Best Practices in Digital Radiography

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Reports on medical imaging use and resulting radiation exposure have increased following a series of widely publicized incidents of excessive patient exposure to low levels of radiation during medical imaging examinations or procedures. Increases in exposure initially were attributed to rising utilization of medical imaging as technology has improved the ability to diagnose and evaluate a wide variety of diseases and conditions. However, the increased attention also likely can be attributed to growing concern over risks attributed to medical radiation exposure. Concerns and actions of regulatory bodies, clinical societies, and the public continue to intensify despite a lack of evidence that exposure to low doses of ionizing radiation increases cancer risk. Further advances in technology and reimbursement changes have led to increased use of digital radiography and standardized techniques for indicating exposure.

The benefits of radiography have remained clear over the more than 100 years of diagnostic medical imaging's history. Another fact that has remained clear is the critical role radiographers play in ensuring patient radiation safety during medical imaging procedures. Radiographers must adhere to the "as low as reasonably achievable" (ALARA) principle by keeping occupational radiation dose as low as possible. Radiographers also adhere to similar principles of keeping patient exposure as low as possible without affecting image quality when performing digital radiography (dose optimization).

Digital imaging methods now are common across all indications for and forms of radiography, including fluoroscopy and mammography. As radiographers have adjusted to the widespread use of digital radiography, they have had to refine exposure technique selection and pay closer attention to radiation protection. Digital technologies offer many benefits for acquiring and post-processing images. As a result, radiographers must be particularly concerned about exposure technique and the possibility of using more radiation than necessary.

Radiographers assume extensive responsibility in the radiation safety of patients. The American College of Radiology (ACR) White Paper on Radiation Dose in Medicine places the final responsibility for additional action before radiation exposure on radiographers. Further, the paper states that "technologists are responsible for limiting radiation exposure to patients by ensuring that proper procedures and techniques are followed." A 2010 update to ACR panel recommendations on radiation dose in medicine confirmed the ACR's responsibility for taking specific actions but emphasized that several of its recommendations "encourage radiology practices and departments to take a more proactive approach to radiation safety."

Radiation safety practices in support of dose optimization, as well as occupational radiation safety practices, are based on justifying clinical appropriateness of examinations and optimizing dose while maintaining image quality. The various exposure techniques that radiographers can use continue to evolve. Radiographers must be familiar with the most current dose-reduction techniques and must operate equipment optimally in accordance with safety and image quality policies and procedures. Because digital radiography still is a relatively recent advancement, radiographers' skill levels vary depending on initial education and experience. Radiographers and their patients can benefit from a single source that offers background information, best practices, and recommendations for radiographers on optimizing digital radiography and patient radiation safety.

Scope of White Paper

The ASRT has long championed radiation protection in digital imaging for all age groups, as evidenced by the organization's support of and participation in the Image Gently and Image Wisely campaigns. ASRT helped found and actively participates in these and similar initiatives that aim to reduce radiation exposure from medical imaging and improve education about the issue to consumers and health professionals. In support of this area of professionalism, the ASRT publishes educational and promotional materials for the public and the medical imaging community. In 2012, the ASRT released its first white paper on best practices in digital radiography as a significant and dedicated effort to promote radiation protection for patients and professionalism for radiologic technologists.

The 2012 white paper combined information from trusted sources such as ACR guidelines, textbooks, professional and government organizations, and periodical literature on exposure to support transition of radiographers to digital radiography. The paper also examined elements of best practices for digital image quality and dose reduction techniques in digital radiography (DR) from a radiographer perspective.

In 2018, the ASRT convened a new workgroup to update and revise the 2012 best practice recommendations. This white paper is the result of a year-long effort to ensure timely and helpful guidance for practicing radiographers. The best practices and recommendations included in this white paper serve as a resource for radiographers who perform digital radiography examinations. This white paper is not, however, an all-inclusive document, nor should any of these recommendations be taken as superseding institutional policy or state regulations. Much like the constantly advancing technology used during digital radiography, this white paper is meant to be a fluid, living document.

Digital Radiography Background

The first form of digital imaging, digital subtraction angiography, was introduced in 1977 and put to clinical use in 1980. Computed radiography (CR) technology also was used in clinical practice beginning in the 1980s. CR uses a storage phosphor plate. According to IMV Medical, a medical imaging market research firm, although nearly 50% of radiography systems installed in the United States in 2015 included CR equipment, as many as 70% of sites with fixed CR systems said they were planning to purchase new DR equipment or retrofit CR equipment with DR in the coming year. In 2017, the Centers for Medicare and Medicaid Services (CMS) reduced payments by 7% to imaging providers with claims for CR and analog (film-screen) examinations in a concerted effort to encourage more radiology providers to switch to digital technologies and therefore promote dose reduction.

Fewer imaging facilities use CR technology today with DR (direct or indirect capture or conversion) as the modality of choice. Both the direct and indirect types of DR technology measure attenuated rays and produce electronic signals that are sent to software to rapidly produce images in grayscale format on a monitor. The first flat-panel detector still is common in modern systems. These indirect DR detectors used amorphous silicon as a photodiode, measuring the light emitted from a scintillator material excited by exposure to x-rays. Some fixed DR systems (dedicated chest radiography rooms, mammography systems, etc.) included charge-coupled devices (CCDs) to generate an electronic signal from the emitted light. Direct DR systems commonly use amorphous selenium as a photoconductive material, directly converting the energy of x-ray photons into electrical signal without the need for light as an intermediary. Roch et al reported in 2016 that flat-panel detectors have been shown to lower radiation dose to patients as much as 30% over CR phosphor technology. Indirect capture DR systems use either a

CCD or indirect flat-panel detectors to capture x-rays and process image data, although indirect flat-panel detectors offer superior quality to CCD detectors and are more common.

Dose Optimization and Image Quality

When following the dose optimization principles, radiographers should strive to minimize patient exposure during all radiography examinations. Including mammography, radiography examinations represent 74% of all radiologic examinations performed on both adults and children in the United States and contribute to about 11% of the annual per capita radiation exposure from medical imaging, according to the FDA. The appropriate use of digital image receptors requires careful and consistent attention to institutional protocol and practice standards and can result in lower patient dose. Digital radiography incorporates discrete acquisition, processing, and display processes that function together to produce an image of acceptable diagnostic quality. In situations where suboptimal radiation exposure levels have been used, the DR system still might display a diagnostically acceptable image. It is possible to make adjustments to compensate for exposure technique errors during image postprocessing and display, although this is not a best practice.

As a component of image quality, the contrast resolution of the radiographic image depends heavily on the degree to which the exposed anatomic region attenuates the x-ray beam. The contrast resolution of the radiograph represents the relative differences in receptor exposure across the image and has two primary components, subject contrast and display contrast. Subject contrast is related to the absorption of the x-ray beam by the subject's tissues and the corresponding energies imparted to the image receptor. The tube potential (kVp) applied during x-ray exposure affects the degree of differential attenuation within the anatomical area and the recorded subject contrast. Conversely, display contrast can be modified through postprocessing after image recording, by adjusting several different processing parameters.

Very low contrast (many shades of gray) makes it difficult for the reviewer to differentiate between adjacent structures and to identify anomalies or pathologies; an image must have sufficient contrast to demonstrate differentiated structures and to be diagnostically useful. Very high contrast (very few shades of gray) reduces the image to a scale of mostly black-and-white, which can also hinder visibility of anatomic details. In digital imaging, display contrast is the ratio of brightness of adjacent structures to one another, and the displayed grayscale represents the dynamic range of brightness levels.

Subject contrast is determined by different absorption of the x-ray beam by various tissues, anatomic thicknesses and tissue densities in the body. The penetrability of the beam primarily is controlled by kVp. Subject contrast cannot be digitally manipulated and an insufficient degree of subject contrast cannot be recovered with postprocessing; it is directly affected by how the x-ray beam is attenuated in anatomic tissues, such as bone and soft tissue, and the absorption of different x-ray energies by the image receptor.

The ability to adjust display brightness and contrast during postprocessing can affect radiographers' attention to the primary principle of radiation protection: optimal image quality with minimal patient exposure. Radiographers must pay careful attention to all aspects of radiographic exposure technique to provide diagnostic image quality and minimize patient exposure, helping to maximize benefit over potential harm. In addition, the increased sensitivity of digital image receptors to different energies and exposure levels has allowed for a wider exposure latitude for image processing and display. Because image receptor exposure is not readily apparent in the displayed image, there is further disconnect between image capture and the resulting patient exposure.

In digital radiography, the computer automatically adjusts an overexposure to display an image of diagnostic quality. This automatic adjustment disconnects the processes of image acquisition and display, which can contribute to increased patient exposure because of a lack of visual feedback for dose errors. Excessive exposure to a patient during a DR examination does not affect image quality, except at extremely high levels of exposure. In fact, the increase in exposure will increase the signal reaching the image receptor, causing an increased signal-to-noise ratio (SNR). This increase