Challenges Associated With the Incorporation of Digital Radiography Into a Picture Archival and Communication System

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Digital radiography (DR) has recently emerged as an attractive alternative to computed radiography (CR) for the acquisition of general radiographic studies in a digital environment. It offers the possibility of improved spatial and contrast resolution, decreased radiation dose due to improved efficiency of detection of x-ray photons, and perhaps most importantly, holds out the promise of increased technologist productivity. To achieve maximum efficiency, DR must be completely integrated into existing information systems, including the hospital and radiology information systems (HIS/RIS) and, when present, the picture archival and communication system (PACS). The early experience with the integration of DR at the Baltimore Veterans Affairs Medical Center (VAMC) has identified several challenges that exist to the successful integration of DR. DR has only recently been defined as a separate Digital Imaging and Communications in Medicine (DICOM) modality and images obtained will, at first, be listed under the category of CR. Matrix sizes with some DR products on the market exceed the current size limitations of some PACS. The patient throughput may be substantially greater with DR than with CR, and this in combination with the larger size of image files may result in greater demands for network and computer performance in the process of communication with the HIS/RIS and PACS. Additionally, in a hybrid department using both CR and DR, new rules must be defined for prefetching and display of general radiographic studies to permit these examinations to be retrieved and compared together. Advanced features that are planned for DR systems, such as dual-energy subtraction, tomosynthesis, and temporal subtraction, will likely require additional workstation tools beyond those currently available for CR.

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Despite the trend toward an increase in the utilization of cross-sectional imaging modalities such as computed tomography (CT), ultrasound (US), and magnetic resonance imaging (MRI), general radiography or "plain film" studies continue to account for approximately 70% of the

studies performed in radiology departments. Until recently, digital or filmless imaging departments had only two major choices for general radiographic examinations; computed radiography (CR) or digitized film.¹ Digitized film has a large number of disadvantages,² including a limited dynamic range of contrast and a large number of artifacts associated with the digitization process. It also is inefficient and expensive with regard to personnel and space requirements. This method has been largely abandoned in favor of CR by departments with large scale picture archival and communication systems (PACS).

CR has a number of advantages, which make it well suited for a digital imaging department.³ The photostimulable plates have a wide dynamic range in comparison to conventional film, which has been documented to result in decreased retake rates. The wider dynamic range has been reported⁴ by a number of investigators to improve diagnostic accuracy under certain circumstances and the decreased spatial resolution seems to have a relatively minor effect on diagnostic accuracy. The cost of CR systems has decreased substantially in recent months and CR has gained popularity, especially for portable radiographs and in the emergency department. We have documented improved technologist efficiency at the Baltimore Veterans Affairs Medical Center (VAMC) with the use of CR in comparison to conventional film.

CR does, however, have a number of important limitations similar to those of a conventional film-screen-based system. Technologists using CR must still transport the imaging cassettes to a plate reader after the exposure in an analogous way to bringing films to a daylight processor. This can create substantial delays depending on the distance traveled and the potential for bottlenecks that can occur when technologists must wait in line for access to the readers. Additionally, there continues to be physical "wear and tear" to the plates themselves, which are physically removed and replaced into the cassettes in the process during which they are read. This introduces scratches and other artifacts on the

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CR images, necessitating replacement of the plates and cassettes after approximately 2,000 to 6,000 "reads."

Recently, an alternative to CR has emerged that uses one or a group of digital detectors. This alternative method of acquiring a general radiographic study has been marketed under a number of different names, but for the purpose of discussion will be referred to here as digital radiography (DR). This technology has the potential to continue the evolution of general radiography away from the constraints of a cassette and to eliminate the need for the technologist to leave the examination room to obtain the image. Images obtained using DR can be immediately checked for positioning, patient motion, and image quality. As is the case with CR, the DR unit must be fully integrated with the hospital information system (HIS) and the PACS. This integration can result in automatic downloading of patient information from the HIS and automatic transfer of images to a PACS and confirmation of successful reception of those images by the PACS.

Although not fully tested clinically, DR additionally promises the potential to maintain or increase spatial resolution depending on the system used, increase contrast resolution, and, in some cases, increase detected quantum efficiency resulting in decreased radiation exposures. Relative disadvantages of current systems include increased cost in comparison to CR and the lack of a practical solution to portable (bedside) radiography. Additionally, there are a number of challenges that are associated with the incorporation of DR into a PACS.

CHALLENGES ASSOCIATED WITH INCORPORATION OF DR INTO A PACS

The decision by the imaging department of the Baltimore VAMC to install a DR unit has resulted in detailed discussions with three major vendors that provide this modality, and in extensive discussions and preliminary testing with one of these vendors. The experience detailed in the following discussion is a result of these discussions and the preliminary testing that has occurred at the medical center.

New Modality

The Digital Imaging and Communications in Medicine (DICOM) committee has recently recog-

nized DR as a separate modality from CR or any other previously defined modalities. Our current list of modalities at the Baltimore VAMC include CT, US, MRI, nuclear medicine, digital fluoroscopy, CR, and "other," which includes film digitization. DR represents the first new modality to be added to our PACS database since we began operation in 1993. The addition of the DR modality requires a number of changes to the PACS database, as well as the addition of DR to the radiology information system (RIS) database. Studies will continue to be ordered by clinicians without requiring them to specify CR or DR, and scheduling clerks and technologists will be given the ability to determine which specific patients will have their requested studies performed using CR or DR. Technologists will indicate to the RIS immediately before the procedure whether a particular study is to be performed as a CR or DR examination. This will be necessary because of the different look-up tables for display and different ways of handling patient information between the two modalities. In the future, clinicians will be given the ability to request that a particular study be performed using the DR technology. This will become particularly important for such specialized studies that may be unique to DR as tomosynthesis, dual-energy subtraction, and temporal subtraction studies. This will require that additional menu choices become available on the clinician ordering menus on the HIS.

Worklists and Prefetch Algorithms

Radiologists who interpret conventional radiographs currently can select the studies to be read from the PACS by selecting one of the CR worklists currently available on the system such as "Baltimore unread CR," "Perry Point unread musculoskeletal CR," or "all unread CR." These lists will have to be redefined to include studies performed using DR as well. Similarly, the automatic retrieval of old studies for display and comparison with the current study will need to be redefined to retrieve historic CR and DR studies when a new study of either type is to be read. Finally, CR and DR will need to be associated for algorithms that require transfer of images from long- to short-term storage (prefetch) when a patient is to be seen in clinic, admitted to the hospital, or a new examination is to be performed.

Unique Characteristics of DR

Given the time required for the fairly extensive software modifications required by DR for the HIS/RIS and the PACS, DR studies will initially be entered as though they were CR examinations. This temporary solution eliminates the potential problems described above for worklists and prefetch algorithms. Unfortunately, this solution does not take into account the unique characteristics of DR.

DR images are acquired and processed in a different manner than CR studies. The optimal parameters for display, including the look-up tables, differ between the modalities. Image settings optimized for CR will not work properly for DR, potentially resulting in either suboptimal image quality, increased time required for image manipulation, or a combination of these. Also, unlike CR, DR systems have the potential to include additional patient and study information for transmission to the PACS, as well as technologist comments. These comments can be made at the time an image is obtained and include such statements as "unable to remove earrings," "patient unable to move his arm," etc.

Additionally, DR matrix sizes vary considerably from vendor to vendor and may differ considerably from that of CR. Some of the PACS are unable to adequately handle the larger matrix sizes without downsampling the image to a smaller size. Currently, a radiologist is able to measure distances such as the diameter of a lung mass with CR. Unfortunately, it seems likely that the calibration for distance measurement with DR will differ from that of CR, another major limitation to identifying DR studies as though they were CR examinations. In addition to distance measurements, current CR systems capture a value (the S number for our Fuji [Tokyo, Japan] CR), which is roughly proportional to the amount of radiation used to obtain the image. Again, this value will differ for DR in comparison to CR and is yet another reason to define DR as a separate modality from CR.

As has been described above, one of the major clinical advantages of DR in comparison to CR is the ability of the technologist to stay in the examination room without the need to process a film or plate. To ensure that the PACS has successfully received images sent from a DR unit, one of

two mechanisms must be in place. Either the department must place a PACS workstation in the examination room or the DR system will need to be able to receive confirmation by the PACS of the successful (or unsuccessful) receipt of the images. It is important to have this bidirectional interface operational between the DR system and the PACS; both the PACS and the DR providers must develop this interface.

Finally, future developments in DR by the vendors in the acquisition of multiple images will introduce techniques such as tomosynthesis, dual-energy subtraction, and temporal subtraction. These enhancements will necessitate the development of new workstation tools for display and manipulation of these series of images that are not available on current workstations.

CONCLUSION

The introduction of DR as a new modality for general radiography has been greeted with a good deal of enthusiasm. However, it is important to recognize that to meet its full potential, this new modality will need to be fully integrated into current and future PACS and HIS/RIS systems, which will require a good deal of software development. Coordination of this effort will require detailed planning and cooperation among imaging departments, vendors, and information technology staff. Our preliminary experience at the Baltimore VAMC indicates that careful planning and integration, before the equipment becomes fully operational, will be essential to the clinical success of DR.

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