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GUEST EDITORIAL

Making Filmless Radiology Work

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DESPITE 2 DECADES of optimistic and confident predictions that filmless radiology was imminent, the centennial commemoration of Wilhelm Roentgen's discovery of the x-ray will come and go this year with only a small number of radiology departments interpreting more than a small fraction of imaging studies using a computer workstation. The reasons for this undoubtedly represent a combination of economic constraints, concerns about image quality and time required for image interpretation, and the inertia that must be overcome with any paradigm shift as great as is required to abandon film for the largely uncharted waters of digital imaging.

The combination of construction funding associated with the Veterans Administration's (VA's) new high-tech showcase, exhaustive investigation into quality and productivity issues associated with digital imaging, a great deal of energy and enthusiasm, and perhaps a bit of naiveté resulted in the decision to pursue filmless operation at the Baltimore VA Medical Center.

The anticipated advantages of the picture archiving and communication system (PACS) included better image management with fewer lost and unread studies, the use of computer enhancement to produce consistently higher-quality images, the ability to provide real-time image interpretation, easier access to images for clinicians and radiologists, reduced average radiation doses, and teleradiology. These anticipated advantages, for the most part, have indeed been realized now that the system has been in routine operation for approximately 2 years with one year of near-filmless operation. Workstations located throughout the hospital have access to all images stored in both short-term and long-term (optical jukebox) archives. Modalities interfaced to our commercial PACS include computed radiography, digital angiography, the cardiac catheterization laboratory, digital fluoroscopy, ultrasound, computed tomography (CT), magnetic resonance imaging, and nuclear medicine. Mammograms are currently produced using conventional film/screen technology and subsequently digitized into the PACS. The mammographers interpret the images from film rather than using the computer workstation because of the spatial resolution limitations of non–film-based technologies currently available for mammography. Nonradiology images from such diverse sources as dermatology, pathology, endoscopy, bronchoscopy, and intraoperative photographs are acquired, archived, and displayed using a separate PACS developed by the VA as part of the hospital information system (HIS). All of the radiology/nuclear medicine images in the commercial system are also archived and can be retrieved using this second PACS.

The workstations in the radiology department use a Macintosh II or Quadra 950 system with four (2,048 × 1,536-pixel) monitors. Workstations throughout the remainder of the medical center are in a two-monitor (1,152 × 1,078-pixel) configuration and use the Quadra 950 computer. The average brightness of the 2,048 × 1,536-pixel monitors is approximately 50 foot-lamberts and their refresh rate is approximately 60 MHz. The monitors are ar-

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ranged in a horizontal four-across rather than a two-monitors-on-top-of-two-monitors configuration.

The relatively gentle transition by the radiologists to soft-copy interpretation took place over a period of approximately 5 months. During this interval, the department continued to print films generated by the computed radiography laser imagers. These films were brought to the film library and were given to the radiologists with the old film jacket as had been the case before the PACS was used. The radiologists then used the name on the examination request to retrieve the images from the PACS.

This modus operandi, in which the paper requisitions and current and old films were made available, accomplished three purposes. The films served as a security blanket to reassure novice soft-copy readers that they were not missing any imaging findings by using the computer workstation. For the first few days, this seems to be important, especially for those radiologists who had many years of experience with film and only minimal confidence with computers, mice, and track balls. The fact that the old films were available during those first few months of soft-copy interpretation with film view boxes located adjacent to workstations made it possible to digitize only a minimal number of historical films. Because it was estimated that it would take about 7 years to digitize the last 5 years of film, the radiologists willingness and even preference to view old films on a conventional light box proved to be fortuitous. Finally, this process of manually entering each patient's name from the requisition and then selecting the images to be reviewed proved to be laborious. At the end of the 4-month transition period, the new films, old film jackets, and paper requisitions were no longer given to the radiologists who were expected to perform all image interpretation and comparison with prior studies using the workstation. The manual system of typing in each patient's name and searching for specific images was replaced with an automated work list that contained a list of studies that had not yet been interpreted. The radiologist merely had to use the mouse or track ball to point to the next study to be read, and the list of historical studies was retrieved. The change from manually typing in the patient's name to simply highlighting a study on the worklist resulted in many fewer keystrokes on the workstation. This improvement made the loss of the film security blanket more palatable to the radiologists and resulted in a relatively smooth transition to soft-copy reading.

The rate at which individual radiologists made the transition during this 4-month transition period varied widely and was not as dependent upon age and computer experience as we had anticipated. The two most enthusiastic radiologists were two of our oldest radiologists, one of whom had no prior computer experience whatsoever. Although some radiologists began using the PACS for most images in the first few days, a few continued to read the majority of examinations using film. After the transition period, films were not generally made available to the radiologists. Staff members from the University of Maryland who were new to the PACS at the VA generally required approximately 2 to 3 days of experience to become somewhat comfortable and proficient with the PACS, with 2 to 3 weeks required to achieve maximum speed using the system. After this amount of time using the PACS for soft-copy interpretation, there seems to be very little difference in speed or general comfort level with the system based on age or level of prior computer experience.

The clinicians in the medical center made the transition to soft-copy interpretation even more rapidly than did the radiologists for a number of reasons. In general, the house-staff consisted of relatively young and computer-savvy residents and interns who were assisted by the even more enthusiastic medical students. This group of physicians began using the PACS almost immediately after it was installed in the medical center. In response to questionnaires, the vast majority of physicians indicated that they preferred PACS to film because of better access, availability, and speed. They also responded that less or much less effort was required with the PACS than with a conventional film-based system.

One of the more difficult challenges faced by the radiologists was to overcome the idea that the goal of soft-copy image manipulation is to make the image on the monitor look identical to what they would want to see on film. With experience, the radiologists (and clinicians) learned to use the tools available at the worksta-

tion to maximize their ability to see relevant image detail. Increasing experience with soft-copy interpretation results in a greater awareness that there is no ideal combination of window/level (contrast/brightness) settings for many images. For example, the best settings for imaging the toes are usually not optimal for viewing the metatarsals and would be extremely limited to view the tarsal bones. A good technologist working with film consequently uses a very different technique for the toes than for the hind foot and must choose one or the other. A radiologist experienced with soft-copy interpretation manipulates the image settings when interpreting images of the foot obtained with computed radiography to view the entire foot. After a relatively few days, this process seems to become intuitive and can be performed very quickly.

The actual reading time per case for conventional radiographs is only slightly longer using a computer workstation in comparison with film, despite the fact that the images take approximately three times as long to display as on a film alternator (15 *v* 6 seconds) and slightly longer than when the radiologist hangs their own films.

Additionally, the overall productivity of the radiologists has increased roughly 10% to 30% after the conversion to soft-copy interpretation (the total number of radiologic examinations increased without requiring additional radiologists). This increase in number of cases interpreted per radiologist per day occurred without any noticeable change in the amount of time available for academic and teaching activities.

This paradoxical increase in productivity despite slightly longer time to read each case is probably caused by the other increased efficiencies associated with the PACS. These include easier, more rapid, and more reliable access to old images and reports, elimination of interruptions by clinicians and file-room staff who are looking for films, and better ability to distribute the workload in the department with less dependence on the film file-room personnel. The recent addition of default display protocol software has further increased the radiologists productivity. This software enables the workstation to automatically retrieve the current study and previous related exams and display them in a logical fashion on a workstation.

The amount of time required to interpret cross-sectional images such as CT has decreased by approximately 10%. This is largely because of the fact that images can be brought up quickly with 36 to 48 images typically available on a four-monitor workstation. Additionally, multiple window/level setting combinations such as lung, mediastinal, and abdominal settings can be invoked with image presets that are applied very rapidly. This is much faster than hanging and reviewing many films of the same anatomy printed in these various settings. A related advantage of soft-copy interpretation of CT images is the ability to routinely review images using multiple additional window/level combinations very rapidly. This enables the radiologist to routinely review CT images of the thorax, eg, using not only lung, mediastinal, and abdominal settings, but liver and bone settings as well. The ability to view CT images in multiple window/level combinations has resulted in additional clinically significant findings that have been made that would have been missed on film.

Another factor affecting productivity that was not entirely unexpected was radiologist fatigue when using the workstation. The radiologists need to take more frequent breaks (every 40 to 50 minutes) than they would when using film (every 1 to 2 hours). This fatigue is most likely caused by a combination of factors including the relatively decreased brightness of the monitors in comparison to a film view box, the monitor flicker, the small cursor, and the active role in image manipulation required for soft-copy interpretation. The default display protocol software has anecdotally diminished the degree of fatigue somewhat.

The radiologists' subjective perception of image quality using computed radiography and soft-copy interpretation is generally very positive. The general impression is that the vast majority of images on the workstation are of comparable or near comparable quality to that achieved by the best (perhaps the top 10% to 20%) films. This consistent high image quality has been one of the major advantages of the PACS cited by both radiologists and other physicians. These subjective impressions have been supported by cadaver studies evaluating film and computed radiography soft-copy interpretation, comparisons of soft-copy interpreta-

tion versus film in the trauma setting, and retrospective analysis of missed or misdiagnosis rates before and after the use of the PAC system. Film retake rates have dropped from 4% to less than 1% after the transition from film to filmless operation.

One of the biggest challenges to soft-copy interpretation in an academic medical center has been training of not only the large pool of radiologists who work at both the VA and the University of Maryland hospital, but also the much larger number of other physicians who rotate between the two institutions. Radiologists in the department are trained both by our in-house PACS instructor and by other radiologists experienced with the system. However, only approximately 20% of clinicians have had the formal mandatory training course required for a valid account name and password for the system. The other 80% learn the system from peers with varying levels of experience with the system. This is, in part, because of deficiencies of the system that permit more than one user to log onto the system with the same account name and do not require users to change their passwords after a predetermined time period. Studies at our institution will determine the relative proficiency of those users who have and have not had formal PACS training.

There are a number of interesting psychologic and sociologic consequences of image interpretation using the computer workstation in addition to the performance and image quality aspects of soft-copy image interpretation. One such psychologic phenomenon is a consequence of the fact that the computer displays all unread examinations and, thus, makes the radiologists very aware of the exact amount of work remaining to be done at any time. This constant reminder of the unread studies has been a great motivator to keep as current as possible with the workload with the consequence being that studies performed during regular working hours are often interpreted within a few minutes of being performed. Another interesting sociologic consequence of the computer worklist is the fact that radiologists no longer grab a pile of films for which they are responsible. Instead, they are reading one case at a time from a common worklist. This has resulted in a diffusion of responsibility that has not been a problem operationally in our facility, but could be an important issue in other radiology departments, particularly when radiologists are reading in separate rooms. The lack of dependence of radiologists on film file-room personnel has resulted in a much greater ability to work flexible hours including very early morning, some evening, and greater weekend image interpretation without the need for supporting film-room personnel. A final psychologic issue that should be mentioned is the fact that many clinicians and radiologists find that soft-copy image interpretation is fun. Factors that contribute to this include the ability to manipulate images, the uniqueness of soft-copy interpretation, the relative ease of use of the computer interface, and the fact that image interpretation becomes a more active process.

A number of interesting lessons have been learned based upon the 2 years of practical experience with soft-copy interpretation of radiology and nuclear medicine images. One of the most important of these is the fact that the speed at which the workstation retrieves images is only one of many factors that determine productivity and usability of the system. Equally important is the software that automates the process of image retrieval and image arrangement for current and historical examinations. PACS vendors have put far less time and energy into intelligent image navigation and image-arrangement software than is necessary. A related lesson is the fact that overall productivity is also multifactorial and radiologists only spend a fraction of their day actually dictating cases. Consequently, other factors such as ability to share workload, to minimize interruptions, and availability of old exams and reports also have a major impact on radiologists' output. Additionally, radiologist fatigue with soft-copy image interpretation is an important consideration. Improvements in monitor technology including brighter 2,000-pixel displays, faster refresh rates to minimize flicker, which may be fatiguing even when the flicker is not noticeable, and greater consistency of brightness, contrast, and even tube color will help to reduce fatigue. Intelligent image-display software is also critical in reducing fatigue. The fact that only a minority of clinicians have been through the formal training course indicates that on-line computer-

based training could be useful. An on-line library of normal variants and perhaps normal anatomy would likely be valuable for both clinicians and radiologists.

Any radiology department planning to make the transition to filmless operation should consider the following requirements to be essential: (1) sufficient funding not only for the PACS purchase but also for a source of recurring monies with about 5% to 10% set aside for maintenance and about 5% to 10% for system upgrades such as additional workstations and storage capacity; (2) greater than 99% up time (as has been the case at the Baltimore VA Medical Center) with adequate back-up systems to permit continued operation of the PACS, despite failure of a major component; (3) a critical mass of workstations to permit all health-care workers convenient access to any image at any workstation. Each workstation should be able to retrieve a recently acquired chest posteroanterior and lateral or image from a head CT in less than 10 seconds. The radiologists workstations need to support a four-monitor configuration with the monitors capable of at least 1,500- × 2,000-pixel display; (4) on-line short-term storage of at least 2 weeks and on-line long-term storage of at least 5 years; (5) enthusiastic endorsement by the chief of the radiology department; (6) a bi-directional interface between the PACS and the radiology information system (RIS) and/or HIS; (7) one or more image projection systems or large monitors for conferences and demonstrations; (8) adequate space for a PACS computer room; and (9) a sense of humor.

Finally, it is important to recognize that the radiologist's diagnosis is based not only upon the image content, but upon the clinical information available. Soft-copy diagnosis should consist of a combination of both textual and image data. The VA HIS PACS interface currently provides ordering information and demographic information. This should be supplemented with recent laboratory data, patient problem list, and progress notes or the discharge summary (currently a work in progress at our facility).

In conclusion, the last 2 years of clinical experience at the Baltimore VA Medical Center has shown that the light-boxes can indeed be turned-off in a medium-sized (300-bed) academic medical center and that soft-copy interpretation can replace film with the current technology. Our experience has suggested that one of the most important determinants of successful conversion to filmless operation is the enthusiasm, commitment, and patience of the administration including the chief of the radiology department as well as the hospital administration. Making the transition during a move to a new hospital or clinic may be easier because of the expectations of change in the new facility. Our experience suggests that a very rapid transition (a few weeks or months) may be preferable to a slower, more conservative transition, if possible. Enforcing proper utilization of the system and discouraging dependence on films may be easier when the transition is rapid and films are or will soon be no longer available. Just as was the case in converting coworkers from manual typewriters to word processors, the transition to soft-copy interpretation involved convincing radiologists and clinicians that short-term pain would result in long-term gain.

ADDITIONAL READING

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