Digital radiography: Next-generation systems

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Digital radiography, despite its fascinating technology, its tremendous potential, and the fact that it remains the primary and dominant diagnostic imaging screening modality, is not considered by most radiologists to be "sexy." No major conferences for radiologists are currently dedicated to digital radiography, and the number of abstracts and papers about the technology is Lilliputian compared with those about multidetector computed tomography (CT), positron emission tomography/CT, and magnetic resonance imaging (MRI). General radiography is arguably in danger of becoming a lost art. A thoracic radiologist trained before the use of picture archiving communications systems (PACS) recently lamented the fact that today's radiology residents seem to pay scant attention to "plain films"; they immediately ask for a CT study when shown a chest radiograph at the American Board of Radiology examinations in Louisville, KY. This seems unfortunate and ironic, not only because the roots of diagnostic radiology are in conventional radiography but also because this continues to be the most common type of imaging study performed in the United States and throughout the world. Conventional radiology continues to represent an important and fundamental diagnostic tool.

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Digital radiography was originally conceived and marketed in the 1980s and early 1990s as a way to improve the image quality of film by taking advantage of an innovative detector (photostimulable plate) that had a substantially wider dynamic range than had been possible using film, performing image processing to extract the most clinically important imaging information, and printing this image to film. Initial versions of this system printed 2 images on a single film, each processed differently to present 2 perspectives of the radiograph.

By the early 1990s, however, it seemed increasingly clear that film's days were numbered. The substantial increases in computer workstation speed, network performance, and storage capacity (along with major reductions in prices) finally made it possible to create a practical filmless radiology department and healthcare enterprise. Conventional radiography was the one remaining nondigital modality in most departments, and digital radiography became an enabling technology not only for film-based image enhancement but for entirely filmless operation. Digital X-ray technology and options have expanded dramatically over the past several years (as has ambiguity about the terminology used to describe these options).

Current state-of-the-art digital X-ray systems offer excellent dynamic range with similar or reduced quantum detection efficiency (permitting dose reduction with equivalent image quality) and, along with image processing, offer significant potential to substantially improve on the image quality that is typically achieved with film. These systems combine the advantages of digital imaging, such as image processing, direct transfer to PACS, and elimination of film and associated chemicals, with the advantages of conventional X-ray, such as low cost, portability, flexibility in positioning, and very low radiation dose (typically <5% of the dose that is required for CT).

However, the overall quality of digital radiography studies in actual practice has not met the potential of the technology to improve on conventional film radiography and, in many cases, has actually fallen behind the quality achieved on film. This is the result of a combination of the increased complexity of digital radiography, limited training for technologists in digital X-ray techniques, relatively low interest by radiologists in the modality, and a general lack of understanding about digital image processing and the artifacts and pitfalls associated with it.[1,2] Despite initial reports by our group and others about decreased retake rates due to the improved dynamic range of digital radiography, image retake rates are still unacceptably high and image quality is too frequently suboptimal.[3]

The mantra of PACS has been to have images available at any time and any place to anyone who needs to review them. The mantra of digital radiography must be to be able to acquire images any time and any place, make these images available immediately for quality review, and then send them to a PACS for near real-time display. This can be achieved either by having a cassette reader available in every hospital area in which studies are obtained or, alternatively, by using a technology that reads/processes the images immediately and then displays them for evaluation by the technologist and simultaneously sends them to the PACS. This type of immediate read/processing digital system has been introduced within the past few years and will continue to become faster, lighter, more rugged, and more affordable over time.

Portable digital radiography is currently the area with the greatest potential for improvement in digital radiography and will continue to be for the foreseeable future. Challenges for optimal or even adequate image quality include the following: portable generators with limited power; difficulties in positioning critically ill, unstable, or fragile patients for standard views; challenges with the use of grids in portable studies; limited time to obtain the study; and inability to visualize the image during the examination to determine whether the study was adequate. Another problem is the required trade-off between performing multiple studies and having to wait a relatively long time to process images, as well as the inefficiencies associated with taking plates down to the main department.

Additional clinical challenges include the need for improved productivity because of staff shortages and space limitations; the need to reduce costs to enable digital imaging solutions in lower-volume imaging locations, such as family practice, orthopedic, podiatric, and chiropractic settings; and the need to improve image quality and image acquisition and transmission times for remote locations (such as the intensive care unit, emergency department, and operating rooms), particularly in settings where patient positioning is challenging. Productivity can be enhanced by evaluating and redesigning workflow processes. Technologists should spend a higher percentage of their time performing studies than they do performing the clerical/manual steps typically required by many digital radiographic systems today. Multi-institution time/motion studies evaluated by our research team have documented that technologists spend >40% of their time on clerical and image quality assurance steps. Improving this imbalance will require integration of digital X-ray systems into the radiology and hospital information systems as well as additional automation of the technologists' workflow.

Despite major advances in digital radiography, the basic way in which images are obtained has not fundamentally changed during the past 100 years. In order to achieve a major advance in the evolution of digital radiography, we need to take advantage of the unique capabilities of digital X-ray technology, rather than using it as a mere substitute for film. For example, digital detectors have a different "k-edge" from that of film, giving us flexibility in rethinking the energy of the radiation in addition to dose. Digital systems make image subtraction relatively simple, and we can take advantage of this by utilizing dual-energy subtraction. We have made the transition to dual-energy subtraction for all outpatient examinations at our facility and have found that this improves sensitivity and specificity for lung nodules and other pathology as well as for bony lesions in the chest. We plan to perform research on this technology in other areas of the body. Dual-energy technology may give way to multienergy X-ray and photon-counting devices that, in the future, could provide even greater contrast and spatial resolution at reduced doses. Digital X-ray may bring a renaissance in the use of tomography and tomosynthesis because of the relative ease of computer processing of multiple images using technology developed for CT. This could produce much higher contrast images than are possible with planar X-ray techniques, with far lower doses than are achievable using CT. Digital image acquisition also facilitates the use of computer-aided detection of lung nodules, microcalcifications and masses on a mammogram, and detection of interstitial lung disease and life support lines in ways that would be difficult to achieve with film.

Conclusion

Despite the sometimes astonishing advances in CT, MRI, and optical and molecular imaging, the good news is that radiology's mainstay—conventional radiography—is making exciting and innovative advances. The challenge is to engage and educate the diagnostic imaging community about the very real advantages and potential that digital radiology is bringing to our most time-honored imaging modality.

References

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