



# The State of Forensic Radiography in the United States

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[We] have been presented with a photograph taken by means of a new scientific discovery the same being acknowledged in the arts and in the science. It knocks for admission at the temple of learning and what shall we do or say? Close fast the doors or open wide the portals? ... Modern science has made it possible to look beneath the tissues of the human body, and has aided surgery in the telling of the hidden mysteries. We believe it to be our duty, if you please, to be the first to so consider it in admitting in evidence a process known and acknowledged as a determinate science. The exhibits will be admitted in evidence.<sup>1</sup>

Judge Owen E. Lefevre of the District Court of Denver spoke these words in 1896 as he presided over a malpractice suit, becoming the first U.S. judge to admit radiographs into evidence in a civil case. As the courts struggled with the role of radiographs and expert testimony into the early 20th century, most judges adopted the basic procedure applied by Judge Lefevre. This included establishing that “a skilled operator, operating with adequate equipment under proper conditions, had produced the particular image.”<sup>2</sup>

Today, digital imaging requires that operators understand and pay attention to variable technical factors.<sup>3</sup> The use of computed tomography (CT) in forensic investigation is growing and other technologies once reserved primarily for diagnostic medical imaging are proving useful to forensic investigators.<sup>4,5</sup>

In effect, any diagnostic imaging examination can be considered a forensic examination.<sup>6</sup> Radiologic technologists, the medical personnel who perform diagnostic imaging examinations in hospitals, outpatient imaging centers and physician offices, perform radiologic procedures for the 2 million women who are physically assaulted by their partners each year in the United States<sup>7</sup> or the nearly 200,000 children a year who are victims of physical abuse.<sup>8</sup> The radiologic technologist may not know at the time that the examination findings may be used as critical legal evidence.

Forensic radiography is more than imaging of human remains or bullet fragments; it is the application of diagnostic imaging technology and examinations to questions of law.<sup>6</sup> In the United States, however, the definition, scope and use of forensic radiology examination results are poorly defined. Although radiography is one of the most common scientific methods used to accumulate and analyze forensic evidence, forensic radiography is not recognized formally as a forensic science discipline in the United States.<sup>5</sup>

As a result, the availability and performance of forensic radiography examinations — whether on a cadaver in a medical examiner’s office or a patient who may be a victim of a violent crime in a community hospital — vary greatly in protocol, procedure, technique and

quality. The educational preparation and qualifications of the person performing the examination also vary widely.<sup>5,9,10</sup>

## **The Evolution of Forensic Radiography**

Forensic sciences have received more recognition from the general public in recent years, largely because of popular television shows. Results of forensic investigations can help identify victims of a mass casualty event, lead to development of improved technology to prevent future deaths or serve as the difference between acquittal and conviction in a court of law.<sup>10,11,12</sup>

Forensic medicine is not new, however. Medicine and law have interacted for thousands of years. The distinct discipline of forensic medicine appeared in the late 16th and early 17th centuries. Massachusetts established the first U.S. medical examiner system in 1871 and other states followed. The modern forensic system developed in the 20th century and remains a loosely related arrangement of various legal and medical disciplines.<sup>13</sup> Radiologic technology not only has provided evidence for legal cases but has helped lead to the development of new legal theories and practices regarding visual evidence.<sup>2</sup>

Dr. B.G. Brogdon, a former chairman of the department of radiology at the University of South Alabama and a consultant in forensic radiology to the Office of the State Medical Examiner, is considered the foremost U.S. authority on forensic radiology. He defines it as the performance, interpretation and reporting of radiological examinations and procedures for use in courts and legal matters.<sup>13</sup> For the purposes of this paper, the term forensic radiography is used rather than forensic radiology because the paper addresses the work of the personnel who perform the imaging examinations. Radiology refers to the broad field of medical imaging, but radiography refers to the “recording” or conducting of the examinations.

Wilhelm Conrad Roentgen’s discovery of the x-ray in 1895 led to increased use of the noninvasive technology to help diagnose disease. The first use of x-rays in criminal forensics actually occurred a few days before Roentgen submitted his discovery for publication when a radiograph helped demonstrate a bullet fragment lodged in a shooting victim’s leg. A physics professor in Canada had conducted the x-ray examination; the radiograph was submitted as evidence of attempted murder in court.<sup>14</sup>

Today, forensic radiography comprises primarily digital radiography and CT. The scope of application is broad, sometimes underutilized and largely undefined. Forensic science

agencies and organizations are dealing with issues such as funding and staff training that may or may not include radiologic imaging. Overall, the United States lags behind other developed nations in education and systematic use of forensic technology.<sup>12</sup> Forensic radiography is evolving continually to include other radiologic specialties; diagnostic and forensic use of imaging is blending in the medical setting.<sup>6,14</sup>

The term “forensic imaging” also requires clarification for this paper. Professionals and literature in radiologic and other medical fields commonly use the term “imaging” to refer to a hospital’s radiology department or the use of radiography and other diagnostic imaging modalities to examine patients. Within the forensic science field, “forensic imaging” generally encompasses preparation and examination of all photographic and videotaped evidence and preparing court exhibits vs. specifically radiography; therefore we have avoided use of the forensic imaging term and referred to all medical imaging under the radiography umbrella.<sup>15,16</sup>

## **A Quality Imperative**

Regardless of the current state of forensic radiography in the United States, one fact remains clear: the law has influenced medicine, and medicine has influenced the law. Specifically, early use of medical x-rays was influenced by legal legitimization of the radiography as credible evidence and radiographs have helped influence legal decisions.<sup>2</sup>

There is a fundamental obligation to ensure that all forensic examinations and procedures are performed with quality and safety as priorities. As the world’s largest radiologic science organization, the American Society of Radiologic Technologists (ASRT) represents 134,000 medical imaging and radiation therapy professionals (see Appendix A). Therefore, it is essential that the ASRT examine the state of forensic radiography in the United States. The purpose of this white paper is to explore current issues regarding the performance of forensic radiography and to recommend suggestions for further discussion or improvement.

## **Forensic Radiography Task Force**

In 2007, the ASRT formed a Forensic Radiography Task Force. The purpose of the task force was to gain recognition for forensic radiography in the United States and to encourage development of continuing education in forensic sciences for radiologic technologists. These representatives of forensic radiography practice and education discussed technologist

membership in the American Academy of Forensic Sciences, international recognition of forensic radiography, educational opportunities in forensic radiography and responses to U.S. disasters through regional Disaster Mortuary Operational Response Teams, or DMORT.

The task force members designed the ASRT Forensic Radiography Survey. It was sent to all 720 National Association of Medical Examiners (NAME) members in September 2008. A total of 77 NAME members responded to questions about radiographic equipment and performance, interpretation and quality of radiographic procedures at their facilities. Most medical examiners (88.3% [95% CI, 82.3% - 94.3%]) indicated that images were produced at their facilities.<sup>9</sup> The survey results were shared with NAME and distributed to task force members.

In November 2008, task force members discussed a visit to the United Kingdom to gather information on forensic radiography programs and practice. Task force members also prepared questions for the ASRT Enrollment Snapshot of Radiography, Radiation Therapy and Nuclear Medicine Technology Programs 2009 to determine interest in forensic components of curriculum and access to medical examiner offices.

In March 2009, task force representatives met with forensic radiographers and educators in the United Kingdom. The U.K. radiographers shared information on equipment, maintenance, documentation, forensic radiography guidelines and protocols and education programs (Connie Mitchell, M.A., R.T.(R)(CT), assistant professor and radiography program director, Nebraska Medical Center School of Allied Health Professions; and Linda K. Holden, M.S., R.T.(R)(QM), RDMS, FASRT, director of radiography department, Western Medical Associates in Casper, Wyo., written communication, March, 2009)

The task force met again in October 2009 to discuss suggestions for improving the quality of forensic radiography in the United States and plans for development of an educational framework for forensic radiography. The task force member names and biographies are included in Appendix B.

### **The Role of the Radiologic Technologist**

Matters regarding radiologic technology practice normally involve hospitals, private physician offices and outpatient imaging centers. Examining forensic radiography issues involves a number of medical, government and industrial settings and equipment models. Forensic radiography is unique in that the subject of a forensic examination often is not a live

patient (e.g., postmortem examination or radiography of suspicious packages, forged documents, antiques or suspected art forgeries). In addition, people who are not radiologic technologists often perform these examinations. On the other hand, radiologic technologists working in diagnostic medical settings routinely perform radiologic procedures on patients who may be victims of nonaccidental injuries. The images the technologists produce are important legally as well as clinically. It is important to ensure that technologists understand the medical-legal aspects of these examinations.

As task force members have investigated and discussed the issues surrounding the current state of forensic radiography, they have remained aware of the many social, legal, ethical and policy concerns involved.

## **Scope of Forensic Radiography**

The most recognized use of forensic radiography is postmortem study, particularly to determine cause of death or injury.<sup>9,17</sup> Forensic radiography may be used to investigate accidental or nonaccidental injury. The scope of forensic radiography does not end with these types of investigations. Forensic professionals often rely on imaging, increasingly CT, to help identify remains at local medical examiner offices or at the scenes of mass casualties. Radiologic evidence may be used in civil and criminal court cases ranging from fraud to assault. In all legal uses of radiologic imaging, the image must be of a quality high enough for admission as credible evidence. The person who performs the examination must accurately mark and notate the image for the radiologist and other health or science professionals and expert witnesses who will interpret the image.<sup>3,17,18</sup> The following summary of forensic radiography applications is not comprehensive, but provides an overview of some of the common uses of radiologic imaging for forensic purposes. Appendix C defines some of the radiology terms used in the following sections.

### **Evaluating Nonaccidental Injury**

Radiography's role in documenting fractures, injury patterns and occult injuries is well established.<sup>19</sup> Many children and victims of domestic violence are patients of radiologic technologists. These patients may have vague medical histories or present detail unrelated to the abusive injury, making it difficult for radiologic technologists and radiologists who suspect that the injuries are the result of nonaccidental causes.<sup>20</sup> Guidance for radiographers from the Society

and College of Radiographers and the International Association of Forensic Radiographers states that “all examinations for nonaccidental injuries are forensic examinations.”<sup>6</sup>

### *Child Abuse*

About 10% of all children younger than age 5 years who visit U.S. hospital emergency departments with injuries have nonaccidental injuries.<sup>20</sup> U.S. data on the number of child abuse victims varies from nearly 1 million a year to more than 1.5 million. The discrepancy in totals partly illustrates the difficulty in assessing child abuse prevalence.<sup>21</sup>

For children who are severely abused, a diagnosis of inflicted injury may be based solely on the imaging findings.<sup>22</sup> The medical and radiological community began to focus on the issue of abused children in the late 1950s and early 1960s.<sup>23</sup> Fractures are second only to cutaneous injuries, such as contusions, as the most common findings in child abuse.<sup>21</sup> Today, skeletal surveys are systematically performed series of radiographic images that encompass the child’s entire skeleton or the complete region indicated by clinical signs and symptoms.<sup>24</sup> Skeletal surveys are important in helping to reveal findings that may point to alternative diagnoses that rule out abuse. The surveys also are valuable in providing chronological data that may help identify assailants or evidence of healing fractures suggestive of a pattern of abuse.<sup>3,22,24</sup>

The American College of Radiology (ACR) publishes practice guidelines for performance of skeletal surveys in children. The guidelines include a table outlining the anatomy for complete skeletal survey.<sup>24</sup> The American Academy of Pediatrics (AAP) has stated that the “baby gram” (a study that uses one or two radiographic exposures to image an entire infant or young child), or the abbreviated skeletal survey has “no role in the imaging of these subtle but highly specific bony abnormalities.”<sup>22</sup>

The ACR outlines qualifications and responsibilities of personnel involved in these surveys, including that “the technologist should be aware of the unique circumstances created when children with suspected abuse are brought to the radiology department by caretakers, guardians, and child protective service representatives.”<sup>24</sup> Skeletal scintigraphy (a nuclear bone scan) also may be used to evaluate injuries in children, particularly those older than age one year. Certain fractures, such as subtle fractures and rib fractures, are more easily revealed by scintigraphy.<sup>22</sup> CT scanning often is used in trauma imaging and has proven useful in skeletal surveys of children who may have been abused. CT outperformed radiography in one

retrospective study with the exception of diagnosing metaphyseal corner fractures, which are a hallmark sign in diagnosing child abuse. CT also introduces a higher radiation dose. Magnetic resonance (MR) imaging examinations also are increasingly used to replace bone scintigraphy. MR imaging does not use radiation, but many young children have trouble remaining still for longer MR examination times without sedation.<sup>21</sup>

Other types of trauma from child abuse may involve diagnostic imaging, including spinal trauma, thoracoabdominal trauma and head trauma. Suspected head trauma resulting from shaking or impact forces may be evaluated using CT or MR imaging.<sup>22</sup> Nonaccidental head injury is most common in children younger than age 3 years. Head injuries account for up to 80% of all fatal child abuse injuries in younger victims. When a child younger than age 1 year has a serious central nervous system injury, 95% of the time, it can be attributed to abuse.<sup>25</sup>

Obtaining frontal and lateral skull radiographs is part of the standard skeletal survey protocol. However, consensus opinion from the ACR generally calls for some combination of brain CT or MR imaging for children younger than age 2 years with history of head trauma without neurologic deficits and certain patients up to age 5 years with neurologic signs and symptoms. Neuroimaging with CT or MR also may be recommended for infants younger than age 1 year if skeletal surveys reveal multiple fractures or rib fractures. These imaging studies are used to diagnose injuries and assist in treatment and to document abuse.<sup>25</sup> The documentation may be used as part of evidence for criminal proceedings, child protection cases or other forms of litigation.<sup>26</sup>

### *Adult Abuse*

American society only began to recognize and prosecute domestic violence in the mid- to late 20th century. Abuse is the most common cause of injury among women who seek medical care (accounting for more injuries than motor vehicle accidents, muggings and rapes combined).<sup>27,28</sup> The recognized and reported incidence likely is lower than the actual incidence. Therefore, radiologic technologists may not be aware that they are imaging patients who have injuries resulting from domestic violence. Nevertheless, the actions of these imaging professionals may be pivotal in the identification of injuries and abuse, as well as to patients receiving help.<sup>27</sup> Radiographic examinations can provide evidence of domestic abuse; injuries in nonpregnant women most often occur in the head, neck and face. In addition, medical imaging examinations and records may serve as important legal documentation.<sup>27</sup>



Estimates report about 2 million cases of elder self-neglect and abuse in the United States; these numbers likely are underreported.<sup>29,30</sup> Older Americans are the fastest growing age group, and it is important to understand and recognize the injuries that occur among them. Elder abuse can take the form of negligence or physical assault, and often occurs at the hands of relatives or acquaintances. Much like in radiologic examinations of victims of child abuse or domestic violence, elderly patients that radiologic technologists encounter may have physical signs or radiographic findings that do not match the history provided by the patient or family members.<sup>27</sup>

Regardless of the patient's legal status or willingness to discuss the injuries, radiologic technologists are producing a chain of evidence for these patients by providing accurate documentation and radiographs. Standard radiology department protocols require that radiologic technologists include markers that identify who performed the examination regardless of the clinical indication. Radiologic technologists also are trained in placement of anatomical markers and identifying information, such as patient name, date and time of examination.<sup>5,27</sup> Digital imaging and storage of medical record data helps ensure this information is captured and retained, all leading to a credible chain of custody of evidence if necessary. Emergency and radiologic personnel may have to work closely with legal and forensic professionals in cases of abuse.<sup>3,5,27</sup>

#### *Other Nonaccidental Injuries*

Use of forensic radiography also may involve the investigation of nonaccidental injuries other than domestic violence or child abuse. Since the late 19th century use of a radiograph in a Canadian court to demonstrate a bullet in a victim's leg,<sup>13</sup> radiography has been used to help locate bullets, differentiate calibers, reveal information regarding firing angle and direction and demonstrate bullet paths.<sup>31</sup> The value of CT in postmortem assessment of gunshot wounds to the head was recognized in the 1980s.<sup>4</sup> Data suggest that using CT scanning to image stable patients with gunshot wounds to the neck is safe and reliable, and CT scanning often is used to assess these type of injuries in the emergency department.<sup>32</sup>

Although much of the forensic investigation of violent injuries takes place postmortem, radiographic evidence of nonfatal injuries also may be used in criminal and civil litigation of abuse, assault, medical malpractice, torture and other nonaccidental injuries.<sup>6,17</sup>

## **Postmortem Assessment**

Autopsies can help identify cause of death and trace evidence, pinpoint factors contributing to causes of accidents and provide information for relatives of the deceased on hereditary diseases.<sup>33</sup> Radiologic science is used commonly in postmortem autopsies and as part of mass casualty forensic efforts. Examples include human identification, searching for foreign materials in corpses and documenting injuries.<sup>18</sup>

### *Radiography as Adjuvant Autopsy Exam*

For many years, forensic pathologists have used radiography to acquire a permanent record of part of a deceased person's anatomy and pathology before performing an autopsy. The images, which typically were obtained using conventional radiography or fluoroscopy, helped to document fractures, particularly in areas not easily seen during standard autopsy. Images also helped localize foreign material and collections of gases, prepare individual specimens, detect occult injuries and identify the deceased person.<sup>34</sup> Many objects, such as glass, certain poison substances, aspirated dirt, airplane and automobile parts, shrapnel and bomb fragments, are opaque when viewed on radiographs.<sup>17</sup>

Typically, pathologists have radiographs to support autopsy findings in all gunshot wound cases, deaths of infants and young children, victims of explosions and if a body is decomposed, charred or unidentified.<sup>35</sup>

The AAP and the Society for Pediatric Radiology have set a recommended minimum number of projections for postmortem skeletal surveys for suspected child abuse. The NAME has agreed and suggested that the technologists conducting the surveys have appropriate training.<sup>36</sup>

### *Use of Cross-sectional Imaging*

As clinical use of cross-sectional imaging methods such as CT and MR has increased, many forensic centers also have begun to evaluate these technologies as potential tools in postmortem investigations. Worldwide, a small number of centers have adopted protocols that involve routine use of CT and MR scanning at shared mortuary locations. The use of CT has evolved into the "virtual autopsy" (or "virtopsy") concept. This involves a complete forensic investigation using CT and MR imaging combined with 3-D reconstruction and postprocessing.

The images are taken before the conventional autopsy begins.<sup>34,37</sup> New multidetector computed tomography (MDCT) scanners increase volume acquisition of data sets along the same axes, which may be measured in two and three dimensions. The resulting reconstruction closely resembles standard autopsy.<sup>19</sup>

MDCT is effective at evaluating projectile entry and exit locations, path and associated tissue injury to characterize penetrating and perforating injuries. The method has limitations compared with clinical application, such as the inability to use contrast to better distinguish among soft tissues and vascular structures. MDCT usually is performed in the supine position, which can affect projectile tracks and organ shifts. However, the technique is noninvasive and potentially can enhance investigations.<sup>38</sup>

Even without contrast, CT provides images with excellent sensitivity in depicting bone fractures and presence of gas.<sup>37</sup> MR imaging has proven useful compared with standard autopsy in evaluating the central nervous system.<sup>39</sup> It will be possible in the future to use contrast in postmortem CT and MR imaging to better demonstrate organ injuries and aortic ruptures.<sup>37</sup> Use of contrast media such as oily liquids and hydrosoluble preparations, for postmortem angiography, is being tested today.<sup>40,41</sup>

Those who use virtual autopsy have stated that postmortem CT is a noninvasive alternative to standard or refused autopsy. An invasive autopsy may be refused by the deceased person's family, often based on religious doctrine.<sup>42</sup> Researchers still are comparing virtual autopsy with standard autopsy results, as well as comparing virtual autopsy to use of standard autopsy plus adjunct CT.<sup>43</sup> Comparison is difficult because of the pace at which imaging technology changes, as well as comparison of imaging methods to conventional autopsy. For example, an article published by Molina et al in 2007 suggested that CT scans alone were inadequate as courtroom testimony for forensic pathologists.<sup>44</sup> The article's methods were based on clinical antemortem CT exams performed on CT scanners that are several generations behind the MDCT systems used in many clinical and virtual autopsy settings today.<sup>45,46</sup> In general, postmortem cross-sectional imaging is becoming increasingly accepted in the field of forensic pathology.<sup>47</sup>

### *Victim Identification*

Using radiography to help identify individuals or human remains is a landmark contribution to forensic science. As early as 1898, Dr. Fovau d'Coumelles wrote, "Knowing the

existence of a fracture in a person, who has been burned or mutilated beyond recognition, we can hope to identify him by the x-ray ...”<sup>48</sup> Comparison of antemortem and postmortem images is critical, which means that the positioning and technique of postmortem images must conform to standard diagnostic medical imaging methods well enough for useful and accurate comparison.<sup>48,49</sup>

The use of forensic radiography can provide clues as to the victim’s age, sex, stature and other information. Radiography can help demonstrate dental and anatomical structures, trauma or pathological conditions that lead to or confirm identification if successfully compared to antemortem images.<sup>6,49</sup> For example, if a suspected decedent has a known history of fracture to a particular bone or presence of a foreign body, postmortem imaging may reveal this information and allow for matching to antemortem images.<sup>48</sup> Imaging may reveal personal effects that are not visible on physical inspection. Use of 3-D reconstruction can help create facial reconstruction for identification purposes.<sup>6</sup> Cox et al reported in 2009 that superimposition of an antemortem radiograph of the suspected victim’s frontal sinuses over a postmortem radiograph has helped provide correct identification in 100% of cases.<sup>50</sup>

### *Mass Casualty Identification*

Incidents ranging from major motor vehicle accidents to natural disasters or acts of terrorism may call for mass casualty response and identification. In general, any incident in which the number of casualties is greater than local arrangements typically can manage may be considered for disaster response.<sup>6</sup>

Following the 9/11 attacks, more than 200 military and federal personnel assisted in identifying remains and conducting forensic investigations of the deaths that occurred at the Pentagon. The investigations occurred at Port Mortuary, Dover Air Force Base, Del., and radiographic analysis was a key step in the investigation and victim identification. Whole-body radiographs of remains that ranged from intact bodies to small body-part fragments helped to process and identify remains. The radiographs helped establish presence of body parts, personal effects and other materials in specimens and to note distinguishing features to help establish victim age.<sup>51</sup>

As described above, MDCT can replace radiography in supplying this information in mass casualty identification. Mobile MDCT units have been used to replace radiography and

fluoroscopy; the full-body postmortem scan can be completed in about 15 minutes. Single-body or multiple-fragment bags can enter the scanner unopened if necessary. Technologists can scan the images of deceased individuals and remains at higher resolutions because there is no concern for patient exposure.<sup>42</sup>

Blau et al reported on use of MDCT to identify victims of a small airplane crash in Victoria, Australia, that had scattered over a 650-yard area. Although the physical remains were largely unrecognizable, 3-D volume-rendered CT images of the bags containing collected remains allowed for digital separation of soft tissue layers from skeletal remains to more easily develop an inventory of body parts.<sup>52</sup> According to Rutty et al, MR imaging can be used in permanent and temporary mortuaries, and CT scanning can be used in virtually all circumstances, including at the scene of the incident. Mobile CT scanners can be operational within approximately 20 minutes of arriving at the site.<sup>53</sup>

DMORT is a program of the U.S. Department of Homeland Security that responds when requested to disaster situations and mass fatality incidents. Forensic radiographers may be an integral part of a DMORT, as they were in response to Hurricane Katrina.<sup>5,54</sup> There are 10 DMORT regions in the United States, and many of them responded in 2005, deploying before the hurricane made land. Radiography was used to help DMORT pathologists identify badly decomposed bodies that had been in the water for some time; remains still were being recovered up to seven weeks after Hurricane Katrina. DMORTs are dispatched in advance of potential mass fatality incidents from terror attacks or when natural disasters occur.<sup>55</sup>

### **Other Uses of Forensic Radiography**

As early as the 19th century, the French customs service was using fluoroscopy to image contraband in smugglers. Imaging may detect packages in body cavities; advanced techniques, such as CT, have proven more useful in detecting modern packaging.<sup>56</sup> Smuggled drugs may be incidental findings when patients who have been assaulted or in motor vehicle accidents are imaged.<sup>12</sup> Imaging also has been used to detect other ingested materials and to identify nonballistic material in the body, such as knife blades and needles.<sup>6</sup> Radiographic methods also have been used to detect art forgeries.<sup>57</sup> Advanced imaging techniques not only have improved forensic investigation but also have provided more powerful and informative exhibits for jurors.<sup>58</sup>

After discovery of the iceman in the Tyrolean Alps in 1991, international cooperative efforts were made to study the 5,000-year-old corpse. These efforts included imaging with CT and radiography. Imaging helped to reveal the cause of death and how postmortem mummification occurred in the glacier in which the body had frozen.<sup>59</sup> Forensic radiology of injuries provides data that can contribute to improved design in the automobile industry and of military protective equipment.<sup>12</sup>

Finally, neuroimaging may be used as evidence to support mental health expert testimony. A defense expert used a CT scan of John W. Hinckley's brain to support the notion that he suffered from schizophrenia when he attempted to assassinate former President Ronald Regan. Functional neuroimaging techniques such as positron emission tomography can demonstrate blood flow changes that are associated with changes in neural activity. Functional neuroimaging evidence has been used in criminal cases to support insanity defenses, claims that a defendant was incompetent to stand trial or for pleas of leniency in sentencing; the imaging information is an adjunct to behavioral and clinical data.<sup>60</sup>

## **Global Perspective**

The United States lags behind Europe, Australia and Japan in forensic radiography. Other countries have more education and use more advanced forensic technology. There are only two departments or institutes specific to forensic radiology for physicians in the United States compared with 100 to 150 such institutes in Europe.<sup>12</sup> Most forensic pathology research takes place in Europe, Scandinavia and Japan.<sup>61</sup>

The Victorian Institute of Forensic Pathology in Victoria, Australia, was created following the Coroners Act in 1985. In 1995, the Institute merged with Monash University to include the professional discipline of clinical forensic medicine and changed its name to the Victorian Institute of Forensic Medicine (VIFM). The institute's mission is to provide forensic pathology services, education and research in Victoria. These services and training include forensic radiology.<sup>62</sup> When bush fires struck the area in February 2009, radiology specialists were among more than 140 volunteers who helped for nearly 2 months in disaster response. The fires killed 173 people. In 2009, the VIFM reported that research is being conducted on further uses of CT in a postmortem setting.<sup>63</sup>

The International Association of Forensic Radiographers (IAFR) was formed in the United Kingdom in 1998 to “promote best practice in forensic radiography through education, training, research, communication and coordination of forensic radiography both in the United Kingdom and internationally.” The IAFR is recognized as a global leader in promoting and developing forensic radiography. Most IAFR members have clinical backgrounds and some have been involved in imaging national and international incidents. The IAFR has established a systematic process to ensure that a response team is available to provide forensic radiography services in large-scale disasters without draining local resources.<sup>64</sup>

### **Forensic Radiography in the United Kingdom**

As in the United States, several organizations oversee and support radiography professionals. Similar to the ASRT in the United States, the Society of Radiographers promotes the professional and educational development of radiographers in the United Kingdom, as well as public and industry well-being. The College of Radiographers addresses the education and research needs of Britain’s medical imaging professionals, such as by accrediting courses that lead to professional qualification.<sup>65,66</sup> However, unlike the ASRT and the American Registry of Radiologic Technologists (ARRT), which are completely separate, the College is a subsidiary of the Society; they are collectively known as the Society and College of Radiographers (SCoR). The IAFR is the forensic radiography organization that focuses most of its efforts in the United Kingdom.<sup>64</sup>

Registration with the Health Professions Council is required for all radiographers who work in the U.K.’s National Health Service (NHS) and private practice.<sup>67</sup> Nearly all forensic imaging of live patients occurs in NHS hospitals. Much of the postmortem radiography occurs in mortuaries attached to NHS hospitals, so it also largely is performed by registered radiographers (Mark Viner, MSc, FCR, Fellow of Cranfield University Forensic Institute and senior manager at Barts and The London Hospitals, London, England, written communication, December 2009).

In 2003, the Home Office, a British government department that handles immigration, passports, drugs, terrorism and law enforcement,<sup>68</sup> reviewed forensic pathology services and recommended centralizing all cases and staff. Its suggestion to build appropriate facilities and improve training were incorporated into the Royal London Pathology Unit, which became the first forensic center of its kind in southeast England.<sup>69</sup> This fully digital center has pathologists

on site 24 hours a day, and its success has improved relations with coroners, pathologists, law enforcement officials, support staff and local academic institutions. Approximately one-third of all deaths in England and Wales require a coroner's involvement.

In 2008, SCoR and IAFR produced the *Guidance for Radiographers Providing Forensic Radiography Services* as an in-depth outline for all U.K. radiographers and radiographic facilities to follow regarding forensic examinations.<sup>6</sup> To ensure continuity, the SCoR and IAFR guidelines provide standard definitions and specify involved modalities, including digital and analog radiography, dental radiography, fluoroscopy, CT, MR, ultrasound and nuclear medicine. The guidelines also cover the various applications in which forensic radiography is required, including nonaccidental injuries, locating evidence, determining cause of death and identifying remains. SCoR and IAFR guidelines also emphasize the need for prompt imaging services and provide recommendations on location of postmortem examinations.<sup>6,26,70,71</sup>

Only "specially qualified persons" can perform an examination on a body.<sup>6,70</sup> The SCoR and IAFR guidelines name medical imaging professionals with forensic training as "the most appropriate professionals to undertake forensic radiography examinations."<sup>6</sup> All radiographers interested in working on forensic cases must maintain clinical competence and be a member of an organization such as SCoR or IAFR. Efforts have been made in the United Kingdom to introduce registration specifically for forensic radiographers. The push has been for all professionals who perform forensic radiography (on live or deceased subjects) to have state registration and additional education and training. "Our argument is this," says Mr. Viner: "An imaging examination produced in order to assist with a question of law requires the highest possible technical standards and should be undertaken in accordance with robust protocols in order to assure its probity for the courts" (written communication, December 2009). Common institutional protocols include making a list of volunteer radiographers trained in forensic procedures. Before receiving forensic-specific training, radiographers generally are fully trained in trauma, dental and pediatric imaging. A protocol may state that only staff on the list vs. general on-call employees will perform forensic evaluations.<sup>71,72</sup> Because not all forensic exams involve cadavers, however, SCoR emphasizes "that any radiography examination could potentially be forensic in nature."<sup>6</sup> When imaging living patients, consent always is required, and implied consent is never acceptable, because forensic radiography "is an area of practice where validity of consent may be questioned" if the images were used in a judicial case.



U.K. forensic radiographers hope to create a register of trained, registered forensic radiographers. Mr. Viner said that ideally every center that undertakes forensic examinations would have at least one of the registered radiographers in charge of forensic imaging (written communication, December 2009).

## **State of U.S. Forensic Radiography**

As of 2004, the U.S. forensic system varied considerably by state, with 16 states having a centralized statewide medical examiner system, 14 using a county coroner system, seven a county medical examiner system and 13 a mixed county medical examiner/coroner system. At that time, eight states had hybrid systems involving coroners and a state medical examiner office that performed medical-legal duties and the District of Columbia used a medical examiner system. Forensic pathologists in most large cities serve as medical examiners and pathologists.<sup>61</sup>

Most U.S. forensic radiography examinations, particularly those completed for postmortem investigation, are performed in medical examiner and coroner offices; a significant number also are performed in funeral homes that do not have adequate equipment such as basic conventional radiography.<sup>5,9,10</sup>

In the ASRT Forensic Radiography Survey conducted in 2008, 88.3% of respondents reported using radiographic equipment at their facilities. Most use fixed radiographic equipment in a dedicated room and a wet processor; others have no access to fixed equipment. A majority of respondents also have access to portable equipment. Nearly one-half have digital radiography equipment on-site and slightly more than one-fourth have fluoroscopic equipment at their facilities. Only 14% of respondents reported having an on-site CT scanner and nearly 70% reported having no access to CT scanners.<sup>9</sup> According to NAME, many medical-legal offices are poorly equipped and inadequately housed.<sup>10</sup> About one-third of medical examiner and coroner offices do not have the radiography equipment in-house that is necessary to identify diseases, bony injuries, projectiles or identification features in decedents.<sup>61</sup>

### *Staffing*

About 400 to 500 board-certified forensic pathologists practice full-time in the United States.<sup>61</sup> The work load is great and the number of certified professionals is too low in most jurisdictions to handle the number of required autopsies.<sup>10,61</sup> According to the National Institute

of Justice (NIJ), a shortage of qualified personnel, as well as funds to educate personnel, is one of the largest challenges facing the forensic community regarding death scene investigations.<sup>10</sup> The NIJ reported that NAME believes that death investigators “at every level should have appropriate training and perform their duties in accord with professionally accepted standards.”<sup>10</sup>

### *Conducting Radiography Exams*

Among duties of forensic pathologists is employing and often interpreting radiographs.<sup>61</sup> When asked “who performs imaging at your facility” in the ASRT Forensic Radiography Survey, 44.1% of respondents reported that a forensic lab assistant performed this task. Approximately 34% stated that a registered radiographer conducted their imaging examinations. Most personnel conducting forensic radiography examinations are trained on the job.<sup>9</sup>

There may be less concern about training and licensing of personnel conducting radiographic examinations in medical examiner settings than in clinical ones for the obvious reason that the subject of the examination cannot be injured by exposure to ionizing radiation. There are, however, other reasons to ensure that the personnel involved in forensic radiography are qualified professionals.

First are considerations such as positioning, imaging protocols and techniques. Training and experience in these matters help ensure that examinations are of a quality high enough to be admitted as solid and convincing evidence.<sup>3,17,18</sup> “The person conducting the examination must recognize that this is a good study” (Amy S. Boulé, director of operations, Office of the Medical Investigator, University of New Mexico Health Sciences Center, Albuquerque, personal communication, Nov. 20, 2009). Primarily, postmortem images must be as close as possible in positioning and resolution for adequate comparison to antemortem images (Nancy S. Adams, B.S., R.T.(R), clinical coordinator, radiologic sciences, Itawamba Community College, Fulton, Miss., written communication, Dec. 16, 2009). The ASRT Forensic Radiography Survey revealed that nearly 30% of respondents did not have technique charts posted in their facilities.<sup>9</sup>

Although radiation protection may not be a concern for postmortem examination subjects, personnel safety is a consideration. Research supports that repeated occupational exposure to low doses of radiation is hazardous. In fact, the Biological Effects of Ionizing Radiation VII Phase 2 Report stated that there is no “safe level” of radiation. Among radiologic technologists, fluoroscopy and mobile radiography currently account for the highest levels of

radiation exposure.<sup>73</sup> These professionals receive training on radiation biology and patient and occupational radiation protection as part of their standard radiography curriculum.<sup>74</sup>

Personnel should be protected when necessary and their exposure should be monitored through badges and dosimetry reporting. The person conducting an examination must know basic information such as where a primary x-ray beam travels when positioning a C-arm so that the bulk of radiation is absorbed by a primary barrier.<sup>5</sup> The ASRT Forensic Radiography Survey revealed that nearly 36% of respondents produce radiographs in a room that is not dedicated to radiography and structurally shielded with lead walls or equivalent shielding. In addition, nearly 15% of respondents reported that they do not have a radiation safety program that includes personnel monitoring via badges and regular reports; 10% of respondents said they do not have radiation protection devices, such as lead aprons, available. Imaging equipment requires regular maintenance and quality assurance for proper operation.<sup>9</sup>

It is likely that CT and MR imaging will be used increasingly in the forensic setting.<sup>12</sup> These imaging modalities are complex in nature and specific curricula and specialty certifications are available in the radiologic sciences field to accommodate training in the principles, physics and instrumentation involved in use of these advanced imaging technologies. Each also requires particular safety considerations. CT scanning is associated with higher radiation doses in children than radiography; patient and occupational dose are highly dependent on the operator.<sup>75</sup> The equipment is sophisticated; a mobile CT scanner involves interaction of electrical, mechanical and ionizing radiation systems. CT scanning at the site of a disaster can greatly improve victim identification but those conducting the examinations must understand issues such as x-ray tube cooling and slice thickness.<sup>53</sup> For their own safety, they also must understand the principles of radiation protection. National and international accrediting organizations support the certification of personnel who operate CT equipment.<sup>76</sup>

MR scanners may be housed in mobile vehicles, but typically are fixed. Although MR imaging does not involve ionizing radiation, MR scanners present safety issues to patients and personnel, and their use requires extensive attention to site design and access control. If non-MR personnel enter restricted areas with ferromagnetic objects or equipment, the high-strength magnet housed in the scanner can violently pull objects into the equipment's bore, causing injury to personnel and major equipment damage. Accidents can occur even when the magnet is not in use.<sup>77</sup> Conducting MR imaging examinations involves skills that differ from radiography exams.

Radiologic technologists who receive MR certification study MR parameters, pathology, instrumentation, pulse sequences, image formation and the physical principles of MR imaging.<sup>78</sup>

The effect of advanced technologies has been felt in all clinical settings. The increased use of digital radiography in medical diagnostic imaging has emphasized the need for radiologic technologists' attention to technical factors and protocols. These new systems may correct for overexposure, but this is a problem if the person conducting the exam does not realize the dose implications of the poor technique that caused the overexposure.<sup>79</sup> Special attention to imaging protocols is required in digital imaging to prevent reliance on postprocessing and to ensure that high-quality radiographs result from the procedures.<sup>3</sup> Even if exposure to the examination subject is not an issue, reliance on automatic exposure control and postprocessing over knowledge of basic radiographic principles leads to lower quality images and thus, legal evidence. It also may lead to increased risk of occupational exposure.

The ASRT continues to emphasize the importance of establishing minimum standards by the federal government for personnel who perform medical imaging exams and deliver radiation therapy treatments through support of the Consistency, Accuracy, Responsibility and Excellence in Medical Imaging and Radiation Therapy (CARE) bill. Task force member Thomas King reports that the Oregon Board of Radiologic Technology, for example, is beginning to discuss including forensic radiography minimum standards in applicable Oregon administrative rules under applicable statutes (written communication, Thomas King, B.S.R.S., R.T.(R) chairman, Oregon Board of Radiologic Technology, February 5, 2009)

#### *State of Forensic Radiography Education*

The United States lags behind many other nations in forensic radiography education. Preliminary data from the Bureau of Justice Statistics' crime laboratory census reported that the training and continuing education budgets of the United States' 50 largest laboratories were less than one-half of 1% of their total budgets. Collaborations and alternative delivery, such as electronic media, were among the recommendations made by an NIJ special report to Congress as means to close the training and continuing education gap. The NIJ also recommended minimum standards be established for each forensic discipline for equipment, techniques, training and documentation.<sup>10</sup>

As with radiologist education, there is little formal forensic radiography education in the United States for radiologic technologists. There is some course work, such as courses offered at Quinnipiac University in Hamden, Conn. Quinnipiac courses include scope of forensics, preservation of evidence, identification and presence of trauma or child abuse. Currently, students can earn up to seven credits in forensics as part of their work toward a bachelor's degree in radiologic sciences (Tania Blyth, M.H.S, R.T.(R)(M)(CT), clinical coordinator for diagnostic imaging, Quinnipiac University, personal communication, Oct. 23, 2009).

For the majority of personnel performing forensic radiography exams in medical examiner offices, there is no formal education program for radiography. With the exception of facilities that cooperate with affiliated radiology departments that employ registered technologists, many medical examiner and coroner offices use forensic or morgue assistants to conduct their radiographic examinations. These staff members usually are trained on the job for laboratory and radiography duties and the training varies from one location to another.<sup>9,10</sup> These positions may require only a high school diploma as formal education (Amy S. Boulé, Albuquerque, N.M., personal communication, Nov. 20, 2009). The ASRT Forensic Radiography Task Force spearheaded development of an educational framework to help identify education gaps for professionals who may perform forensic radiography exams in both medical and forensic settings.

Continuing education also is a concern of the NIJ and of the ASRT. In response to the ASRT Forensic Radiography Task Force recommendations, the ASRT recently published a forensic radiography self-directed learning activity for its members.

The National Research Council of the National Academies report on strengthening forensic science stated that the “shortage of resources and the lack of consistent educational and training requirements prevent investigators from taking full advantage of tools, such as CT scans and digital x-rays, that the health care system and other scientific disciplines offer.”<sup>61</sup> The NIJ states that “maintaining and increasing professionalism within the forensic science community is critical to the delivery of quality services.”<sup>10</sup>

## **Conclusion**

Forensic radiography, although not formally recognized as a forensic science discipline in the United States, is a science. The evidence produced by radiologic methods can provide a

scientific basis for investigation. As stated in the National Research Council report, science places a premium on “precision, objectivity, critical thinking, careful observation and practice, repeatability, uncertainty management and peer review.”<sup>61</sup> There is little in the literature regarding the reliability of forensic radiography and its evaluation,<sup>80</sup> but there is no doubt that radiologic technologists are educated and measured in the scientific aspects of their practice and profession.

With the advent of virtual autopsy and increasing reliance on radiography in forensics, it is clear that more evidence, collaboration and education are needed.<sup>61</sup> The time has come to increase awareness of forensic radiography as a formal tool in the forensic investigator’s arsenal. With this in mind, the ASRT suggests the following:

- Efforts begin to improve awareness of the use, scope and value of forensic radiography within the radiologic and forensic science fields to include:
  - Acceptance and best or most resourceful use of radiologic imaging methods in nonaccidental and postmortem investigations for both fields.
  - Forensic sciences recognize the importance of radiographic image quality for use of radiographs and other diagnostic medical images as evidence and for comparing antemortem and postmortem images, the complex nature of radiographic techniques and positioning, particularly with advanced and cross-sectional imaging.
  - Forensic sciences recognize and respond to appropriate radiation safety concerns.
  - Radiology providers increase awareness of medical-legal procedures and recognize that any examination could have forensic implications.
  - Hospital protocols should emphasize forensics and chain of custody more than most currently do.
- Collaboration should improve among diagnostic medical imaging providers, supportive and regulatory organizations with forensic pathology providers and forensic science organizations.
  - National Research Council efforts in the forensic community should extend to appropriate medical imaging constituents as needed.
  - Collaboration may occur at a national level to help underscore improved standardization, education or regulation of forensic radiography practice.

- Local level collaboration between many hospitals and medical examiner officers can lead to coordinated radiography services, particularly in academic settings.
- Further improvement can be made in formal inclusion of forensic radiography in coordination of local, regional and national disaster response.
- Efforts should be made to examine the disconnect, quality and regulatory issues surrounding use of radiographic equipment and services in all aspects of forensic science.
- Address the education of personnel performing forensic radiography.
  - If possible, forensic radiography examinations should be performed by a registered radiologic technologist.
  - If it is not possible to employ or contract with a registered radiologic technologist, personnel performing the exams should be prepared according to an agreed-upon minimum standard.
  - An educational framework that provides gap analyses for those involved in forensic radiography can guide those who prepare personnel in forensic and medical settings. For example, a limited x-ray machine operator (LXMO) and forensic assistant lack education in the basic principles of digital radiography; the LXMO has some training in radiographic density factors, but the forensic assistant has none. On the other hand, a forensic assistant has training in admissibility of scientific evidence and federal rules of evidence, but a radiologic technologist and LXMO have none. By performing the analysis, employers and educators can identify the gaps in training and education to better prepare personnel to safely and accurately acquire and handle radiologic images for forensic purposes.

The educational framework has been reviewed by a group of educators and is in draft form for public comment; other suggestions may take time to implement because of the complex system under which our medical and legal systems interface. Ultimately, the goal is to raise the level of quality of forensic radiography in the United States. More than 100 years after Judge Lefevre entered x-rays into evidence, questions remain as to how experts and jurors interpret what the images may demonstrate,<sup>2</sup> but the information radiologic technology can produce in the hands of a skilled operator is no less critical or dramatic.

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## **Appendix A**

### **Radiologic Technologists**

Radiologic technologists are the medical personnel who perform diagnostic imaging examinations and administer radiation therapy treatments. They are educated in anatomy, patient positioning, examination techniques, equipment protocols, radiation safety, radiation protection and basic patient care. They may specialize in a specific imaging technique, such as bone densitometry, cardiovascular-interventional radiography, computed tomography, mammography, magnetic resonance imaging, nuclear medicine, quality management, sonography or general radiography. The radiologic technologists who specialize in radiation therapy, which is the delivery of high doses of radiation to treat cancer and other diseases, are radiation therapists and medical dosimetrists.

Registered radiologic technologists must complete at least two years of formal education in an accredited hospital-based program or a two- or four-year educational program at an academic institution and must pass a national certification examination. To remain registered, they must earn continuing education credits. The examination and registration are administered by the American Registry of Radiologic Technologists (ARRT).

Currently, 38 states require a license to perform radiography exams. In 30 states, limited x-ray machine operators (LXMOs) may perform certain examinations; generally they are not permitted to perform fluoroscopy examinations.

### **About the ASRT**

The mission of the American Society of Radiologic Technologists is to foster the professional growth of radiologic technologists by expanding knowledge through education, research and analysis; promoting exceptional leadership and service; and developing the radiologic technology community through shared ethics and values.

Founded in 1920, the ASRT now has more than 133,000 members. The ASRT is governed by an elected seven-member Board of Directors and a House of Delegates. The ASRT also has affiliate relationships with 54 state or local societies for radiologic technologists. The national organization's business office is located in Albuquerque, N.M.

**About the ARRT**

The American Registry of Radiologic Technologists is the world's largest credentialing organization seeking to ensure high-quality patient care in radiologic technology. The ARRT tests and certifies technologists and administers continuing education and ethics requirements for radiologic technologist annual registration. The ARRT is headquartered in St. Paul, Minn.

Historical



## **Appendix B**

### **Forensic Radiography Task Force Members**

#### **Chairman Nancy Adams, B.S.R.S., R.T.(R)**

Ms. Adams is the clinical coordinator for the radiography program at Itawamba Community College in Fulton, Mississippi. She received her bachelor's degree in radiologic sciences from Midwestern State University, Wichita Falls, Texas. Ms. Adams has worked in radiologic sciences instruction for more than 25 years, serving as a clinical instructor and radiography program director before assuming her current position as clinical coordinator. Ms. Adams has contributed to textbooks and presented numerous workshops on the topic of forensics for radiologic technologists. She also has developed online resources in forensic radiography for continuing education credit.

Ms. Adams developed an early interest in forensic radiography as a student and has continued to take an active role in addition to her other duties. She is x-ray section leader for the Region 4 Disaster Mortuary Operational Response Team (DMORT) and has deployed numerous times in response to national disasters. She was the first radiologic technologist to be accepted for membership in the American Academy of Forensic Sciences, and works closely with the International Association of Forensic Radiographers.

#### **Tania Blyth, M.H.S., R.T. (R)(M)(CT)**

Ms. Blyth is director of clinical education for the diagnostic imaging program at Quinnipiac University in Hamden, Conn. She has worked as an educator for four years. Ms. Blyth's current academic responsibilities at Quinnipiac include radiography image production and forensic imaging course work, lab and clinical courses. She was responsible for the design of a new forensic investigation seminar course that began in spring 2010. Ms. Blyth has served as a radiology consultant for the Office of the Chief Medical Examiner in Farmington, Conn., since 2005.

Ms. Blyth has a bachelor of science degree in diagnostic imaging from Quinnipiac College in Hamden and a master of health science degree in medical laboratory sciences from Quinnipiac University. Her early clinical experience included trauma, operating room, portable

and general radiography, as well as mammography. Ms. Blyth has published and presented workshops on forensic imaging topics.

**Dale E. Collins, M.S., R.T.(R)(M)(QM), RDMS, RVT**

Mr. Collins is employed as a full-time sonographer performing general, vascular and interventional sonography in Anchorage, Alaska. He also is a faculty member of the University of Arkansas for Medical Sciences medical imaging department, serving as clinical coordinator for the university's radiologist assistant program. Mr. Collins also is a faculty member of Massachusetts General Hospital Institute of Health Professions medical imaging program.

Mr. Collins received his master's degree in vocational education from the University of Alaska Anchorage in 1998, a bachelor's degree from Midwestern State University in Wichita Falls, Texas, in 1992 and two associate degrees in 1987. He has worked in medical imaging since 1984 when he began his career with the United States Air Force radiography program. Mr. Collins served as the first program director of the University of Alaska Anchorage radiography program and as faculty and program director at the State University of New York Upstate Medical Center in Syracuse. He continues to develop and administer online course material for the programs he is associated with and writes about issues related to medical imaging education.

**Linda K. Holden, M.S., R.T.(R)(QM), RDMS, FASRT**

Linda K. Holden is the imaging director at Western Medical Associates in Casper, Wyo., and currently is the Chairman of the Board of Directors of the ASRT.

Ms. Holden received her master's degree in health services administration and management from Regis University in Denver, Colo., in 2000. She has worked in the radiologic sciences in many specialties and positions, including radiographer, sonographer, assistant manager, manager and educator.

While in education Ms. Holden was the program's clinical coordinator and initiated the first ultrasound program in the state of Wyoming. Ms. Holden prides herself on becoming a member of every ASRT affiliate that she has visited. Currently, she is a member of 18 ASRT affiliates around the country.

**Linda W. Jainnney, B.S., R.T.(R)(T), ROCC**

Mrs. Jainnney is the Radiation Oncology Manager at the AnMed Health Cancer Center in Anderson, S.C. Mrs. Jainnney received her bachelor's degree in radiation therapy from the Medical College of Georgia in 1999. She has worked in radiologic sciences for more than 10 years, serving as a chief radiation therapist before becoming a department manager.

**Stephanie Johnston, M.S.R.S., R.T.(R)(M)(BS)**

Stephanie Johnston is director of the Breast Center of Texoma in Wichita Falls, Texas. Ms. Johnston completed her radiography education at Doña Ana Community College in Las Cruces, N.M. She received her bachelor's degree from New Mexico State University in Las Cruces and most recently received her master's degree in radiologic science from Midwestern State University in Wichita Falls, Texas. Ms. Johnston is an active lecturer and researcher in mammography and management.

**Thomas R. King, B.S.R.S., R.T.(R)**

Mr. King is the imaging projects coordinator for Salem Hospital in Salem, Ore. He also has served as a clinical coordinator and instructor; he has practiced as a radiologic technologist for more than five years. Mr. King is involved as a forensic radiographer with several forensic and disaster organizations, including the National Disaster Medical System and the Disaster Mortuary Operational Response Team (Region 10). He currently is working on a master's degree in business administration.

**Diane Mayo, R.T.(R)(CT)**

Ms. Mayo is quality assurance coordinator in diagnostic imaging at St. Dominic Hospital in Jackson, Miss. She also serves as the clinical site coordinator for Copiah-Lincoln Community College in Wesson, Miss. Ms. Mayo completed a certificate program at St. Dominic-Jackson Memorial Hospital and has worked in the radiological sciences for more than 35 years in many capacities, including diagnostic radiography, computed tomography supervisor, special procedures supervisor, quality assurance technologist and clinical site coordinator.

Ms. Mayo currently serves as president of the ASRT Board of Directors. She appointed members to the Forensic Radiography Task Force.

**Connie L. Mitchell, M.A., R.T.(R)(CT)**

Ms. Mitchell is an assistant professor and radiography program director at the University of Nebraska Medical Center in Omaha. She received her master's degree in health education from the University of Nebraska at Omaha in 2001 and her undergraduate degree in health care administration from Bellevue University, Omaha, in 1995. Ms. Mitchell has worked at the University of Nebraska Medical Center for almost 40 years since becoming certified in radiography. She has served as an assistant instructor, instructor, clinical supervisor, clinical education coordinator and assistant professor and instructor before becoming radiography program director.

Ms. Mitchell is a past president and chairman of the ASRT; she formed the ASRT Task Force on Forensic Radiography in 2007. She traveled to the United Kingdom for information and education needs of forensic radiography in the U.K. Ms. Mitchell currently serves on the Mass Fatality Committee of the Omaha Metropolitan Medical Response System.

**James B. Temme, M.P.A., R.T.(R)(QM), FASRT**

Mr. Temme is the associate director of radiation science technology education at the University of Nebraska Medical Center in Omaha. He received his master of science degree in public administration from the University of Nebraska Medical Center in 1984 and a bachelor of science in radiologic technology in 1974.

Mr. Temme is the president-elect of ASRT and a life member of the Nebraska Society of Radiologic Technologists. He has been a frequent speaker at meetings and symposia on the role of radiologic technologists during terrorist events.

## Appendix C

Some terms that are mentioned in the paper and may be less familiar to forensic practitioners than to those in the radiologic science professions. A few of these terms are defined below:

***Chain of evidence.*** Formal documentation of the custody and path of evidence to establish that each person had possession or custody of the evidence. The purpose is to ensure that the evidence will maintain integrity and be admissible in court. Similar terms are chain of custody and continuity of evidence.

***Computed tomography (CT).*** This medical imaging technique combines special tomographic x-ray equipment with computers to produce multiple cross-sectional images of the body for viewing on a workstation monitor. Using special algorithms, CT images can be postprocessed into 3-D models.

***Contrast medium.*** Contrast media or contrast agents are internally administered substances that have a different opacity when viewed on a radiographic or other diagnostic image. Use of contrast media seldom is used in postmortem radiography and CT because the blood system generally distributes the contrast.

***Digital radiography.*** Increasingly, the images produced by x-rays are being captured, stored, transmitted and displayed using digital systems. Computed radiography uses a photostimulable storage phosphor that adapts to conventional analog systems and direct radiography uses special digital converters to detect and capture the image. DR eliminated “wet processing” and “wet reading,” or the actual film development and reading on a light box. The technology also introduced many postprocessing adjustments that allow operators to compensate for technical factors after an image is captured.

***Fluoroscopy.*** This is a form of radiography that captures x-rays on an image intensifier and projects still or moving images in a sequence onto a monitor.

**Forensics.** Pertaining to, connected with or used in the courts. Forensic medicine is a science that applies the medical facts and knowledge to legal problems.

**Magnetic resonance imaging.** MR imaging uses a powerful magnetic field and radio frequency pulses to produce an image that is processed on a computer and displayed on a workstation. Like CT, MR imaging produces cross-sectional data. It is most useful for imaging soft tissues, bones and other internal body structures. MR does not use ionizing radiation.

**Projection.** The radiographic projection is the path the x-ray beam takes as it passes through the body.

**Radiography.** Radiography is the oldest form of medical imaging. It uses x-rays to produce images. Conventional radiographic equipment includes an x-ray tube, collimator and cassette. Fixed radiographic equipment have an x-ray table for the patient (or body), a built-in tray for the film, cassette and grid, a transformer, a control panel and a tube mount in which the x-ray tube is housed. The tube mount usually is suspended over the patient or mounted in the floor.