 65% of U.S. hospitals have never treated a patient with tPA, which is attributed to a number of factors such as the hospitals not being classified as stroke centers.[15]

Most patients who have ischemic stroke are ineligible for tPA treatment.[12,15,17] To be effective, tPA must be administered within the FDA-approved 3-hour treatment window, which requires that patients' stroke symptoms be recognized, and that patients are transported to the hospital and diagnosed in time.[2,5,11,16] In addition, tPA only should be administered in the absence of significant bleeding conditions and severe hypertension.[11,16] Guidelines recommend that no more than 60 minutes should elapse between the time the patient arrives at the hospital and tPA treatment begins.[11] Only one-fifth of stroke patients are diagnosed and treated within this recommended time frame, making time the most limiting factor in the use of tPA.[11,13,15-17]

Encouraging new studies have shown that the 3-hour treatment window could be extended to 4.5 hours, yet many patients still would not arrive at the hospital in time for treatment.[13] Many factors contribute to patients not meeting the recommended tPA treatment time, including delays in arriving at the hospital after onset or delays at the hospital. For example, if a patient reaches the hospital 30 minutes after onset, health care workers have 2.5 hours to diagnose and begin treatment; if the patient comes to the hospital 2.5 hours after onset, the staff only has 30 minutes. Risk of post-thrombolytic hemorrhage is another tPA limitation and the primary reason physicians avoid thrombolytic therapy.[16] Administration of tPA can increase bleeding and could potentially make a hemorrhagic stroke worse.[18] When more than one-third of the middle cerebral artery territory is involved, there is a 3.5-fold risk of parenchymal hemorrhage following tPA administration.[19]

Specific contraindications to tPA include:

- A noncontrast CT examination demonstrating multilobar infarction with hypodensity in more than one-third of the cerebral hemisphere.
- A patient history of intracranial hemorrhage and uncontrolled hypertension at time of treatment.
- Witnessed seizure at stroke onset.
- Active internal bleeding or acute trauma.
- Acute bleeding disorder.
- History of intracranial or intraspinal surgery in the past 3 months.
- Serious head trauma.
- Arterial puncture at a noncompressible site within the past 7 days.[3,11]

The high cost of tPA and its potentially life-threatening complications must be considered when clinicians make stroke treatment decisions. These decisions should be made on a case-by-case basis and evaluated based on each patient's unique risk vs benefit ratio.

Stroke Diagnosis

Delay in stroke diagnosis and subsequent treatment results in increased neuronal loss and higher morbidity, which emphasizes the need for effective and efficient diagnostic techniques and tools.[2] The first steps in diagnosing stroke are a patient history, a brief neurological exam, blood tests, and an electrocardiogram.[2] Verbal tests to assess stroke severity can be conducted before the patient reaches the hospital using prehospital stroke assessment scales. Severity can be reassessed again in the emergency department using an acute assessment scale.[20] Results are based on the answers to questions that patients provide and, if possible, several physical and mental tests. Examples of prehospital scales include the Cincinnati Stroke Scale, Los Angeles Prehospital Stroke Scale (LAPSS), and the ABCD score.[20]

Although a variety of acute assessment scales are available for use at the patient's bedside by physicians, nurses, or therapists, the National Institutes of Health Stroke Scale is the most commonly used and recommended by stroke centers.[2,11,20] It is a systemic assessment tool that provides a quantitative measure of stroke-related neurologic deficit. Originally designed as a research tool to measure baseline data on patients in acute stroke clinical trials, the scale is now widely used as a predictor of both short- and long-term outcomes of stroke patients. The scale is simple, valid, and reliable consisting of a 15-item neurologic examination to evaluate the effect of acute cerebral infarction on the levels of consciousness, language, neglect, visual-field loss, extraocular movement, motor strength, ataxia, dysarthria, and sensory loss.[20]

Stroke Imaging

Stroke imaging serves 2 purposes: to diagnose or confirm the occurrence of a stroke for planning management strategy and to assess potentially salvageable brain tissue and irreversibly infracted tissue to predict disease course and outcomes.[11,12] Treatment advances for acute ischemic stroke have been limited in the past 15 years, but the same cannot be said for diagnostic imaging of strokes.[20-23] In recent years, there has been an explosion of technologic advances in neurovascular imaging, providing new options for physicians to incorporate into acute stroke triage and treatment.[4,16] CT and magnetic resonance (MR) imaging can provide excellent information about the intracranial vasculature and brain perfusion as accurate "snapshots in time."[24-26] Each modality offers advantages and disadvantages (see Box 1) and likely is selected based on practical factors such as presenting symptoms, local radiologist and neurologist expertise, equipment and technologist availability, and potential patient contraindications.[24-26]

Both CT and MR can contribute unique imaging information to a comprehensive acute stroke triage.[16] CT is the most commonly used diagnostic technique for acute stroke, largely because it is most often available at all hours in large hospitals and can produce images rapidly.

The 4 P's of Acute Stroke Imaging

The first task of stroke imaging is to determine whether the stroke was an ischemic or hemorrhagic event because this distinction is the initial critical branch in acute stroke triage.[22,24] Rowley introduced the concept of the 4 P's, which provides a practical method to help organize and recall each of the events that occur during stroke and to remember the necessary steps during imaging and diagnosis.[6,11,12] To understand the cause and potential treatment options for ischemic or hemorrhagic stroke in a particular patient, clinicians consider and measure each of the 4 P's in order:

- Parenchyma.
- Pipes.
- Perfusion.
- Penumbra.[12]

The 4 P's can be measured in minutes using either CT or MR imaging.[24-26] Imaging of the parenchyma can

Box 1
CT Perfusion and MR Diffusion/Perfusion[16,24-27]

CT Perfusion
Advantages:
Can be used with pacemakers, defibrillator, or claustrophobia.
Produces fewer motion artifacts than with MR imaging.
Study can be completed in 5 to 10 minutes.
Provides good visualization of major venous structures.
Widely available.
Provides information on salvageable penumbra.
Has overall accuracy of 90% to 100%, depending on vein or sinus.
Helps to rule out subarachnoid hemorrhage.
Identifies acute symptoms in an emergency.
Disadvantages:
Exposes patient to ionizing radiation.
Provides low resolution for small parenchymal abnormalities.
Poor at helping to detect cortical and deep venous thrombosis.
Accompanied by risk of contrast reactions.
MR Diffusion/Perfusion Imaging
Advantages:
Displays superficial and deep venous systems.
Defines brain parenchyma.
Can help provide early detection of ischemic changes.
Does not expose patient to ionizing radiation.
Can help detect cortical and deep venous thromboses.
More effective than CT for identifying small ischemic strokes or small, slow chronic hemorrhage when time is not critical.
Acute or subacute onset of symptoms when time is not critical.
Disadvantages:
Limited availability compared with CT and after hours.
Patient contraindications such as claustrophobia, metal implants, and pacemakers.
Examination is lengthy (up to 45 minutes).
Accompanied by low risk of gadolinium reaction.

be accomplished with either a noncontrast CT scan or diffusion-weighted MR imaging, or both, to identify early signs of ischemia and rule out hemorrhage. This step is critical to subsequent treatment decision-making.

Stroke begins as a vascular event on either a large or small scale, and the pipes in the 4 P's refers to the large arteries or veins involved in hemorrhage or infarction. The pipes are grossly visible (0.5 mm or larger) vessels and include the aortic arch, carotid and vertebral vessels, the major branches of the circle of Willis, and the proximal cortical branches. Identifying lesions in the arteries and veins has important therapeutic implications and can be demonstrated with CTA or MR angiography. CTA currently is the study of choice.[3,24,27] CTA is useful in assessing stenosis or occlusion of the carotid arteries or vertebral arteries in the neck, which can be predisposing factors for strokes. It is also possible to evaluate intracranial arteries accurately using CTA; its use gradually is replacing digital subtraction angiography for this purpose.[6]

Perfusion indicates the total CBF arriving at a particular brain region at a given moment in time. It is not sufficient to know at what level arteries and veins are occluded; rather, it is the individual variation in collateral veins, vascular autoregulation, and resulting net perfusion that indicates brain survival or infarction. CT and MR perfusion imaging offer noninvasive perfusion assessment.[12,27]

Penumbra is the most important indicator in ischemic stroke and is the focus of all that precedes it.[12,28,29] Current treatments cannot reverse an infarction that already has occurred. The best intervention is to identify the penumbra, and the key to detecting the penumbra is based not on a single measurement, but the integration of information on the site of occlusion, the extent and degree of perfusion at that moment, and the mismatch between this perfusion defect and the brain region already infarcted (parenchyma).[12]

CT Imaging

CT is widely used as the initial neuroimaging examination for patients with new neurological symptoms such as headaches, seizure, mental alteration, or focal neurological signs.[24] CT also occasionally demonstrates a tumor that mimics a stroke.[30] A noncontrast CT scan can be performed in a matter of minutes to exclude hemorrhage and acute meningitis from the patient's diagnosis as explanations of the stroke-like symptoms.[16,30] Relying on a noncontrast CT scan alone for stroke assessment has limitations; approximately 40% of patients have normal scans within the first few hours of their strokes.[24]

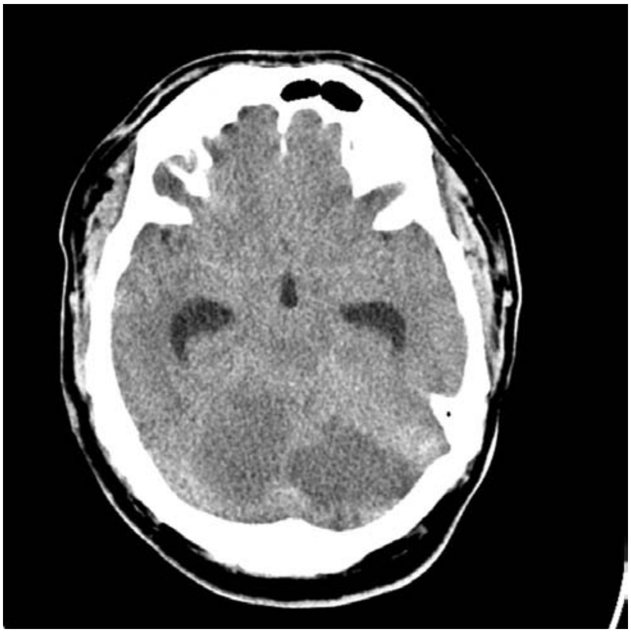

Figure 4. *Noncontrast CT. Image courtesy of Ulrich Rassner, MD, University of Utah Health Care, Salt Lake City.*

Noncontrast CT can help radiologists detect the presence of a thrombus in a major vessel, but it cannot help them distinguish tissue destined for irreversible damage from potentially salvageable surrounding penumbra.[24] The noncontrast CT examination cannot provide the level of detail neurosurgeons prefer before opening a cerebral arterial branch to treat thrombolysis or a mechanical clot (see Figure 4).[21] Using CTA to study the arteries and veins of the head and neck can provide critical information on the patient's vascular anatomy, but does not help identify salvageable brain tissue (see Figure 5).[21,30]

CT Perfusion Imaging

CT perfusion is the latest CT diagnostic option for stroke assessment. It can provide detailed information and has proven to be more sensitive and accurate than noncontrast CT in the diagnosis of stroke.[4,23,24,31] CT perfusion has improved early stroke diagnosis by displaying intravascular thrombi and salvageable tissue indicated by a penumbra.[6,22,24,30] A CT perfusion study involves acquiring sequential CT sections while

Figure 5. *Carotid CTA demonstrates head and neck vessels, but cannot identify salvageable brain tissue. Image courtesy of Siemens Health Care, Washington, DC.*

administering iodinated contrast agents intravenously. Analyzing results allows the physician to calculate the patient's regional CBV, the blood mean transit time (MTT) through the cerebral capillaries, and the regional blood flow. The computer applications produce a quantitative measure of regional hemodynamics by demonstrating blood flow in each pixel of the cerebral parenchyma imaged. The technique is based on the central volume principle, which states that cerebral blood volume can be calculated as the product of the cerebral blood flow and the time needed for the cerebral blood passage: CBF = CBV/MTT.[3,16,23,24] A workstation equipped with commercially available perfusion software that interfaces with helical scanners can perform these complex calculations quickly.

Multimodal CT

The combination of conventional CT, CTA, and CT perfusion is collectively referred to as multimodal CT. It is performed on multidetector CT scanners and can demonstrate all segmental ischemic lesions and most large segmental infarctions.[32-34] The combined approach is useful in considering indication and contraindication for thrombolysis and allows for assessment of the vascular occlusion site, the infarct core, and salvageable brain tissue. Multimodal CT also helps assess the degree of collateral circulation.[4,28,33,35,36]

A study completed by Schellinger suggested that the 3-hour treatment window for tPA could be extended when using multimodal CT because together these CT studies provide sufficient information to make an informed clinical decision within the critical time limit required for tPA administration.[22] CTA with CT perfusion is fast, safe, and typically adds no more than 5 minutes to the time required to perform a noncontrast CT scan of the head; adding the 2 additional studies does not delay intravenous thrombolysis.[4] The only requirement for performing all 3 examinations is the addition of software to modern helical scanners.[29]

CT Perfusion Clinical Indications

CT perfusion promises more efficient use of imaging resources and, potentially, decreased morbidity.[30] CT perfusion is an effective method of diagnosing acute ischemic stroke in clinical practice, particularly major intracranial vessel strokes that result in more devastating outcomes.[32] Most importantly, current CT technology permits the incorporation of CT perfusion as part of a comprehensive acute stroke examination to triage patients with strokes quickly and accurately.[30]

In addition to evaluating acute stroke, CT perfusion is useful for evaluating vasospasms and tumor grading, and determining cerebrovascular reserve capacity in patients who have chronic cerebral ischemia related to underlying vascular stenosis.[4,11,34] Cerebrovascular reserve capacity describes how far cerebral perfusion can increase from a baseline value after a stimulus is applied, providing a "stress test" for the brain. The stimulation is in the form of an intravenous drug such as acetazolamide. A routine CT perfusion scan, followed by a second CT perfusion after acetazolamide administration, is typical for evaluating cerebrovascular reserve capacity.[3,4,11]

CT perfusion performed on patients who are candidates for permanent balloon occlusions to manage aneurysms or intracranial head and neck tumors can help identify those patients who might not be able to tolerate the balloon occlusion.[3,4,11,16] The patient undergoes angiography and a temporary test balloon occlusion. Patients who pass the clinical portion of the examination are brought to the CT suite with the uninflated balloon in place and a routine, unenhanced head CT scan is performed. The neurointerventionalist inflates the balloon, and after inflation, CT perfusion is performed. The balloon is deflated and the CT perfusion is repeated with a second injection of contrast.[3]

A lack of phase III clinical trials and inadequate published evidence that CT perfusion imaging improves outcomes over standard noncontrast CT means that some health care insurers consider CT perfusion to be experimental for assessing patients suspected of having acute strokes.[18,21] There is no FDA-approved treatment available that uses the information gathered from CT perfusion studies in treating acute strokes, rendering CT perfusion useful only in the context of clinical trials.[21]

In 2003, the American Medical Association assigned a CPT category III code 0042T to CT perfusion, rendering the examination an acceptable billable event.[37] However, the nature of the code, as determined by Medicare, does not specifically address coverage of CT for acute stroke assessment. Instead, Medicare has granted local Medicare contractors the discretion to determine the specific circumstances under which they will pay for CT perfusion imaging.[37] This allows the acceptable billing of CT perfusion for clinical indications besides acute stroke, such as balloon implant integrity and tumor grading.

CT Perfusion Protocols and Technique

When a stroke code is activated at a facility, the CT scanner dedicated to emergencies should remain available and CT staff should prepare for the patient's arrival.[38] Typically, radiologic technologists load the power injector with at least 125 mL of nonionic contrast material (300 mg of iodine per milliliter) and 50 mL of saline solution, depending on the department's established protocol. Once the patient arrives, staff must gain adequate peripheral venous access to an antecubital vein with an 18- to 20-gauge cannula to support the 4 mL to 7 mL per second injection rate needed for CT perfusion.[4,38] Staff should be sure to remove any metallic objects from the patient, including dental and hair prostheses, earrings, or other jewelry.

In the emergency assessment of acute ischemic stroke, the complete CT perfusion examination has 3 components: noncontrast CT; vertex-to-arch CTA; and dynamic first-pass cine CT perfusion, performed over 1 or 2 sections of tissue.[3,4,38] Correlation of all imaging findings with the vascular anatomy and clinical findings is crucial and must include all information from the perfusion CT and CTA.[35] Patients are monitored during scanning, which allows the intravenous thrombolysis to be started on the CT table as soon as hemorrhage is ruled out.

The brain perfusion protocol begins with a noncontrast CT scan of the entire brain to evaluate for parenchyma.[4] Sections of the posterior fossa are obtained in 5-mm slices to reduce beam-hardening artifacts, and then reformatted into 10-mm thick sections for viewing to improve the signal-to-noise ratio.[3,6]

The CTA portion of the examination takes place immediately following the noncontrast CT. Bolus tracking is used for CTA to time the image acquisition to the peak of contrast in the cervical vessels by sampling the carotid just below the skull base.[4,38] The anatomy is covered with semiautomated threshold-based triggering of 100 mL to 105 mL of low-osmolar, nonionic contrast infused at 4 to 5 mL per second with a saline push power injector (see Figure 6).[4,6,34,38]

Dynamic CT perfusion is performed next. CTA source images are available immediately before the CT perfusion acquisition begins to help locate the region of abnormal perfusion and guide the choice of imaging plane through that region.[4] Monitoring the passage of iodinated contrast through the cerebral vasculature helps to distinguish infarcted tissue from penumbra and determine the volume of the core,

Figure 6. *CTA of circle of Willis is acquired after the noncontrast CT examination during brain perfusion protocols. Image courtesy of Siemens Health Care, Washington, DC.*

which is the goal of CT perfusion imaging. From this data, CT perfusion provides absolute and relative information about brain perfusion parameters, which allows for quantitative and qualitative evaluation of cerebral perfusion.[4,24,38] The evaluated parameters are cerebral or regional blood flow, cerebral or regional blood volume, MTT, and time to peak. MTT is the time between the arterial inflow and venous outflow. Time to peak refers to the time it takes the contrast to achieve maximum enhancement, known as the Hounsfield unit value. It is measured in the selected region of interest before enhancement begins to decrease. CBV is the volume of blood available per unit of brain tissue; it usually is measured as milliliters per 100 g of blood.[3,4,38-40]

The most common technique associated with CT perfusion scanning is based on the first pass of a contrast bolus through the brain tissue.[4,34,38] The contrast bolus is delivered at a rate of 4 mL to 7 mL per second during continuous cine imaging, over a single location of the brain. Imaging begins after a 5-second delay from when the contrast infusion was started.[3,4,6,38,39] The term cine imaging in CT perfusion means the same region of interest is repeatedly scanned from the same table position.[4,38] Multislice scanners allow several z position slices to be scanned simultaneously.

The levels of interest generally are determined by the radiologist or neurologist based on findings on the noncontrast CT and from the presumed area of infarction based on the neurological examination.[3] For example, when an anterior circulation infarct is suspected, data acquisition is performed at the basal ganglia level and if posterior circulation infarct is suspected, data are obtained at the level of the midcerebellum. If the level for scanning the enhanced portion of the study has not been selected, a transverse slice through the level of the basal ganglia contains tissues supplied by the anterior, middle, and posterior cerebral arteries, helping clinicians investigate each of the major vascular regions.[3,4,41]

CT perfusion requires an additional 45 to 60 seconds of scanning time at the end of the examination, and an additional 40 mL to 50 mL of contrast per section over the amount needed for the CTA.[4,16,38] Most scanners obtain 2 cm to 4 cm of coverage per bolus (5 mm- or 10 mm-thick slices). Some centers routinely obtain 2 sections, which requires an additional bolus of 40 mL of contrast, to double the coverage. Imaging parameters are 80 kVp, 200 mA, and 1-second rotation time. At least 1 image slice must contain a major intracranial artery for CT perfusion map construction.[4,40]

Older helical CT scanners were limited by 10-mm to 20-mm maximum coverage.[3,42] Limited coverage of the brain in the z-axis often required an additional bolus of contrast so the patient could be scanned at a different level, typically in a more cephalad direction above the lateral ventricles.[3] This is no longer an issue with newer CT scanners equipped with multidetector arrays. A 64-slice scanner allows 40 mm of anatomic coverage for a perfusion study.[3,19] Recent studies have investigated the possibility of accomplishing 80-mm coverage in 1 bolus with a technique known as table toggling; this technique could decrease radiation dose.[42] The 80-mm coverage was found to be useful as an initial imaging method in assessing acute ischemic stroke, although it had low sensitivity for detecting small acute infarctions.[42]

CT Postprocessing

The source images from the whole-brain CTA vascular acquisition provide clinically relevant data concerning tissue-level perfusion.[4,16,38] Evaluating the source or base images along with reconstructed images is important because reconstruction is operator dependent and there is some loss of information in these techniques.

Data postprocessing is completed using specialized CT perfusion software that interfaces with helical scanners. The technologist can produce maximum intensity projection reformatted images or 3-D surface-shaded images while the radiologist evaluates the CT perfusion study on a separate workstation (see Figure 7).[3] In an acute stroke setting, the technologist and radiologist generally work alongside each other. Postprocessing of CTA and CT perfusion images once was considered more labor intensive than MR diffusion postprocessing; however, automated CT perfusion software, along with training, quality control, 3-D reconstructions of CTA data sets, and quantitative CT perfusion maps, have made CT reconstruction faster and more reliable.[43]

The first step in postprocessing a CT perfusion study is to select a reference artery and vein. The reference artery, most commonly the anterior cerebral, should have 1 of the following characteristics:

- Be visible in cross-section.
- Be one of the first arteries to enhance.
- Produce a curve with a high enhancement peak.
- Produce a curve with a narrow width.[3,38]

The reference vein should be the largest vein available or the 1 that produces an enhancement curve with the highest peak.[3] The superior sagittal sinus is the most common reference vein selected. A region-of-

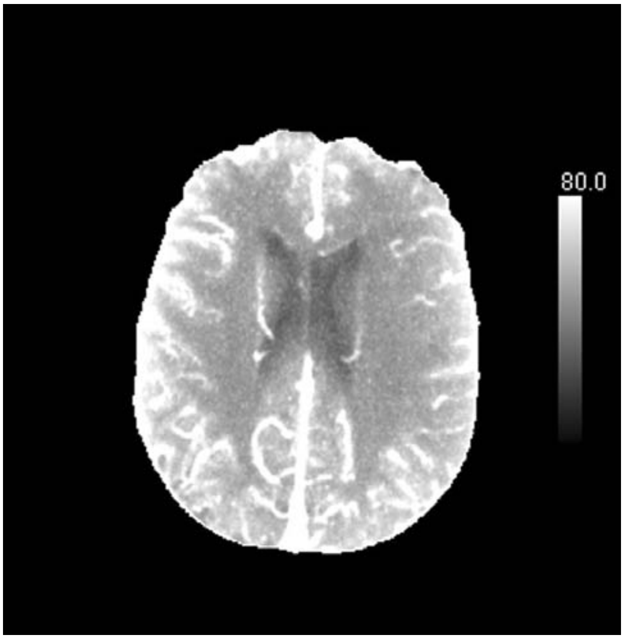

Figure 7. *CT perfusion maximum intensity projection image demonstrating blood flow in shades of gray. Image courtesy of University of Utah Health Care, Salt Lake City.*

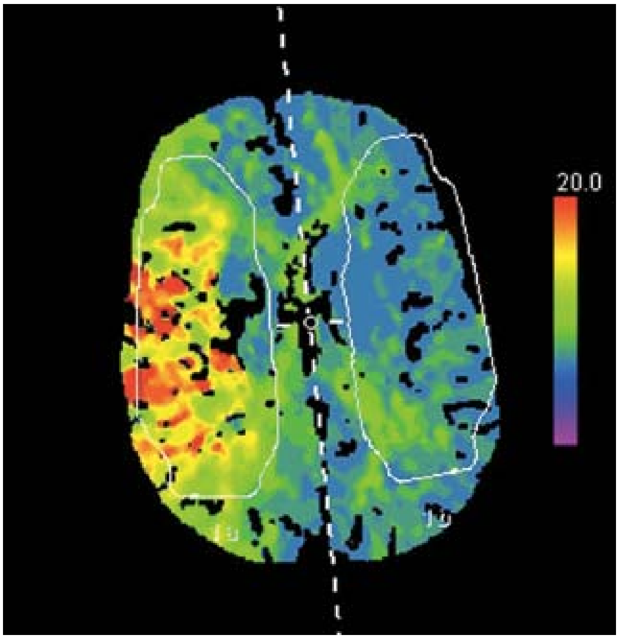

Figure 8. *Color-coded CT perfusion image demonstrating the mean transit time or time to drain. The circles designate the area of interest on 1 side and the corresponding half on the other side. The areas that drain the slowest are in red, with yellow, green, and blue following. Blue represents the fastest draining areas. Red areas indicate infarction, and yellow represents the penumbra.*

interest indicator is placed on the reference artery and reference vein so the perfusion software can generate contrast enhancement curves. The perfusion software performs the complex mathematical formulas quickly. Color perfusion maps and time-attenuation curves can be calculated for any area of interest. The time attenuation curves quantify the time to peak by the MTT, CBV, and CBF.

By measuring these values, CT perfusion can help identify how much of the brain is ischemic or infarcted. If CT perfusion demonstrates a decrease in CBF with a stable or increased CBV, the finding signifies irreversible infarction; generally 20% of normal value is the point at which autoregulation fails.[6,40,43]

Data Interpretation

CT perfusion data can be analyzed qualitatively and quantitatively. Analysis of contrast enhancement curves guides the selection of pre-enhancement and postenhancement images. The pre-enhancement image is the last image taken before contrast reaches the area of interest. The postenhancement image captures the point immediately after the first pass of the contrast bolus when the time attenuation graph begins to flatten.[4,6,38,43]

The color-coded perfusion maps showing CBV, MTT, and CBF can be used to identify large ischemic areas rapidly with a reported sensitivity of 90%.[4,6] Quick visual assessment and accurate quantitative assessment of the perfusion maps can be used to search for abnormalities. Quantitative assessment is done by placing multiple regions of interest in the suspected ischemic area and at the corresponding location in the contralateral lobe to obtain the relative percentage reduction and absolute values in the region of interest. The values and various colors assigned to tissue are used to differentiate between normal, ischemic, and penumbra brain tissue (see Figure 8).[3,4]

The difficulty with interpreting CT perfusion parameters is assigning a specific threshold value below which ischemia is known to be irreversible and correspondingly above which damage might be reversible.[4,6,39,43] No definite values have been set to date. Volume and values can vary considerably depending on the type of postprocessing software used, which causes differences among vendor systems.[44] Recent studies have shown that CBF is the optimal CT perfusion parameter to use when assessing infarct core, though more research is needed in this area.[39]

Radiation Dose and CT Perfusion

In October 2009, the FDA announced a safety investigation of facilities performing CT perfusion scans. The investigation was prompted by incidents at a single facility where 206 patients received radiation overexposures during CT perfusion imaging to diagnose stroke over an 18-month period.[45] Because of incorrect settings on the CT scanner console, the patients received radiation doses that were approximately 8 times higher than the expected level.[45,46] Instead of receiving the expected dose of 0.5 Gy (maximum) to the head, these patients received 3 Gy to 4 Gy.[45]

In some cases, the excessive dose resulted in epilation, and about 40% of the patients lost patches of their hair.[46,47] CT perfusion studies can be more prone to substantial radiation exposure if performed incorrectly because of the cine nature of the acquisitions; however, a similar event in Arcata, California, demonstrated how overexposure is possible with any type of CT procedure if proper care is not taken.[47] In the Arcata incident, radiation overexposure was caused by the repeated use of CT protocols with inappropriate acquisition parameters. The protocols had been saved on the CT scanner and used on several patients without the technologist or radiologist realizing the error.[47]

In December 2009, the FDA released an update to the CT perfusion investigation reporting that they had identified 50 additional patients who were exposed to excess radiation during CT perfusion scans.[48] An investigation of the CT equipment manufacturers revealed no equipment violations.[48] As a result of the finding, the FDA released recommendations for radiologists and radiologic technologists at all imaging facilities to help prevent additional cases of excess exposure.[48] Radiologic technologists should review the recommendations because a number of items reference the radiographer's responsibility in protecting patients from overexposure, along with educational resources that should be made available to technologists performing CT studies (see Box 2).

Box 2
FDA Interim Recommendations to Address Radiation Exposure Concern[48]

- Facilities assess whether patients who underwent CT perfusion scans received excess radiation.
- Facilities review their radiation dosing protocols for all CT perfusion studies for correct dosing.
- Facilities implement quality control procedures to ensure that protocols are followed.
- Radiologic technologists check the CT scanner panel before performing CT perfusion for correct dosing.
- For patients having multiple studies, adjust imaging parameters for each study.

The potential for similar cases of undetected radiation overexposure exists. Unless quality control measures are taken routinely, CT protocols resulting in overexposure could go unnoticed because they would not decrease image quality. High radiation levels could be delivered without specific attention being paid to scan parameters or physical signs of overexposure.[48] If undetected and unreported, incorrect parameters could expose many patients to increased risk for long-term radiation effects such as certain cancers and cataracts without the patients' knowledge.[48]

A subsequent update on the safety investigation of CT brain perfusion scans was issued in November 2010.[49] By this time, a number of lessons had been learned and the overexposure of patients was believed to have been caused by several factors.[49] In response to these findings, the FDA added specific technologist training recommendations to their report. Specifically, the FDA recommended that facilities ensure that all radiologic technologists operating CT scanners receive training on CT scanners and procedures and that this training be documented; the agency also recommended training CT operators on dose-saving features of CT equipment.[49]

The FDA developed a letter to the Medical Imaging & Technology Alliance, providing the following ideas for manufacturers:

- Brain-perfusion CT – Provide particular information and training on brain perfusion protocols to all facilities that receive CT equipment, regardless of whether the facility purchases the related software enabling quantitative analysis or cerebral dynamics. The training and information should include manufacturer-recommended parameter settings; a concise description for each scanning parameter; an explanation regarding why a relatively poorer quality image is appropriate; and an explanation of how peak skin doses relate to CT dose index (CTDI).[50]

- Automatic exposure control – Clarify parameters affecting dose, along with clear instructions on how to set those parameters appropriately, describe how to use automatic vs manual modes, including examples when automatic exposure control operation might unnecessarily complicate successful operation. CT perfusion studies are an example; the manufacturers should provide directions on how to modify manufacturer-recommended scanning parameter sets.[50]
- Pop-up notification at threshold of deterministic injury – Institute a pop-up notification so when operating conditions associated with any protocol yield an expected $CTDI_{vol}$ greater than or equal to 1 Gy, a notification alerts the operator before scanning begins of the potentially high radiation dose.[50]
- User-accessible organization of dose-related information – Organize all dose-related information into 1 section of each user manual.
- Protocol specifications – Provide facilities with hard copies or Adobe Acrobat files specifying the dose-associated parameter settings recommended for particular clinical applications.

The American College of Radiology established a voluntary CT accreditation program in which institutions are invited to submit phantom and patient images, along with dose measurements, from their CT protocols, to demonstrate that they abide by the College's dose guidelines.[46] In an editorial regarding the FDA investigations, Wintermark et al suggested that neuroimagers might want to create a repository of optimized CT protocols representing all types of CT scanners from all vendors and all types of CT studies, which would be shared freely by the radiology community.[46] In 2003, for example, the Council on Cardiovascular Radiology of the American Heart Association provided guidelines and recommendations for perfusion imaging in the evaluation of acute stroke, chronic ischemia, vasospasm, carotid occlusion evaluation, and head trauma.[4] The advantages and disadvantages of xenon-enhanced CT, CT perfusion, single photon emission CT, and MR perfusion-weighted imaging were summarized with recommendations for technique for different patient conditions. In regards to CT perfusion in evaluating acute stroke, the council concluded that CT perfusion was useful in distinguishing reversible from irreversible damage and that CT perfusion's ability to produce quantitative measures made it useful in acute stroke diagnosis and management. Advantages of CT perfusion included wide availability of the equipment, rapid assessment, and the ability to quantify perfusion parameters. The primary disadvantages were the concern over the high radiation dose. The council did not recommend CT perfusion imaging for evaluating chronic ischemia, vasospasm, or head trauma. Instead, MR was recommended for these conditions.[4]

A comprehensive stroke protocol that includes noncontrast CT, postcontrast CT, CT perfusion, and CTA of the cervical and intracranial arteries could deliver a mean effective dose up to 6 times that of a standard noncontrast CT.[51] However, not every scan sequence needs to be completed on every patient. Even though perfusion imaging enables physicians to select patients appropriately for salvageable tissue, evidence to support routine use in acute stroke is sparse and lacking clear-cut guidelines.[27,34] When deciding whether a CT perfusion study — or any CT procedure — is clinically indicated, the FDA's initiative to reduce unnecessary radiation exposure from medical imaging advocates the universal adoption of 2 principles of radiation protection: appropriate justification for ordering each procedure and careful optimization of the radiation dose used during each procedure. Every patient should have the right imaging exam, at the right time, with the right radiation dose.

The future likely will bring more studies focusing on ways to decrease dose and maintain image quality during CT perfusion examinations.[52-54] A recent study published in the *American Journal of Neuroradiology* focused on the possibility of reducing temporal resolution to limit radiation and allow for increased spatial coverage.[52] CT perfusion data sets are commonly acquired using a temporal resolution of 1 image per second. In this study, CT perfusion data obtained at 2-second temporal resolution typically were found to be diagnostic, and the same therapy would have been provided if 1-second temporal resolution was used. However, the 1-second temporal resolution was preferred because of quantitation and image-quality-based confidence.[52]

Future Trends

Better clinical outcomes in early neurointerventional treatment of stroke might depend more on acquiring data regarding successful treatment approaches vs diagnostic tools or techniques.[21] The amount of information and detail that can be obtained from both CT and MR imaging currently is far ahead of the available, approved therapies.[21] Endovascular mechanical thrombectomy techniques and devices are emerging as alternative methods of restoring blood flow to the brain, particularly in patients who are not eligible for tPA therapy.[54,55]

A catheter-based system called the Merci Retrieval System (Concentric Medical, Mountain View, California) is a minimally invasive system designed to retrieve and remove clots in patients experiencing acute ischemic stroke.[54] The retriever is delivered to the lesion in a linear formation and deployed to its coiled shape, where it engages and retrieves the clot. The FDA approved the Merci retriever in 2004, and since then, the retrievers have been used in more than 14 000 patients throughout the world. In May 2010, the Merci retriever was the first thrombectomy device to be approved in Japan, resulting in a significant change in management of acute stroke for Japanese patients.[54,55]

In the Merci trial, the catheter-based retrieval system was used in 151 patients who were ineligible for tPA to restore vascular patency during acute ischemic stroke within 8 hours of stroke onset.[54] The Merci retriever restored blood flow in 55% of patients when used alone, and 68% of the time when used in conjunction with other treatments. In the United States, there are now 2 approved devices gaining acceptance without documented randomized trials: the approved Merci retriever clot extraction device and Penumbra (Penumbra Inc, Alameda, California) clot aspiration catheters.[18]

The future of stroke imaging appears to be directed toward the use of faster scanners, proven outcomes, and new dose-reduction strategies such as iterative reconstruction technique for reducing body radiation.[56] Preliminary results from a small trial of 39 patients who had scans on a second-generation 128-slice dual source CT manufactured by Siemens acquired images of the entire heart faster than first-generation scans, allowing physicians to view artery blockages and reduced blood flow.[57] The remarkable result in this study was that the scans were accomplished using one-tenth of the radiation of current CT scans.[57]

If we have learned lessons from the reports of radiation overexposure, manufacturers of CT equipment, clinical applications support, technologists, radiologists, and physicists must work together to remain current in CT imaging technology, operate equipment with low-dose protocols, and ensure that all technologists operating CT scanners have the information and resources they need to perform scans safely.

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1. Approximately _______ Americans older than 20 years of age have a new or recurrent stroke each year.
   a. 795 000
   b. 820 000
   c. 875 000
   d. 900 000

2. The 18% increase in hospital admissions for intracerebral hemorrhage in the past 10 years is largely because of:
   a. reliable screening procedures.
   b. an increase in the number of elderly people who lack adequate blood pressure control.
   c. increased numbers of obese patients.
   d. an increase in the number of patients with diabetes.

3. The risk of recurrence is greatest immediately following a stroke.
   a. true
   b. false

4. Most of the cost associated with caring for stroke patients during the first 90 days of their care comes from:
   a. rehabilitation.
   b. physician costs.
   c. medications.
   d. initial hospitalization.

5. _______ is a type of ischemic stroke.
   a. Intracerebral
   b. Thrombotic
   c. Subarachnoid
   d. Hypotensive

6. An episode of cerebrovascular insufficiency usually associated with partial occlusion of the cerebral artery by an atherosclerotic plaque or an embolus is known as:
   a. transient ischemic attack (TIA).
   b. subarachnoid hemorrhage.
   c. arteriovenous malformation (AVM).
   d. hypotensive episode.

Continued on next page

Directed Reading Continuing Education Quiz

7. Without treatment, one-third of patients who have had a TIA experience a stroke within:
   a. 1 month.
   b. 5 months.
   c. 1 year.
   d. 5 years.

8. Stroke symptoms in the retina or cerebral hemisphere are an indication of:
   a. subarachnoid hemorrhage.
   b. hypotensive stroke.
   c. TIA in the carotid arteries.
   d. AVM.

9. _______ is the most powerful modifiable risk factor for stroke.
   a. Cigarette smoking
   b. Obesity
   c. High cholesterol
   d. High alcohol consumption

10. Abnormally high levels of homocysteine can occur with deficiencies of:
    a. niacin.
    b. vitamins B_6 and B_{12}.
    c. vitamins D_3 and D_{12}.
    d. biotin.

11. Which of the following states are included in the "stroke buckle"?
    a. Utah, Nevada, and Wyoming
    b. Illinois, Indiana, and Wisconsin
    c. North Carolina, South Carolina, and Georgia
    d. California, Oregon, and Washington

12. _______ refers to areas of damaged brain cells arranged in a patchwork pattern around areas of dead brain cells following a stroke.
    a. Ischemic penumbra
    b. Infarct
    c. Perfusion
    d. Parenchyma

13. What percentage of acute stroke patients actually receive tissue plasminogen activator (tPA) for stroke treatment?
    a. 4%
    b. 8%
    c. 21%
    d. 33%

14. The FDA-approved window of time for administering tPA to stroke patients is _______ hour(s).
    a. 1
    b. 3
    c. 6
    d. 8

15. Magnetic resonance (MR) diffusion/perfusion imaging has proven to be more effective than CT in imaging:
    a. small ischemic strokes.
    b. salvageable penumbra.
    c. subarachnoid hemorrhage.
    d. acute rapid triage.

16. Which of the following lists correctly identifies the order of the "4 P's" that must be evaluated in stroke patients?
    a. perfusion, penumbra, parenchyma, and pipes
    b. pipes, perfusion, parenchyma, and penumbra
    c. penumbra, pipes, perfusion, and parenchyma
    d. parenchyma, pipes, perfusion, and penumbra

Continued on next page

Directed Reading Continuing Education Quiz

17. _______ is gradually replacing digital subtraction angiography in the evaluation of intracranial arteries.
    a. CT perfusion
    b. Noncontrast head CT
    c. MR angiography
    d. CT angiography (CTA)

18. Which of the following statements is ***true*** regarding noncontrast CT and stroke?
    a. Noncontrast CT can help radiologists distinguish tissue that might be irreversibly damaged from salvageable tissue.
    b. The technique provides high levels of detail to help neurosurgeons before opening cerebral arterial branches to treat clots.
    c. Noncontrast CT can help radiologists detect the presence of a thrombus in a major vessel.
    d. It often can be relied on alone for stroke assessment.

19. Which of the following are calculated during CT perfusion brain scans?
    1. cerebral blood volume (CBV)
    2. cerebral blood flow (CBF)
    3. mean transit time (MTT)
        a. 1 and 2
        b. 1 and 3
        c. 2 and 3
        d. 1, 2, and 3

20. The addition of CTA and CT perfusion to a noncontrast head CT scan typically adds _______ to the total examination time.
    a. 5 minutes
    b. 15 minutes
    c. 50 minutes
    d. 1 hour

21. In addition to diagnosing acute ischemic stroke, CT perfusion is indicated for:
    a. migraines.
    b. tumor grading.
    c. headaches.
    d. concussion.

22. The approximate injection rate of contrast media during a CT perfusion study is _______ mL per second.
    a. 1 to 2
    b. 2 to 3
    c. 4 to 7
    d. 8 to 11

23. The CT perfusion parameter MTT measures:
    a. time between arterial inflow and venous outflow.
    b. time for CBF to reach the penumbra.
    c. time for contrast media to reach the ventricles.
    d. time between CTA and CT perfusion sequencing.

24. Which of the following are recommended imaging parameters for a CT perfusion study?
    a. 70 kVp, 200 mA, and 1-second rotation time
    b. 80 kVp, 200 mA, and 1-second rotation time
    d. 90 kVp, 100 mA, and 2-second rotation time
    d. 100 kVp, 150 mA, and 2-second rotation time

25. The first step in postprocessing the images with the perfusion software is to:
    a. determine the CBF.
    b. calculate the MTT.
    c. select a reference artery and reference vein.
    d. produce 3-D surface shaded images.

Continued on next page

Directed Reading Continuing Education Quiz

26. Which of the following signifies irreversible infarction when demonstrated on a CT perfusion study?
    a. an increase in CBF with a stable or decreased CBV
    b. an increase in MTT with a stable or increased CBF
    c. a decrease in CBF with a stable or increased CBV
    d. a decrease in MTT with a stable or decreased CBF

27. Color-coded maps can be used to look for large ischemic areas and rapid assessment with _______ % sensitivity.
    a. 60
    b. 70
    c. 80
    d. 90

28. What is the difficulty with interpreting CT perfusion parameters?
    a. performing the quantitative analysis without the perfusion software
    b. assigning a specific threshold value to determine reversible or irreversible ischemia
    c. data support from the CT perfusion software companies
    d. calculating the threshold values for each arterial and venous branch

29. _______ was determined as the main reason for more than 200 patients receiving 8 times the expected amount of radiation during CT perfusion studies conducted in 2009.
    a. Leakage of the x-ray tube in the CT scanner
    b. Malfunction of safety device on the CT scanner
    c. Incorrect settings on the CT scanner console
    d. A technologist repeating the study without patients' knowledge

30. The 2010 FDA recommendations for facilities and practitioners regarding radiation exposure and CT perfusion included to:
    a. confirm all radiographers who operate CT scanners are ARRT CT certified.
    b. ensure and document technologists' training on CT scanner and procedures.
    c. verify all CT perfusion protocols have been approved by the American College of Radiology.
    d. ensure that all radiographers who perform CT perfusion have a minimum of 3 years of CT experience.

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Directed Reading Evaluation
Stroke and CT Perfusion

asrt DIRECTED reading

1 2 8 0 3 - 0 4   3 4 1 7 1 5

Thank you for taking the time to complete this survey. 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. What is your primary area of practice?

- ○ Administration/Management
- ○ Bone Densitometry
- ○ Cardiovascular-Interventional
- ○ Computed Tomography
- ○ Education
- ○ Magnetic Resonance
- ○ Mammography
- ○ Nuclear Medicine
- ○ Quality Management
- ○ Radiation Therapy
- ○ Radiography
- ○ Research
- ○ RIS/HIS/Information Systems
- ○ RN
- ○ Sonography
- ○ Other ______________

2. Which of the following best describes the highest educational level you have attained?

- ○ Student who has not yet taken Registry exam
- ○ Certificate
- ○ Associate degree
- ○ Bachelor's degree
- ○ Master's degree
- ○ Doctoral degree (e.g., Ph.D. or Ed.D.)

3. Why did you choose to complete this DR?

- ○ Interested in the topic
- ○ DR had the right number of CE credits
- ○ Topic pertained to my area of practice
- ○ Needed CE credits immediately
- ○ Other ______________

4. How relevant is this DR to your practice?

○ Extremely relevant ○ Very relevant ○ Relevant ○ Somewhat relevant ○ Not relevant

5. How beneficial is this DR to your professional or personal development?

○ Extremely beneficial ○ Very beneficial ○ Beneficial ○ Somewhat beneficial ○ Not beneficial

6. How would you rate the level of difficulty of this DR?

○ Too difficult ○ Somewhat difficult ○ Just the right level ○ Somewhat easy ○ Too easy

7. How would you rate the length of this DR?

○ Too long ○ Somewhat long ○ Just the right length ○ Somewhat short ○ Too short

8. Did this DR meet your expectations?

○ Yes ○ No ○ Partially

9. Would you recommend this DR to a colleague?

○ Yes ○ No

10. Overall, how valuable are the Directed Readings to you?

○ Very valuable ○ Considerably valuable ○ Valuable ○ Slightly valuable ○ Not very valuable

If you have comments 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.

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Stroke and CT Perfusion

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2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9

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CE Answers Section

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

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

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

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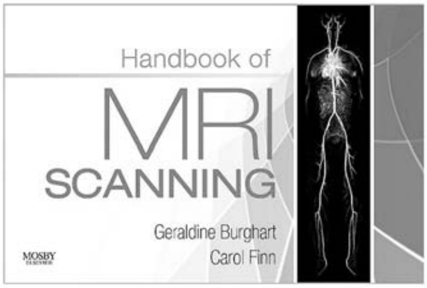
Carefully cut or tear here.

Wealth of Imaging Information

"Literature Review" features contributions from volunteer writers from the radiologic sciences, reviewing the latest in publications and communication materials produced for the profession. Suggestions and questions should be sent to communications@asrt.org.

HANDBOOK OF MRI SCANNING.
Burghart G, Finn C. 2011.
416 pgs. Mosby-Elsevier.
www.us.elsevierhealth.com. $49.95.



Handbook of MRI Scanning by Geraldine Burghart, MA, R.T.(R)(MR)(M), and Carol Finn, R.T.(R)(MR) — an educator and manager, respectively — is a helpful guide for magnetic resonance students and technologists. This first-edition text is well organized and the content flows well, skillfully combining MR protocol, positioning, and anatomy with pathology sections in a compact reference tool. The publisher, Mosby-Elseiver, ensured the book was MR-safe by giving the soft-cover text a plastic spiral binding. The book is easy to carry and can fit next to the scanning console.

The text begins as you would begin an MR procedure with a patient: "Patient Preparation" and then "MRI Safety Guidelines." After the preparation and guidelines review, the text provides 6 chapters covering the head and neck, spine and bony pelvis, upper extremities, lower extremities, thorax and abdomen, and pelvis. Each section begins with important considerations for scan acquisition, which includes subsections on scan considerations, coils, pulse sequences, and imaging options that convey important information in quick, easy-to-digest bullet points. The text then provides suggestions on which coil to use, patient positioning, landmark location, motion-minimizing pointers, slice acquisition direction, slice alignment, and area of anatomic coverage. Clear MR images are presented with a labeled illustration of anatomy and, in some cases, pathology presented. Helpful imaging tips appear throughout the text. After the positioning, anatomy, and pathology topics are presented, suggested protocols with select parameters are listed for 1.5-T and 3.0-T scanning. Space also is provided for readers to write in their site-specific protocol after each suggested protocol.

I was impressed that the text covered what many may consider standard exams and the advanced MR exams of breast, cardiac, and prostate imaging. The text also addresses advanced neuro applications of functional, diffusion, perfusion, and spectroscopy MR. The text is printed entirely in black ink on white paper, so readers cannot fully appreciate the color perfusion and tractography maps of the neuro applications.

After the imaging exams are presented, the text has 2 appendices on "Gadolinium-Based Contrast Agents" and "Vendor MRI Acronyms." Readers might note that the authors use GE-specific terminology throughout the book, so the acronyms appendix serves as a great tool for understanding the vendor terms. There is also a thorough glossary of MR terms. A detailed index concludes this helpful and comprehensive text.

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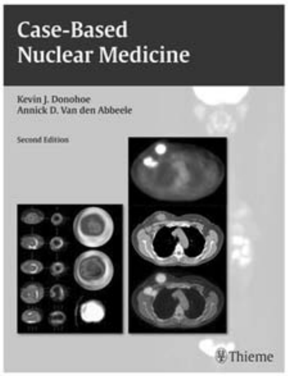
CASE-BASED NUCLEAR MEDICINE, 2nd ed.
Donohoe KJ, Van den Abbeele AD. 2011. 600 pgs. Thieme. www.thieme.com. $99.99.



The second edition of *Case-Based Nuclear Medicine* is a fact-based casebook. The foreword states that it is not intended for use as a textbook and should not be referred to as one, and I agree with this statement.

The purpose of the book is to challenge everyone from students to highly trained clinicians. With this in mind, this book is extremely helpful for technologists familiar with nuclear medicine. I have never worked in nuclear medicine so, it was a struggle to figure out the techniques being used. Luckily, the authors thought of everything and included an appendix on properties of radioisotopes. That said, I am sure technologists working in nuclear medicine will understand almost everything. Using the appendix and glossary, I was able to understand the concepts.

The book is full of medical images from many different modalities including radiographs, computed tomography scans, and nuclear medicine scans. Even with my limited knowledge of nuclear medicine scans, the descriptions and instructions helped me begin to understand what I was seeing.

I enjoyed learning and reading about the various patients, their diagnoses, what the scans meant, and whether the diagnosis was correct, and why. The results were discussed and broken down, and the pearls and pitfalls at the end of each section added to the "I got it" moment.

The book flows easily from chapter to chapter and is well written. I found only 2 drawbacks: It is extremely heavy and, after only 1 month, the binding was separating from the pages. The pages are thick, and the print is easy to read. I would recommend this book to others, especially if they are interested in learning more about nuclear medicine scans and what they help diagnose.

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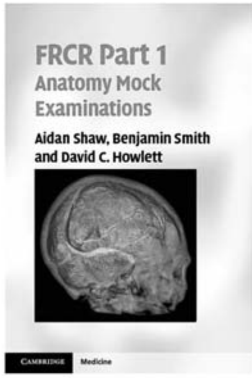
FRCR PART 1 ANATOMY MOCK EXAMINIATONS.
Shaw A, Smith B, Howlett DC. 2011. 240 pgs. Cambridge University Press. www.cambridge.org. $42.



This text provides mock exams for medical students studying to become radiologists in the United Kingdom. One of the requirements is to become a fellow of the Royal College of Radiologists (FRCR) which requires successful completion of a 2-part formal examination. The first exam includes physics and identifying radiographic anatomy. Medical students taking the FRCR exam are expected to identify anatomy on 20 radiographic images. The second test consists of case studies, reporting sessions, and oral exams. This book is specifically geared toward providing practice for the radiographic anatomy section of the first exam only.

This book does not contain new information, but offers workbook-type practice of labeling anatomy. Occasionally, the images are accompanied by an inquiry for additional review such as, "What passes through this structure?" or "What muscle lies here?" Some captions identify the type of image. For example, when asked to identify tendons and fat pads in the knee, "This is an MRI of the right knee," appears below the image. Likewise, brief definitions of the labeled anatomical parts are provided in the answer sheet following each mock exam.

The book is not organized by body part, but instead provides comprehensive images of the head, neck, thorax, abdomen, pelvis, and the musculoskeletal system. The selected images follow the content presented in the 2010 FRCR syllabus and include age-specific parts from both adults and children. There is not a reference or index for the specific images. The table of contents simply makes a generic statement of questions and answers with page numbers and immediately jumps into the first of 10 mock exams.

Individual exams consist of 20 separate images, with 200 images overall. This format is intentionally modeled after the authentic FRCR exam, and each image has between 4 and 12 identification labels. The mock exams contain various body parts from head to toe. The images are presented in a variety of projections from the different imaging modalities, including computed tomography, magnetic resonance, ultrasonography, nuclear medicine, and mammography. Various studies are included such as venograms, orthopantomograms, sialograms, fluoroscopy, angiograms, and sectional images with and without contrast. I found 1 3-D reconstruction of a cardiac CT scan. All other projections were frontal, coronal, sagittal, transverse, longitudinal, anteroposterior, lateral, or oblique. The images are of average quality and are black and white. Some images are clearer than others, but all parts are recognizable.

Student radiographers could use this book as a supplemental resource for studying sectional anatomy and identifying various imaging studies during an undergraduate radiography course. Any R.T. could easily identify the anatomy presented in the mock exams. This book serves its purpose for reviewing radiographic anatomy for medical students seeking recognition as clinical radiologists in the United Kingdom. However, I would recommend a more organized sectional anatomy book for radiographers who are preparing to further their education in additional certifications.

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The Life of an Educator

Tracy Iversen

"My Perspective" features guest editorials on topics in the radiologic sciences. Opinions expressed by writers do not necessarily reflect those of the ASRT. Those interested in writing an editorial should e-mail communications@asrt.org.

Although being an educator is often rewarding, no one ever said it was easy. In fact, being an educator is hard work. Our job is to help students become the best radiologic technologists possible, but we must overcome hurdles to make students' dreams a reality.

Educators live in a world of constant change. Each year we bring in a new group of students and say goodbye to others. We have to stay on top of changes with technology and the radiologic science curriculum. There is always a lecture that needs to be revamped (or even tossed and redone), a class to conduct, a meeting to attend, a topic to research, or a student who needs immediate attention. The list goes on and on, as does the need for extra time in the day.

Challenges

Educators face many challenges, including the generation gap. Today's educator is typically a baby boomer or from generation X, whereas the majority of students are from generation Y, with a few from other generations mixed in. The varied generations have different work ethics, motivations, and learning styles. Therefore, educators must teach concepts multiple ways to account for the differences.

Current students are in the digital era, and educators must adapt to meet the technological demands. Using transparencies for class is no longer acceptable. At a minimum, students demand PowerPoint presentations (Microsoft, Redmond, Washington) and are thrilled with podcasts. By the way, can anyone explain to me what a podcast is?

Many students are attached to the Internet, Facebook, and the dreaded cell phone. Students expect an immediate answer or solution. They question the relevance of textbooks when there are information sources such as Wikipedia, and they seem to disregard the risk of inaccuracy in online sources of information. Each year educators have to spend more time teaching students about plagiarism and the pitfalls of cut and paste, which forces me to question the school system. Do the students not care, were they never taught how to write properly, or have they never been held accountable for dishonest practices? How do students begin a radiography program without having written a research paper or even knowing proper research techniques?

Another challenge is the ever-changing curriculum. Educators must continually evaluate and adjust programs to ensure they meet the curriculum requirements. The amount of information the students need to learn keeps increasing, and classes are often rearranged or added to meet the curriculum demands. Our 24-month program is already packed, but with all the changes, the biggest fear is that we will have to expand it by an extra 2 or 3 months.

For educators schooled in the film-screen era, it can be difficult to switch to digital imaging. Radiographic density is now considered brightness; film latitude is called dynamic range. Window leveling and detective quantum efficiency did not exist in film-screen technology. Detent will soon be a thing of the past. Some equipment now can be lined up to the Bucky remotely. No more fighting the tube. But how does this affect the new student who is trying to learn how to manipulate the equipment efficiently? The rapid growth of technology has made it difficult for textbook authors to keep up. A limited number of textbooks pertain to digital imaging, and those available are difficult to understand or may even have contradicting information. Where can educators obtain the information needed to teach their students the digital technology? There are several conferences available to educators, but it can cost several hundred if not thousands of dollars for just 1 educator to attend. What if a facility has several educators?

Educators are not the only group experiencing growing pains. Students and staff technologists experience these challenges, as well. For students, it can be a challenge to learn about film-screen technology without ever using — or even seeing — an automatic processor or film-screen cassette. Students are taught the concepts of digital imaging in the classroom to apply in the clinic. However, staff technologists also need digital training. This might be achieved through vendor training, but many vendors assume R.T.s know the basics and understand digital imaging terminology, and what is said can be easily misinterpreted. This can cause problems in the clinical setting because the students often have more education concerning digital imaging than staff technologists. If students are not careful with how they communicate information, a rift between the student and the technologist may result. Many times, students need to be taught the art of communication to get answers to questions or make a point without alienating themselves or the staff technologists.

In addition, technologists have resources that can help them become better mentors to students. Continuing education helps R.T.s understand the differences between film-screen technology and digital imaging while learning the basic concepts behind digital imaging.

Educators have many challenges to overcome, but for many, the bright spots outweigh the frustrating moments. Some of these moments include seeing the student's excitement after performing their first exam on a patient, the amazement when everything "clicks," and the reaction to understanding a new concept. I feel like a proud mother each year when a class graduates, and I know they are ready to succeed in their chosen profession of radiology. Although it is sad to see the graduates leave, I know a new class is eagerly waiting to live the life of a radiologic technology student just as I did many years ago. I just have to remember not to say, "When I was a student … ."

Tracy Iversen, BS, R.T.(R)(M)(QM), is a medical radiography program instructor for Rapid City Regional Hospital in Rapid City, South Dakota. The author may be reached at tiversen@regionalhealth.com.

Solving Grid Cutoff

Beth Siegelbaum

"Technical Query" is a troubleshooting column that covers image acquisition and processing.

Although the technical factors were appropriate, many L5-S1 spot images appeared grainy and gray. A radiologist at the small facility suggested angling the tube less, but this resulted in only minimal improvement. The radiologic technologists who did not use any tube angulation for the L5-S1 spot projection did not experience this problem. After obtaining a radiograph of a well-positioned sacrum, with appropriate technical factors but extremely poor quality (see Figure 1), someone identified the problem as grid cutoff.

Figure 1. *Low-quality radiograph.*

Grid cutoff is an undesirable absorption of primary x-ray beams by grid strips, which prevents the useful x-rays from reaching the image receptor. It is caused by improper grid positioning and most often occurs with parallel grids. Poor penetration over the entire image pointed to x-ray beam misalignment with all grid interspaces as the cause of the problem.

Figure 2. *Radiograph after grid correction.*

The Solution

The clinical engineer was called in to check the grid. The technologists suggested it might have been installed incorrectly. At first, the clinical engineer said it was impossible, thinking that the grid was rectangular. After he took the table apart, however, he realized the grid was square and indeed could have been installed in the wrong orientation. He turned it 90° and all axial projections after the fix had even optical density (see Figure 2).

Beth Siegelbaum, BA, R.T.(R)(M)(BD), CBDT, is enjoying her second career as a staff technologist for Stamford Hospital's Darien Imaging Center in Darien, Connecticut.

Certification Scrutiny

Jerry Reid

"RE: Registry" addresses issues concerning the American Registry of Radiologic Technologists.

The new year brought increased scrutiny from the news media on how medical professionals become certified, how some candidates for certification attempt to short circuit the system, and how organizations responsible for certification are assuring that candidates earn it by demonstrating professional knowledge rather than cheating. CNN ran stories titled "Doctors Cheated on Exams" (aired January 13, 2012) and "Doctor Cheating Warnings Expand to Dermatology" (aired February 6, 2012) that focused attention on the practice of certification candidates recalling questions from their exams (known as "recalls" or "airplane notes") and passing the information on to future examinees. The first story covered candidates for the American Board of Radiology and the second covered candidates for the American Board of Dermatology.

Cheating on exams is not a new phenomenon. In fact, it probably started in 2200 BCE after China introduced the first exams to assess candidates for civil service jobs. One thing that has changed is the ease with which pilfered information can be quickly and widely communicated to others. Security breaches that once could be contained locally now can mushroom almost instantaneously.

Combine that with evidence from studies indicating an increased frequency of and tolerance for academic dishonesty — including cheating on tests — and you have a problem worthy of the public's concern. Data collected in 2003 on the Gallup Youth Survey suggested nearly half of 13- to 17-year old students reported cheating on an exam.[1] In 2008, the Josephson Institute of Ethics reported that 64% of American high school students had cheated on an exam sometime during the past year.[2] Longitudinal studies show that cheating on tests is becoming more widespread and more socially acceptable.

Reactions to the CNN stories, as seen on blogs frequented by candidates from the professions named, underscores the problem. Although the certification organizations clearly declared that participating in recalls was considered cheating and unethical, a number of candidates maintained that it was not and that using recalls was a legitimate way to study. Such comments conveniently ignored the fact that, regardless of their personal views on recalls, candidates signed an agreement not to engage in the behavior. They are obligated legally and ethically to comply. Some gave as the rationale for violating the examinee agreement that the exams covered irrelevant information and the only way to pass was to cheat — certainly odd reasoning to rationalize this unethical and illegal behavior.

One of the reasons that examinees and certification organizations view certain behaviors differently is that examinees may not understand the nature of examinations. A common sentiment is, "What's the problem? If I memorize the answers to the questions based upon recalls, haven't I demonstrated that I know the material?" They fail to understand that assessing an individual's knowledge is based upon a sampling model. A relatively small number of questions covering selected areas of the knowledge domain are pulled from a large population of potential questions. The questions included on a form of the exam represent a sample of the population of all possible questions and the score on the sample is used to infer (ie, generalize from sample to population) the candidate's mastery of the entire knowledge domain. If a candidate knows in advance which questions he or she will be asked and memorizes the answers to those questions, the inference from sample to population is compromised. Because determining qualifications to practice is not about memorizing answers to specific questions, but rather about mastering the knowledge domain, recalls subvert the integrity of the exam process.

Another sentiment expressed by some examinees is, "Why not just write new questions for each exam form? Then you don't need to worry about candidates memorizing questions." The thorough process of developing questions makes them expensive. The rule of thumb is that a single question costs about $1000 to develop based on the costs of generation and review by content experts, pilot testing, and statistical analysis. Developing new questions for each exam form would make the process prohibitively expensive for examinees and result in exams of lower quality. Reusing questions that have gone through an extensive process of refinement is considered a best practice in certification testing.

ARRT recognized several years ago that exam subversion was a growing problem and set a course of action to address it more effectively. We started by committing to stemming the rising tide of subversion. This put us in the vanguard among certification organizations on this issue. ARRT established a 3-pronged approach to achieving the goal. The first prong was to clearly describe the types of behavior that constituted exam subversion for ARRT exams. The second prong was to educate the professional community on the problem and set expectations for its examinees. The final prong was to refine the tools used to identify and sanction those involved in exam subversion.

Exam Subversion Defined

Exam subversion is any behavior that undermines or corrupts the psychometric quality of an examination. Attempts to defeat the purpose of the examination (ie, assess an examinee's knowledge) constitute subversion. ARRT's examples of exam subversion include disclosing exam information, receiving exam information, copying or reconstructing exam information, selling or offering to sell exam information, attempting to take the exam for another person, or soliciting someone to take the exam for another person, as well as other behaviors. Although not necessarily new prohibitions — these were prohibited before this initiative — they were more clearly stated and illustrated with examples. Boundaries between what was acceptable for an examinee to disclose and what was not acceptable were crystallized. For example, disclosing information about an exam that was not otherwise publicly available through the ARRT is considered exam subversion. Recalls, even if not exact, are clearly prohibited.

Educate/Notify

Informing candidates for certification is the most important way to prevent someone from unintentionally violating ARRT's policies. ARRT went to great lengths to inform candidates about the prohibited behaviors.

The ARRT's certification handbook covers exam subversion in multiple places. A section in the body of the handbook addresses prohibited activities, and candidates sign an agreement on the application that points out prohibited activities. The *Rules and Regulations* cover exam subversion, and the *Standards of Ethics* has a multipart rule specifically covering exam subversion.

As a reminder to candidates at the test center, the computer presents a nondisclosure agreement that the candidate must electronically sign. Failing to sign to the agreement within the allotted time will end the test administration and the candidate cannot proceed. Although far from the candidate's first encounter with the prohibitions, this reminder at the time of the exam administration reinforces the policy.

In addition to the printed information about exam subversion, ARRT produced a scenario-based video to help candidates for certification understand the behaviors that constitute exam subversion. The video is available at www.arrt.org/examination/exam-security and through YouTube.

Prosecute

When educating candidates and others who interact with candidates about the importance of avoiding exam subversion does not have the desired effect, intervention is required. Our tools for this include both the legal system and ARRT's internal ethics system.

ARRT's first tool is legal action based upon copyright violation. ARRT copyrights all of its intellectual property, and test questions are some of the most important intellectual property owned by a certification organization. Copyright law not only protects exact reproductions, but also covers "substantially similar" material. So even if an individual doesn't produce an item word for word, a copyright violation can be demonstrated when the violator has had access to the material, which they do as examinees. Lawsuits are filed in federal court. Damages include costs to replace the items compromised and the legal fees incurred to prosecute the case. One example was reported in the 2009 *ARRT Annual Report to Registered Technologists*. ARRT was awarded a $250 000 judgment against the offender in that case. At any given time, ARRT has several legal cases underway to protect its intellectual property rights.

The agreement that the candidate for certification signs in the application process is a legally binding contract between the candidate and the ARRT. It specifies what ARRT is agreeing to do and what the candidate is agreeing to do. Violation of the contract subjects the candidate to a lawsuit for breach of contract. ARRT has used this tool as well in pursuing violations through the courts to collect damages.

In 2010, as a result of ARRT lobbying efforts, the state of Minnesota signed into law prohibitions against exam subversion on certification and licensure exams. All candidates regardless of their state of residence agree to be bound by this law when they sign the candidate agreement. This provides an additional tool for ARRT to use against offenders. Incidentally, Minnesota is not the only state to have such a law. California, for example, has a similar law.

In addition to the legal system, ARRT maintains its own internal system for combating exam subversion. The *ARRT Standards of Ethics* lists behaviors considered to be exam subversion. Cases in which candidates for certification or registered technologists are suspected of these behaviors are investigated. If determined guilty under ARRT's ethics process, the individual is subject to sanctions such as permanent removal of eligibility for certification and revocation of any certifications already held.

So What?

So, why does it matter if someone cheats on the exam? The short answer is that exam subversion puts patients at risk by certifying or licensing individuals whose qualifications to practice have not been appropriately evaluated. Cheating undercuts the validity of the scores generated from the certification exam because they do not accurately reflect what an individual knows.

The integrity of the certification process rests upon the integrity of the program's component parts. To the extent that any component is subverted, the value of the overall certification breaks down. Nowhere is this more apparent than for the exam. The recent news stories demonstrate that the public recognizes the necessity of protecting the integrity of medical certification examinations for the public good.

Fortunately, most candidates for certification comply with the expectations. They realize that exam subversion devalues the credential awarded, not just for the individual who cheats, but for everyone else as well. It is in the best interests of both the profession and the patients to maintain clear expectations regarding appropriate exam behavior and to act when those expectations are not met.

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Watch the ARRT's video about exam subversion in the digital version of this issue online now or visit www.arrt.org/examination/exam-security.

Standardized Patients in Education

Marilyn A Rep

"Teaching Techniques" discusses issues of concern to educators. The primary focus of the column is innovative and interesting approaches to teaching.

Georgetown University School of Medicine defines standardized patients as individuals "trained to replicate a clinical encounter consistently and realistically and evaluate students' skills in a variety of areas such as physical exam skills, history taking skills, and communication skills."[1] At Cuyahoga Community College (Tri-C) in Parma, Ohio, standardized patients are used in the radiography positioning labs to evaluate and enhance student communication skills.

Communication Skills

Effective communication is vital to the success of radiography students. In fact, all medical professionals must be able to communicate effectively with each patient, as well as with patients' families and other health care providers. Therefore, radiography faculty and staff have a responsibility to help students strengthen their communication skills.

Communication involves a sender, a message, and a receiver. The process of communication involves what the sender intended to say, what the sender actually said, what the receiver heard, and feedback. It is not just the words spoken, but also the sender's body language, tone of voice, and expressions. How the receiver interprets or perceives the message also plays a role. Radiography students need to be taught how to organize their thoughts, speak directly to the person or people concerned, use "I" statements, own and manage their feelings, and practice listening skills.[2]

History

In 1963, neurologist and medical educator Howard S Barrows was the first to use a simulated patient at the University of South Carolina. At the time, this technique was not seen as a legitimate educational tool, and the Associated Press printed headlines such as "Hollywood Invades USC Medical School."[3]

In 1964, Barrows and Stephen Abrahamson published "The Programmed Patient: A Technique for Appraising Student Performance in Neurology" in the *Journal of Medical Education.* He also began holding workshops for physicians to improve their skills by receiving immediate feedback. Eventually, other educators recognized the value of students encountering realistic situations without jeopardizing the welfare of patients.[3]

In the early 1970s, pediatrician Paula Stillman, MD, began using "simulated mothers" as her standardized patients to teach medical students interviewing skills. The simulated mothers gave histories of common pediatric complaints to students. Stillman developed checklists based on behaviors, which the standardized patients used to provide feedback and grade students. She inspired the Arizona Clinical Interview Rating Scale — the first behaviorally anchored Likert scale to assess medical interviewing skills. The University of Kentucky uses a modified version of Stillman's rating scale to assess medical students' abilities to do physical examinations.[4]

Ohio University Heritage School of Osteopathic Medicine has used standardized patients since 1978 to teach first- and second-year medical students to interview, take histories, and diagnose in a safe and supportive environment. To be selected as a standardized patient, individuals must be unbiased, accurate, and interested in the patient role they are playing. After each student encounter, they complete a communication checklist. The feedback helps students gain confidence in their communication skills prior to beginning a clinical rotation. Standardized patients are invaluable to the educational process.[5]

Discussion

In our radiographic positioning classes, students took turns being the patient or the technologist. The lab supervisor used standardized evaluation forms to evaluate the student's ability to position the patient accurately, manipulate the equipment, provide radiation protection, and communicate professionally. However, problems existed. The students acting as the patient knew what to expect and how to position body parts for the procedure. Often, the well-performing students partnered together, as did the weaker ones. Ultimately, the communication skills were not being developed as well as they could be, so the radiography faculty worked to determine ways to better assess students' communication skills.

The faculty faced several additional communication issues. Some students, including several foreign students, fared well in the classroom but struggled in the clinical environment. Radiography students used a mobile unit to simulate imaging a human phantom. However, working with the phantom did not help students develop communication skills.

Around this time, a tremendous amount of time was devoted to the planning and design of a $6.5 million health technology lab for multiple allied health programs. Allied health representatives shared ideas on innovative teaching methods, and program managers traveled to Baltimore to visit the Walter Reed Army Medical Center. The Walter Reed Center — one of the best hospitals in the United States, particularly in the area of prosthesis — is the principal hospital for soldiers wounded in Iraq and Afghanistan and has served as a leading center for medical research.[6]

Program managers were allowed to tour the teaching laboratories to see how simulations and virtual reality scenarios were conducted. The visit stimulated discussion and ideas for planning their new facility.

At Tri-C, initially standardized patient use was implemented for physician assistant students to practice history-taking skills and evaluate their communication skills. Radiography faculty discovered that its use in radiographic positioning labs would help assess students' communication skills.

Because this was a new initiative, several planning sessions were held to discuss the development of evaluation forms, mock requisitions, and case scenarios for junior and senior students. Initially, some faculty members were reluctant to change their practice of having students work with fellow students as their patients. Students also resisted the idea of not having a student — who was likely a friend — as a partner.

Despite this resistance, an enthusiastic new lab supervisor took charge of the details and worked with another preceptor, who hired and scheduled the standardized patients. The radiography lab supervisor prepared sample forms, which faculty and staff revised, for students to evaluate their video-recorded sessions and for standardized patients to evaluate student performance. Everyone worked together on this project to produce positive outcomes and an evolving process.

Initially, we collected sample requisitions from clinical sites and developed a form with important features for students to recognize, including the acquisition number, patient name, age, date of birth, clinical data, and radiologic procedure ordered.

Next, we created sample case histories to coincide with anatomy being covered in the patient positioning course. It is important for the standardized patients to be able to describe what happened to them and why they are scheduled to have a particular examination.

The standardized patients were instructed on how to complete the evaluation checklist for the students' grades. The importance of patient shielding was

Cuyahoga Community College
Radiography Program
STANDARDIZED PATIENT FEEDBACK CHECKLIST

Student Name______________________ Exam Type________________________

Date __________________

What did the student do well?			
The student:	**Yes**	**No**	**Cannot recall**
Introduced himself or herself.			
Washed hands (observed by me, the standardized patient).			
Properly identified me.			
Demonstrated interest and respect.			
Maintained eye contact.			
Shielded me from radiation.			
Used encouragers (verbal or visual).			
Made me feel comfortable.			
Used words that I could understand (without medical terminology).			
Spoke slowly enough to be understood.			
Spoke loudly enough to be heard.			
Was gentle when assisting me.			
Explained the procedure in a manner I could understand.			
Verified correct body part to be examined.			

My overall impression of the encounter was: *Please circle one.*
Excellent Good Fair Poor

Any additional comments:

Figure 1. *Standardized patients were asked to complete a checklist to help instructors grade students.*

Cuyahoga Community College
Radiography Program
Patient Experience Feedback Project 20 points

Student Name________________________ Exam Type__________________________

Semester/Year ________________________ Group______________________________

Review your standardized patients encounter using the following questions:	Yes	No	Time on DVD
Did you properly identify yourself?			
Did you properly identify the patient?			
Did you question pregnancy status, if applicable?			
Did you verify correct body part to be examined?			
Did you explain what you were going to do before you did it?			
Did you shield patient?			
Did you properly position your patient while maintaining his or her comfort and modesty?			
Were you responsive to any patient concerns?			
Did you complete the exam in an expedient manner?			
Did you manipulate the equipment in the most efficient way possible?			
Did you get a thorough patient history?			
Did you allow adequate time for the patient to respond?			
Did you speak loudly enough for the patient to clearly understand you?			
Did you demonstrate professionalism?			
What could you have done better?			

My overall impression of the encounter was: *Please circle one.*
Excellent Good Fair Poor

Any additional comments:

____

____

Figure 2. *Feedback form to be completed by students after watching recorded encounter with standardized patients.*

emphasized, as well as how well the students explained what they were doing to obtain the radiograph. Comments on the evaluation form were encouraged (see Figure 1).

When we began the new initiative, the standardized patients were students enrolled in the school's theatrical arts program. This cooperative effort between departments gave students an opportunity to learn how to improvise. However, each semester there were different students. For more consistency, we hired standardized patients who were working with the Case Western University Medical Program, which proved to be more reliable.

During the positioning lab, a preceptor video-recorded individual students as they performed a procedure on the standardized patient. At first, students were nervous about being recorded. However, when we explained the benefits and allowed practice sessions prior to the scheduled video date, it was more readily accepted. Following the video session, students were required to view the video and complete a self-assessment form to rate their performance and note how they might improve (see Figure 2). One benefit of recording the lab session when students position a standardized patient is that students can see themselves and the patient.

One of our students was positioning a patient for a Townes view of the skull. The student wanted the patient to tuck in her chin and held onto the patient's chin while repeatedly saying, "tuck, tuck." The student continued to say, "tuck, tuck," and the patient responded by talking and talking. Finally, feeling frustrated, the patient said, "I don't know what you want me to say." The student still did not realize that the patient thought she was saying, "talk, talk," until she reviewed the video. Because it is easy to be misunderstood, students learn a lot when they see themselves from a different perspective.

In another example, a student had no idea how many times he moved the x-ray tube back and forth before he finally centered the tube over the midabdomen until he watched his video.

Because body language, facial expressions, and tone of voice play a big role in how someone interprets the message being sent, viewing the recorded session helped students see and hear what they did or said that could be misunderstood. In particular, with foreign students, the video may demonstrate that although the student knows the words, he or she delivers instructions to the patient in a stern rather than friendly voice.

Using standardized patients in our radiography positioning lab has helped to better prepare students for the clinical environment. With the realistic practice, the students have more confidence and are able to communicate more effectively with the radiology department staff and most importantly with the patients.

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Marilyn A Rep, MS, R.T.(R), recently retired from Cuyahoga Community College in Cleveland, Ohio, where she was the radiography program manager for 26 years and a full-time faculty member for 4 years. As program manager, Ms Rep developed and implemented a diagnostic medical sonography program and a nuclear medicine program. She also initiated a Web-based mammography training award program for graduates and an evening/weekend program for radiography. She completed her radiologic technology training in what her son calls "the Dark Ages" from St Joseph's Hospital in Toronto, Ontario, Canada. Ms Rep received her bachelor's degree in the humanities from Thomas Edison State College in Trenton, New Jersey. Most recently, she graduated from Independence University, based in Salt Lake City, Utah, with a master's degree in health with emphasis on wellness promotion.

Collaboration and Authorship

James Johnston
Kimberly L Metcalf

"Writing & Research" discusses issues of concern to writers and researchers and is typically written by members of the Editorial Review Board. Comments and suggestions should be sent to communications@asrt.org.

For individuals new to research and writing, the concept of authorship may seem a minor detail compared with designing and carrying out a research project. Although more experienced writers may know it can be a difficult issue to work out, they may not know how best to determine authorship and what it truly means. At its core, those listed as authors on a manuscript assume both credit and responsibility for the work and stake their professional reputations on its content.[1] To be listed as an author, one must have invested sufficient effort in a variety of areas of the manuscript's development.[1,2] This article explores the concept of authorship and what one's name on a manuscript should mean. Also discussed are the contributions that constitute legitimate authorship and how to determine and document those. The potential benefits of coauthorship are explored to help aspiring writers undertake the task of writing for publication. Finally, some "food for thought" is offered on how to collaborate and work out the details of authorship.

What Constitutes Authorship

According to the International Committee of Medical Journal Editors (ICMJE), someone listed as an author on a manuscript should have made substantial contributions to the study.[3] It further defines "substantial contribution" as meeting 3 criteria:

1. Substantial involvement in the conceptualization of the study, data collection, analysis, and interpretation.
2. Substantial involvement in writing and editing the manuscript.
3. Having final approval of the manuscript to be published.

Others with more limited roles and other contributions should be listed as acknowledgments, but not as authors.[1-4] For example, obtaining grant funding for a project, being the head of the department or lab in which the research was conducted, or chairing a graduate student's research project does not necessarily constitute authorship, but may deserve acknowledgement. Some journals now require that 1 author be designated the "guarantor" of the work.[4]

The order of authorship is not consistent across disciplines. Generally, in medical and allied health journals, the first author contributed the most to the study and publication; it is assumed that the other authors are listed in descending order of contribution.[5] Although the second author is usually a significant contributor to the work, the contributions of the middle author or authors vary widely.[5] Other disciplines such as mathematics may list authors alphabetically regardless of degree of contribution. Still others may indicate acknowledgements through the order of a name's placement on the author list. Such cases list the most senior research member or lab chair first, whereas others may list him or her last to indicate the most prestigious position within a discipline. So while a journal may be concerned with the legal and ethical responsibility of the work with regards to authorship, the professional community may be more concerned with credit, prestige, or "honorary" listings of authorship.[4] It is not to say that the authors are not concerned with responsibility for the work, but the way they list authorship may not necessarily reflect this concern.

History

In the late 17th and early 18th centuries, the listed author on a publication was the person legally responsible for the content of the work and answerable to the "powers that be" for any inaccuracies.[6] Further, he or she was not necessarily seen as the creator of the work for whom authorship provided some intellectual protection, but rather the responsible party that would be held accountable.[6]

Over time several developments have brought us to where we are today. On the clinical/biomedical side, the trend toward competing for such things as labs, funding, and advancement of one's research has led to collaborations and multi-institutional publications.[1,4] In this competitive environment, bylines of coauthorship have become a "currency" bringing recognition and prestige through association with a particular lab or senior researcher.[1,6] On the academic side, similar competitions exist, with additional motivations such as consideration for tenure, promotion, or career advancement at more "prestigious" institutions.[4] Research conducted in both arenas using first authors of published manuscripts indicates that as many as 26% of the authors listed after them had not contributed substantially to the manuscript when applying the ICMJE criteria.[4,7] Again, although people listed as authors may be more concerned with the benefits of credit, the journals and journal editors may be more concerned with responsibility and accountability for the content of the manuscript.[1-4,6] These conflicting views of authorship give rise to questions of ethics and questionable practices in research publication.

One school of thought in listing authors is simply to give credit to everyone who contributed to the study. In this approach everyone who participated in any way is listed on the manuscript as an author.[4,5] Conversely, in another approach, only those who had a substantial role in the study and can "publicly defend" its content should be listed as authors and the others should be listed as acknowledgments.[1-5] The ethical controversy comes when individuals are listed who made very little or no contribution to the manuscript or are not even aware that they are listed as an author. Such things occur regularly enough to have names. For example, guest authorship (also known as gift authorship or honorary authorship) is the act of adding a name out of tradition or obligation, such as the name of the head of the lab or academic chair.[5] In pressured authorship the true primary author is forced to include the name of an individual who had little or nothing to do with the study by someone in authority over him or her.[5]

Determining Authorship

Determining authorship contributions may be a matter of professional practice (by profession or discipline), institutional policy (policy established by research facility or university), or the journal in which the author is seeking publication. In addition to the ICMJE recommendations, Friedman identified categories that signify appropriate contributions and indicated that 2 or more of these categories should be met to justify authorship inclusion.[2] These categories include parts of the study process such as concept; design; data collection, analysis, and interpretation; literature searches; writing; and critical reviews.

When conducting research and writing with students, the faculty member's name should only appear if he or she made substantial contributions to the manuscript and only then as second author.[1-5] An exception to this would be in cases where the faculty member, for example, took over the study, completed the research without the student, or substantially reanalyzed the data and revised the entire manuscript.[8]

Benefits of Coauthorship

Collaborating on research provides great opportunities for more seasoned writers to mentor less experienced writers.[9] In the radiologic science field in particular, there is a real need for new research and the subsequent dissemination of the findings. Sharing research activities and ideas with others in the profession is a positive way to encourage their involvement in potential research and writing.[10] When coauthoring, the workload is divided among more than 1 person, potentially reducing the time necessary to complete a project. In fact, collaborating with others has been shown to increase research productivity.[11]

How to Collaborate

In collaborations, the issue of authorship should be discussed during the planning stage because it should reflect the work contributions that each member is expected to make. It is certainly easier if the lead author is established from the beginning, with the understanding that this person will assume the additional responsibility of overseeing the entire project and serving as the guarantor of the manuscript's content. In academic settings the order of authorship can have career implications and, as previously stated, the order of authors can mean something different depending on the discipline. This sometimes complex issue of authorship should not dissuade one from collaborating on a research project and publishing the results. Indeed, such collaboration — particularly of the interdisciplinary kind — is quite rewarding.

It also is a good idea to have a journal or journals in mind for the subsequent manuscript and explore their requirements at the beginning. By doing so, one will have established and met their author requirements already. If the research team is very diverse, the subject of parallel publication may be explored in the early stages. This is a process whereby the authors obtain permission from the journals in question to publish the findings in both. Finally, authors must identify and follow any institutional policies regarding authorship and, if it is a multi-institutional effort, seek to resolve any conflicting issues before beginning.

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Hear more on the importance of authorship from Dr Johnston in the digital edition. Visit www.asrt.org/publications.

Parents in Nuclear Medicine Suites

Donna L Mason
Angela Macci Bires

"Case Study" discusses interesting or unsusual cases. Submissions should be sent to communications@asrt.org.

Nuclear medicine combines chemistry, physics, mathematics, computer technology, and medicine to diagnose diseases and treat them with radioactivity. Nuclear medicine is a unique diagnostic technology that provides information about the structure and function of major organ systems within the body. This ability to characterize and, in some instances, quantify physiologic function separates nuclear medicine from other imaging modalities.

Nuclear medicine technologists are highly specialized health care professionals who work closely with nuclear medicine physicians. Technologist responsibilities include preparing and administering radiopharmaceuticals, analyzing biologic samples in the laboratory, performing patient imaging procedures, and performing data analysis, computer processing, and image enhancement for diagnostic interpretation by a physician.

During an imaging procedure, the technologist works directly with the patient. The technologist gains the patient's confidence by obtaining pertinent history, describing the procedure, and answering questions. He or she also monitors the patient's physical condition during the procedure and notes any patient comments that might indicate the need for additional images or help the physician interpret the results of the procedure.

One of the most rewarding aspects of nuclear medicine technology, pediatric imaging requires attention to issues not commonly encountered when imaging adults. Technical considerations (eg, intravenous access, fasting, sedation, and immobilization applications) are challenging but essential to performing state-of-the-art pediatric nuclear medicine imaging.

Pediatric nuclear medicine is used in the diagnosis of many childhood disorders. It helps in the evaluation of different organ systems, including the kidneys, heart, liver, lungs, and bones. Although pediatric nuclear medicine procedures are time consuming, sedation or analgesia cannot always be used because quality imaging sometimes requires patient participation and cooperation. Nuclear medicine technologists who work extensively with children must routinely calm a child's fears. Many imaging suites provide videos and toys to help the child pass the time. In most cases, hospitals encourage parents to stay with their child to help calm the child and decrease his or her motion during imaging. Unfortunately, many children and parents fear any visit to a medical center. This parental fear often is communicated to the child in the form of tears, as well as blame and anger directed toward the technologist, which raises the question of whether parents should be permitted in the imaging suite during nuclear medicine procedures.

Literature Review

A significant amount of literature is devoted to the practice of pediatric nuclear medicine imaging.[1-6] Several researchers recognize that these imaging procedures might require twice as much time for pediatric patients than for the same examination with adults. This variation must be taken into consideration during appointment scheduling to ensure the staff has sufficient time to devote to children and their parents.[7-10] Studies by Gordon and Veitch emphasized patient preparation, instructions, and communication directed toward parents or caregivers.[2,9] Clear communication helps parents understand the reason for the procedure, its necessity, and what the technologist must accomplish to acquire an interpretable study in the first attempt. Depending on the child's age, a technologist can provide a reassuring description of the procedure before and during the examination. Parents may be instructed to schedule the procedure during a younger child's naptime to maximize the chances that he or she will sleep during the procedure.

Gordon and Kotz also stressed the need for diversions such as toys, books, posters, and videos to make children feel comfortable and secure.[2,7] Imaging department staff often can increase cooperation by letting the child have a pacifier, bottle, blanket, or stuffed animal. Décor can make the room more interesting and comfortable. In addition, the researchers suggested using a papoose (an immobilization device), sandbags, or adhesive tape to restrain infants and young children. Such strategies may remove the need for sedation without sacrificing image quality.

The literature focuses on nonpharmacologic and pharmacologic strategies available to help the child cooperate and hold still during an examination. Several organizations, including the American Academy of Pediatrics and the American Society of Anesthesiologists, have published guidelines to help eliminate patient movement during pediatric nuclear medicine imaging.[11-14] Although sedative and analgesic agents are generally safe, complications related to their use can occur. Mild sedation-related adverse events include motor imbalance, gastrointestinal effects, agitation, and restlessness.

The pain associated with most nuclear medicine procedures is limited to a single venipuncture or catheterization of the bladder. With patients for whom the pain of venipuncture is a limiting factor, topical lidocaine preparations may be prescribed before the procedure and applied by a parent before arriving in the nuclear medicine department. Xylocaine jelly can be used for difficult urethral catheterizations.

According to Nadel and Shulkin, new advancements in instrumentation (eg, high-resolution multiple detector imaging and high-quality positron emission tomography) are essential to performing high-throughput state-of-the-art pediatric nuclear medicine imaging.[15, 16] The development of new radiopharmaceuticals may provide lower radiation exposures to patients and technologists, as well as offer a better understanding of the physiological processes under examination.

Although hospital policies dictate whether parents are permitted in the imaging suite during nuclear medicine procedures, few studies have assessed whether the presence of parents ameliorates or exacerbates the compliance of pediatric patients during imaging.

Methods

The purpose of this research was to analyze technologists' perspectives about allowing parents in the imaging suite during nuclear medicine procedures. A total of 28 nuclear medicine technologists who perform pediatric imaging were interviewed for this study. The participants were approached at meetings conducted by SNM (see Box 1). The geographical distribution of the respondents was somewhat limited with 54% from Pennsylvania and Ohio, 39% from the mountain west/western United States, and 7% from the southern United States (see Table 1).

Each participant was asked a series of questions (see Box 2) after granting verbal consent to be interviewed. All interviews were audio recorded. The participants' identities were indicated by a case number rather than by a name. All recordings were transcribed, and any information identifying the interviewee or other individuals mentioned in the interview was deleted from the transcripts. The recordings were destroyed after the accuracy of the transcription was verified.

Box 1
SNM Meetings Where Participants Were Identified

- 33rd Annual Western Regional (Portland, Oregon)
- Pittsburgh Chapter 2008 Fall Symposium (Cranberry Township, Pennsylvania)
- 2009 Mid-Winter Symposium (Clearwater, Florida)
- 56th Annual Meeting (Toronto, Canada)

Table 1
Geographical Location of the Practice

State	No. Respondents
Pennsylvania	14
Washington	4
California	3
Oregon	2
Colorado	1
Montana	1
North Carolina	1
Ohio	1
Virginia	1

Box 2
Interview Questions

1. What is your hospital's policy on allowing parents in the imaging suite during pediatric nuclear medicine?
2. Who do you think developed this policy? Did you have any input in the development of this policy?
3. What reason has been offered for that policy?
4. Do you feel that a parent's presence helps or hurts in the performance of the study?
5. Can you describe an instance in which a parent's presence was positive?
6. Can you describe an instance in which a parent's presence was negative?
7. If you had the opportunity to change your hospital's policy regarding parents in the imaging suite during pediatric nuclear medicine imaging, what change(s) would you make? Why?
8. Do you have any other thoughts or comments?

Results

Demographics

Of the participants interviewed, 10 were men and 18 were women. Of these participants, the highest level of education completed was a doctorate and the lowest educational level was a 2-year associate degree. Most participants (13) had a bachelor's degree. The years of experience were similarly distributed with an average of 16.3 years of pediatric imaging experience and an average of 17.3 years in the field of nuclear medicine technology. Participants also were asked how many procedures per month were performed at their institution (see Table 2).

Table 2
Pediatric Procedures per Month

Procedures per Month	n (%)
< 5	9 (32.14)
5-10	8 (28.57)
11-20	3 (10.71)
21-30	0 (0)
31-40	1 (3.57)
> 40	7 (25)

Participant Responses

All the participants indicated that their hospital's policies allow parents in the imaging suite during pediatric examinations. Of the interview responses, 68% (19) indicated that policies were verbal (ie, unwritten but understood) and 25% (7) indicated that their facilities had a formal written policy. In addition, 7% (2) of the respondents stated that the policies were communicated in both verbal and written form.

When the respondents were asked who created the policy, the results showed that the highest percentage noted senior hospital administrators at 64% (18). Only 4% (1) of policies were developed by nuclear medicine department administrators and 18% (5) were created by technologists. Two respondents stated that they were not sure and 2 did not have a policy. The results showed that 71% (20) of the interviewees did not have any input into the creation of a policy.

Participants identified care, comfort, concern, and cooperation as themes that helped boost compliance from the children and were the impetus in the creation of a policy. One technologist stated that because children are minors, parents or legal guardians have an established right to be present during medical procedures.

When the respondents were asked whether a parent's presence helped or hurt the performance of the study, different opinions emerged. In regards to "helping" situations, 46% (13) were in favor of parents being present in the imaging room and 46% (13) stated that it depended on the situation. Researchers identified 4 factors involved in the case-by-case response:

- The child.
- The parent.
- The relationship between the child and the parent.
- The study being performed.

Only 7% (2) of the participants indicated that parental presence "hinders" or "hurts" the study. Some respondents mentioned that parents can be difficult and, in those situations, the presence of a parent may need to be "dealt" with on a case-by-case basis.

When asked to describe an instance in which a parent's presence was positive or negative, both situations were identified. One participant described a parent talking the patient through the procedure and calming him with her voice. Another participant reflected that with a teenage girl patient, the mother was crying regarding the injection yet the patient was fine. The patient actually asked that her mother be removed from the imaging room.

The final question in the interview asked the respondents to discuss changes they would make as the policy author. Of the participants, 79% (22) stated that they were satisfied with their institution's current pediatric policy regarding parents in the imaging room. One participant was writing a policy, and 18% (5) recommended minor modifications to their current policies such as only 1 parent, no siblings, and granting the nuclear medicine technologist the authority to evaluate on a case-by-case basis. Of the 5 respondents who preferred a modified policy, 1 respondent believed that both parents should have the right to be present and not just 1 parent as her current policy indicated.

Discussion

This research revealed that the hospitals of all 28 technologists interviewed allowed parents in the imaging suite during pediatric nuclear medicine examinations. However, this research indicated that most policies regarding whether parents were permitted in the imaging room were verbal and unwritten. Written policies typically are edited carefully to address the key issues and updated regularly to offer guidance regarding the roles, responsibilities, and continuity of pediatric patient care. Written policies also avoid misunderstandings that can lead to contentious situations.

In general, at institutions with a written policy, the nuclear medicine technologist had limited input into the policy creation. However, soliciting input from the staff responsible for and affected by a policy is integral to implementation. Management can gain valuable buy-in when the responsible nuclear medicine technologist assists in policy development. Nevertheless, the results indicate overall contentment with institutions' current pediatric policies (written or verbal) regarding parents' presence in the imaging room.

Regarding the reason for creating a policy, the participants reflected that the health and safety of the pediatric patient is the main objective. They must deliver effective and safe medical imaging.

Conclusion

This study sought to elicit the views of experienced nuclear medicine technologists regarding pediatric nuclear medicine practices. Specifically the focus of this work related to the presence of parents in the nuclear medicine suite. Most respondents indicated an overall contentment with their institutions' current pediatric policies regarding parents' presence in the imaging room. However, the majority of the respondents specified that there was no written policy documented.

A written policy should be clear and concise to ensure all parties involved have the same understanding of the policy goals and requirements. When developing a written policy, management has an obligation to identify those who will be directly affected by the policy and to consider their views in policy development.

Although the results are interesting, a more comprehensive study designed to address the limited geographical distribution of respondents and small sample size are probably warranted.

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Close Encounters of the Patient Kind

James H Taylor III

"Management Toolbox" focuses on practical issues concerning radiology department management and professional growth.

Although health care management often attempts to define patient satisfaction, the patient's health care experience likely is the best way to understand patient satisfaction.[1] Most patients have expectations for their health care experience, and it is reasonable to assume that patient satisfaction is a summation of their expectations.[2]

Improving patient satisfaction is about enhancing the patient's experience while in your care, and it also can result in a more positive patient evaluation for your facility.[3] Most imaging departments fail to recognize factors valued by patients that could lead to increased patient satisfaction.

Medical Imaging and the State of Health Care

Although the United States faces health care reform, there is concern that principals and concepts of quality in the health care system are being lost. Overwhelming evidence gathered from the past 20 years has indicated that quality of medical care processes and outcomes in the United States are less than optimal.[4] According to a survey conducted by the Employee Benefit Research Institute, only 53% of insured Americans who received health care services said they were extremely or very satisfied with the care they received.[5] The survey results revealed a discrepancy between the current state of health care and what health care could and should be.

More than 300 million medical imaging procedures are performed in the United States each year.[6] The demand for medical imaging services continues to grow because of an aging population and advances in technology. Imaging professionals act as representatives of their respective departments and have a significant influence on the patient care being given every day. Challenging your imaging department to focus on patient-centric care can play a substantial role in achieving the highest level of patient satisfaction.

Patient Satisfaction Makes Business Sense

The dismantling of regulations and economic factors has made the health care industry substantially immune to competition. As a result, medical imaging has become a true customer-oriented industry with patient satisfaction as the main focus.[7] Radiologic technologists are starting to see their departments shift to a more patient-centric focus with a better understanding of the patient satisfaction phenomenon. This shift is important because patient satisfaction is a leading indicator of quality and financial performance.[8] When patient satisfaction improves, there is an increase in return visits, word-of-mouth referrals, new patients, and ultimately revenue.[8]

Word of Mouth and Patient Loyalty

Word-of-mouth referral is the most influencial factor for a patient when it comes to choosing a health care facility.[9] A hospital's estimated cost to recapture a dissatisfied customer ranges from a conservative estimate of $8000 per patient to approximately $400 000 a year in future encounters over that customer's lifetime.[9] The average "wronged" customer will tell 25 people about the bad experience.[10] Word-of-mouth marketing — both positive and negative — is a powerful force for imaging departments and it can be a driving factor for reputation and revenue.[10]

Radiologic technologists must strive to ensure that the service provided stands above the competition to gain patient loyalty.[11] The relationship between patient satisfaction, loyalty, and profitability has been well established. A 5% improvement in customer retention can lead to a 25% to 100% increase in profits.[8] It costs 10 times as much to attract new customers as it does to keep current ones.[10] Systematically improving patient satisfaction to maximize the number of patients who are fiercely loyal to the organization can mean more reliable revenue from patients and their families, and less cost to attract new patients.[10]

Compassion of health care practitioners appears to be the most important influence on patient intentions to recommend the services or return as a patient, regardless of the setting in which the care is provided.[10] This level of commitment requires an understanding of the health care market and an understanding of the consumers as people, not just patients.[11]

The Patient's Role

Imaging is unique among health care professions that involve customer relations. The time technologists spend with patients is minimal and usually limited by scheduling constraints. Technologists must use their time wisely to establish a trusting and professional relationship with the patient and ensure proper patient care.

Inherent Obstacles in Patient Satisfaction

Customer Choice

The disparity in status between the provider and receiver of health care services is monumental in radiology. No other service industry imposes so great a distinction. From the moment the patient enters the health care facility, the subordinate role is established and reinforced. The relationship between the patient and the technologist is established even before the patient arrives at the facility.[7] In general, patients do not desire or elect to have a diagnostic exam. Usually the selection of an imaging facility involves customer choice. However, hospitalization is generally a matter of necessity, and this has afforded caregivers greater leeway to define the terms of the relationship with their clientele.[7] Because of this factor and other barriers to providing patient-centric care, radiologic imaging is less likely to be distinguished by customer service than other industries.[7] Patients expect to receive a basic level of care, but practicing patient-oriented care can separate an imaging facility from its competition.

Evolution of the Patient

Imaging departments must evolve to overcome new challenges and barriers to providing patient-centric care that have been in place for quite some time.[7] As the baby boomer generation ages, they will expect consistent, high-quality health care.[7] Also, in this patient-centric environment, health care professionals can expect better informed patients. This new breed of customer will come armed with information from the Internet and questions about products they have learned about through marketing and advertising.[13] Patients may take a more active role in their care and expect to be engaged partners in decisions concerning their health.[13]

As the patient demands a patient-centric environment, health care facilities will see several workplace changes. Hospital Consumer Assessment of Healthcare Providers and Systems is a new Internet-based service for patients that provides publicly available data with results from a national, standardized survey of patient experiences. Services such as this show the importance of patient satisfaction.[9] Imaging departments can benefit by restructuring the work environment to encourage and reinforce customer service.[7]

Road to Patient Satisfaction

To provide optimal care, imaging departments must find ways to overcome inevitable and unchanging obstacles. Enhancing a patient's experience can be achieved through 5 key drivers of patient satisfaction:

- Understanding.
- Quality.
- Informed communication.
- Timeliness.
- Value.[12]

By understanding their patients' needs, caregivers demonstrate respect for their patients' values and preferences.[12] This involves being empathetic to a patient's circumstances by actively listening and maintaining eye contact with patients during conversation.

Patients expect safe, quality, and customized health care.[12] It is important to create an environment that encourages technologists to go above the patients' basic expectations. Owning the experience can fulfill quality expectations. This involves customizing every patient experience by tailoring the care to a patient's needs and wants. Patients are beginning to pay more and demand better quality service, and they will go elsewhere if they do not receive it.

Patients want a certain level of communication and want the technologist to be knowledgeable and able to answer questions.[12] Active listening and acknowledgment of a patient's concerns expresses sincerity and can make his or her experience less frightening and uncomfortable.[3] Patients also want communication about the potential outcomes or risks involved in the procedure to be able to make the best decisions for themselves.[12] Too often patients are rushed and not informed about a test or procedure. Technologists must not forget their obligation to inform patients about procedures. This will relieve patient anxiety and help prevent technologist liability in a lawsuit. Patients also desire a clear understanding of their follow-up treatment after a diagnostic examination. Technologists must be thorough in these instructions to prevent injuries to their patients. Finally, at the end of the exam, technologists should ask, "Is there anything else I can help you with today?" This influences a patient's experience and can provide assurance that the patient is fully satisfied with his or her health care experience.

Patients want to receive care in a timely manner and want to receive test and treatment results promptly.[12,13] Even though the ordering physician is usually responsible for explaining test outcomes, patients do not always receive them. One study found that 72% of physicians did not inform patients when test results were normal, and only 55% always informed patients when results were abnormal.[14] Patients do not always know who to contact when a problem arises, and they may blame the radiology department for not keeping them informed.[14] Managers should remind technologists to inform patients about their timeline of care at the end of their exam. Making sure patients know what to expect next helps minimize confusion and allows patients to have an active role in their care.

Many patients feel there is disconnect between "what they pay for" and "what they get."[12] Patients expect value from their health care experience as they become responsible for more of their health care bills.[12]

Tools for Evaluating Patient Satisfaction

It is important to evaluate patient satisfaction by measuring the degree to which patient expectations are being met. This is the only way to fulfill patients' needs and to improve future patients' experiences.

Imaging departments commonly use questionnaires. When used, they should measure whether the patient was satisfied and hospital care was of sufficient quality.[15] Data concerning the reliability and validity of questionnaires used in imaging departments are not currently available for analysis. However, questionnaires used in a hospital setting have been very reliable and demonstrate high precision for measuring patient satisfaction and establishing overall hospital care quality.[15]

Achieving R.T. and Patient Satisfaction

The satisfaction of radiologic technologists and patients are intertwined. Many surveys show empirical evidence that patient perception of the care they receive at a facility has a positive correlation with employee perception of the facility.[16] These studies indicate that if an employee is unhappy, it reflects negatively on a patient's perception of care. A satisfied workforce has been known to have lower turnover rates, increased productivity, better care, and an enhanced patient experience. Poor service quality is not usually caused by apathetic staff and unwilling managers, but by a system that fails to support them.[17] The intent of every radiologic technologist is to provide high-quality service, and it is the responsibility of management to make that possible by developing a culture where staff members can best perform.[12]

Improving R.T. Satisfaction

Value and Empowerment

An essential aspect of great patient care is the technologist's ability to respond in a virtually spontaneous manner to the needs of patients.[7] The effectiveness of the imaging staff is contingent on the freedom to act on behalf of the patients' needs.[7] By allowing technologists the autonomy to make decisions needed to provide quality care, their job satisfaction and commitment to the department will increase.[18] A successful hospital environment is created by encouraging employees to act independently, and allows staff members to exercise greater flexibility and resourcefulness to solve problems as they occur.[7] Staff empowerment is an empty slogan unless it is reinforced by management through a system of encouragement.[7] Technologists need to know their department has a standard of quality patient care.

Meaningful Work

Radiologic technologists desire a work process design that is centered on patients and the needs of staff members. This begins with management. When management communicates the "hows" and "whys" of their formula in making decisions effectively, the system allows technologists to be more effective.

Training, Development, and Growth Opportunities

Educational opportunities are important for technologists and allow for personal growth, professional development, and up-to-date best practices.[7] Technologists want to be in an encouraging workspace. This atmosphere is beneficial to management because it allows them to delegate otherwise time-consuming tasks to technologists. At the same time, delegating allows technologists to be challenged to reach their full potential and provides them with an understanding of tasks related to managing the department.

Communication

An open, blame-free environment will support collaboration and demonstrate management's commitment to the organization.[12] When technologists feel they can speak freely in an appropriate setting without fear of retaliation, serious issues can be addressed and solved. Technologists are at the forefront of the patient care experience and can help pinpoint the problems and successes in department processes. Managers must develop a culture where technologists are encouraged to communicate if they wish to have an engaged partner in the patient experience and want their department to be patients' first choice for medical imaging.[17]

Recognition and Compensation

Recognition of top-level performance motivates employees.[12] Every employee wants acknowledgment but not always in a public setting. Most departments use plaques or certificates but, for some, a few words behind closed doors can have an encouraging effect. Knowing the staff and the importance of recognition to them can increase morale and set high standards for the department.

Financial Effect of Patient-centric Caring

Increased demands on the technologist from management to maximize work and increase the revenue has resulted in overlooking the importance of good patient care. Creating a patient-centric environment takes time and may be seen as a deterrent in generating revenue for the department.[20] Contrary to the thinking that quality means sparing no expense, the pursuit of high quality can lead to substantially reduced cost and increased revenue. Imaging personnel who practice patient-centric caring also can help in avoiding unnecessary costs to the facility. Patient-centric care can influence timeliness of procedures by reducing patient stress and creating a positive relationship. Increasing patient confidence going into an examination uses the exam time efficiently and can help prevent nondiagnostic exams and patient callbacks. In addition, practicing patient-centric care may help prevent litigation, which carries high costs.[20]

Establishing an imaging department that practices patient-centric care has several positive outcomes, including employee and patient satisfaction, more efficient processes, liability protection, and a more rewarding caregiver experience.

Conclusion

Although some suggestions in this article may seem fundamental, many health care providers fail to understand the significance of their role in patient satisfaction. Radiologic technologists must become continuous learners of the emerging patterns of a patient's expectation of care, and also must develop a more patient-focused view that fulfills the mission of health care. Patient-oriented care is directly related to better health outcomes, and it is important for addressing health care disparities. It takes into account patients' personal and social contexts and involves tailoring communication, education, and health care to patient values and needs.[19]

Managers must enhance the work environment to increase radiologic technologists' satisfaction as employees, which will have a significant effect on patient satisfaction in imaging departments everywhere.

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Your First Mammogram

This patient education page provides general information concerning the radiologic sciences. The ASRT suggests that you consult your physician for specific information concerning your imaging exam and medical condition. Health care professionals may reproduce these pages for noncommercial educational purposes. Reproduction for other reasons is subject to ASRT approval.

There's a good reason 25 million mammograms, or low-dose x-ray images of the breast, are performed annually. Mammography is the best way to find breast cancer during its early, more treatable stages. The American Cancer Society recommends that women receive annual mammograms after age 40.

Before the Examination

Try to schedule your mammogram for the week following your menstrual period, when your breasts are less tender. Wear a two-piece outfit to the examination, so you only will have to remove your top. Do not apply underarm deodorant, powders, ointments, or creams to your chest area the day of the exam because these products can show up on the x-ray images and make them difficult to interpret. Be sure to bring the name, address, and phone number of the physician who referred you for the mammogram. If you are going to a facility for the first time, bring a list of the places and dates of your past mammograms, biopsies, or other breast treatments. In addition, if you have had mammograms at another facility, you should try to get your most recent x-ray films or digital pictures to bring with you to the new facility (or have them sent there). It is important for the radiologist to be able to compare the past images to the new ones.

Before the examination, you will be asked to undress from the waist up and put on an examination gown. A mammographer will perform your examination. Mammographers are skilled medical professionals who have received specialized education in the areas of mammographic positioning and techniques.

During the Examination

The mammographer will ask you to stand in front of the mammography unit, a special type of x-ray machine. She will place one of your breasts on a small platform attached to the machine. The platform can be raised or lowered to match your height. Your breast then will be gradually compressed between two clear plastic plates. For screening mammography, two images are taken of the breast, one from the top and one from the side. Some patients, such as those with large breasts, may need to have more images taken to ensure the physician can see as much breast tissue as possible. The examination then is repeated for the other breast. Compression spreads and flattens the breast tissue. It ensures a clear picture and reduces the amount of radiation necessary for the x-ray image.

Compression may be uncomfortable, but it should not hurt. Let the mammographer know if the compression is painful, and he or she will try to reposition you to minimize discomfort. Actual compression time is only a few seconds. If you are worried about discomfort, tell your physician. You may be advised to take a mild over-the-counter pain reliever about an hour before your examination.

You will be asked to wait a few minutes while the x-ray images are checked. The mammographer will determine if the images are technically acceptable or if additional views are necessary. Do not be alarmed if you are asked to return for additional images.

After the Examination

The mammography images will be given to a radiologist, a physician who specializes in the diagnostic interpretation of medical images. Under federal regulations, the radiologist must be experienced in reading mammographic images.

The radiologist will send your personal physician a report of the findings, and you will receive a written summary of the report in lay terms. If you have not received your results within one month, contact your physician or the mammography facility. Be sure to note the date and facility that performed your mammogram because that information may be necessary for future examinations. ◆

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PATIENT PAGE

Su primera mamografía

Esta página educacional del paciente provée información general en cuanto a la ciencia radiológica. ASRT sugiere que usted consulte con su doctor para obtener información específica concerniente a su examen de imagen y condiciones medicas. Los profesionales del cuidado de la salud pueden reproducir estas páginas para ser usadas sin recibir lucro económico. La reproducción de estos documentos para ser usadas para otros objetivos necesita la autorización del ASRT.

Hay buenos motivos por los que se realizan anualmente 25 millones de mamografías o imágenes de los senos con baja dosis de rayos X. La mamografía es la mejor manera de detectar el cáncer de los senos durante sus estadios iniciales y más tratables. La American Cancer Society recomienda que las mujeres se hagan una mamografía preventiva de referencia entre los 35 y los 40 años de edad y mamografías anuales a partir de los 40 años de edad.

Antes del Examen

Trate de marcar su mamografía para la semana después de su período menstrual, cuando sus senos están menos doloridos. Vista un traje de dos piezas para el examen; así sólo tendrá que sacarse la parte superior. No use desodorante debajo del brazo, talcos, pomadas o cremas en el área de su pecho el día del examen, pues dichos productos podrán aparecer en las imágenes de rayos X y hacer que resulten difíciles de interpretar. Asegúrese de llevar el nombre, la dirección y el número de teléfono del médico que le pidió la mamografía. Si usted visita a un centro médico por primera vez, traiga una lista de los lugares y las fechas de sus mamografías, biopsias y otros tratamientos mammographicos que ha recibido previamente. Además, si usted ha tenido una mamografía en otro centro médico, usted debe tratar de conseguir sus más recientes radiografías o imágenes digitales para llevar al centro nuevo (o que se los envíen ahí). Es importante que el radiólogo pueda comparar imágenes anteriores contra imágenes nuevas.

Antes de su examen, se le pedirá que se desvista de la cintura hacia arriba y vista una bata de examen. Una tecnóloga en mamografías le realizará el examen. Las tecnólogas en mamografías son profesionales médicas especializadas con estudios en las áreas de posicionamiento y técnicas mamográficas.

Durante el Examen

La tecnóloga en mamografías le pedirá que se pare delante de la unidad de mamografía, un tipo especial de máquina de rayos X. Colocará uno de sus senos sobre una pequeña plataforma sujeta a la máquina. Se puede subir o bajar la plataforma de acuerdo con su altura. Luego, se comprimirá su seno gradualmente entre dos placas de plástico transparentes. Para la mamografía preventiva, se toman dos imágenes del seno: una desde arriba y una desde el costado. Algunos pacientes, como aquellos con senos más grandes, pueden necesitar tener una cantidad más alta de imágenes para garantizar que el médico pueda ver el tejido de los senos tanto como sea posible. Luego se repite el examen para el otro seno. La compresión desparrama y achata los tejidos del seno. Es necesaria para que la imagen resulte clara y para reducir la cantidad de radiación necesaria para la imagen radiológica.

La compresión puede resultar incómoda, pero no debe doler. Si la compresión le hace doler, avísele a la tecnóloga en mamografías para que ella la coloque en posición nuevamente para minimizar la incomodidad. La compresión dura apenas unos segundos. Si le preocupa la incomodidad, avísele a su médico. Se le podrá aconsejar que tome un analgésico suave de venta libre alrededor de una hora antes de su examen.

Se le pedirá que espere unos minutos mientras se procesan las películas radiológicas. La tecnóloga en mamografías entonces determinará si las imágenes son técnicamente aceptables o si se necesitan imágenes adicionales. No se alarme si se le pide que vuelva para imágenes adicionales.

Después del Examen

Luego, se le entrega las películas de la mamografía a un radiólogo, que es un médico especializado en la interpretación diagnóstica de imágenes clínicas. De acuerdo con los reglamentos federales, el(la) radiólogo(a) debe contar con experiencia en la interpretación de imágenes mamográficas.

El radiólogo le enviará a su médico personal un informe con los resultados, y usted recibirá un resumen escrito del informe, redactado con términos laicos. Si no recibió los resultados en el plazo de un mes, entre en contacto con su médico o con el establecimiento de mamografías. Asegúrese de anotar la fecha y el establecimiento que realizó su mamografía, pues dicha información podrá ser necesaria para exámenes futuros. ◆

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