Journal of Digital Imaging

The Cutting Edge: Strategies to Enhance Radiologist Workflow in a Filmless/Paperless Imaging Department

Bruce I. Reiner, MD, Eliot L. Siegel, MD, Guest Editors

IN KEEPING WITH THE PRODUCTIVITY and workflow theme of this issue of *JDI*, we have included articles that reflect the challenges and strategies used by imaging department as they make the transition from film-based to filmless operation. In addition to presenting scientific data, we tapped the collective experience of a number of experts with different training and varied perspectives on the complex relationships between technology deployment and workflow. In this new feature, we have asked these experts to share their experience and observations in an informal Q&A with the readership. We have enlisted the expertise of private practice and academic radiologists (David Weiss and Steve Horii), a departmental chairman (Eliot Siegel), a physicist (Paul Nagy), an architect (Bill Rostenberg), and private PACS and productivity consultants (Ken Johnson and Cynthia Keen) to respond to the key questions that most imaging specialists have when considering this transition. Their insights and advice offer practical support that supplements the articles included in this issue.

***JDI* asked David L. Weiss, MD, Chair of the Department of Radiology at Chestnut Hill Hospital in Philadelphia and a consultant for Talk Technology:**

JDI: Does speech recognition (SR) adversely affect radiologist productivity? What specific strategies or tools can be employed to improve radiologist productivity when adopting speech recognition in practice?

DR. WEISS: The use of SR in radiology reporting clearly has the potential for decreasing radiologists' productivity by increasing dictation time. A number of studies have documented a time penalty in the use of SR.[1–3] Some studies tested an earlier version of the speech engine used for conversion of spoken word to text. Most studies so far have been performed at academic centers with a heterogeneous population of users. At some sites, measurements were made before SR was implemented departmentwide. One recent survey seemed to imply that efficiency within a given department was related at least in part to the extent of SR use.[4] In addition, when comparing SR with conventional dictation, studies may not have taken into account the time the radiologist had previously spent at the end of the day reading and correcting typed reports generated with conventional transcription.

Even without considering the increased time spent in dictation, another and perhaps more worrisome effect of SR use is the possibility of distraction during image viewing, with the potential for decreased interpretation accuracy.[5,6] Many radiologists are understandably reluctant to adopt this new technology and are concerned about the disadvantages of SR use.[7] Some are under pressure from administrators to cut costs; others may feel the need to respond to the service improvements achieved by competitors who have adopted SR.

A number of strategies for SR use will help to maximize efficiency and minimize distraction:

Speech Accuracy. One of the most common causes of recognition error is faulty microphone

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Online publication 15 January 2003
doi: 10.1007/s10278-002-0029-0

position. Many radiologists are in constant motion during image interpretation, which results in a changing microphone location. The use of the headset microphone helps solve this problem and results in increased accuracy.[8] Most SR vendors offer noise-canceling technology that will filter unwanted background noise.[9]

Speech engine software updates user profiles after each dictation session. Individual speech patterns are stored in the server, resulting in continuing performance improvement over time. Some systems allow the user to actively correct and train a word during a dictation session. In addition, users may have access to the system dictionary. A user may add or delete a word or phrase for his or her specific profile. Over the course of several months, the use of these features can greatly improve accuracy.

Macros and Templates. The use of stored reports (macros) and reports with blank fields to be filled in by the user (templates) is essential in efficient use of SR.[10] A macro will not only eliminate time spent dictating but also reduce the time spent reading and correcting a report. This can be an advantage over conventional dictation, with which a radiologist reviewing hundreds of reports at the end of the day may not recall which of them need review or correction.

There is no theoretical limit to the number of macros that can be stored. If macros are named logically across all modalities, recall by voice command is quick and easy and requires little thought. A radiologist can recall an appropriate macro and modify it slightly to dictate a study that is near normal with perhaps one reportable finding. This saves time not only in that it requires dictation of only one phrase or sentence but also because only that single modified portion of the report must be reviewed. The entire process can be performed using only voice commands, allowing the radiologist's eyes to remain on the images. With this in mind, macro text should be structured in such a way as to make it easy and logical to modify.

User Customization. A number of features of SR can be customized by individual users. The use of the programmable buttons on the microphone supplied with most systems is key in increasing the speed of navigation and minimizing the time required for corrections. For example, one of the most frequent dictation errors is use of an extraneous word or phrase during dictation, often in response to background noise. These words can be deleted easily by mapping the keyboard "delete" function to one of the microphone buttons. This allows rapid correction of such errors during image review without the use of the keyboard. Programming the "signoff" command to the microphone is also helpful. Each user can determine which keyboard commands are most useful.

SR/Picture Archiving and Communications System (PACS) Integration. Integration of SR with the PACS can result in great efficiency gains.[11] The two applications can run on the same platform with shared mouse and keyboard commands. The dictation screen appears on the PACS monitors and can easily be relocated, resized, or toggled in front or in back of the images by the radiologist.

The following is an example of one such integration algorithm: The radiologist opens a case within PACS. PACS messages SR to open the appropriate dictation shell with demographics previously sent to the SR database from the radiology information system (RIS). Images are viewed, and the report is dictated. When the study is complete, the radiologist signs off on the dictation using the microphone buttons. SR then messages PACS to close the current case. PACS automatically opens the next case and messages SR to open the appropriate dictation shell. The cycle continues until the worklist has been completed.

This method of dictation can restore speed and efficiency. More important, the eyes and mind of the radiologist can focus solely on the images. Although we have not performed a formal time study, most radiologists in our practice subjectively believe that they work faster with the integrated SR/PACS arrangement than with conventional dictation.

Conclusion. SR has the potential disadvantages of increased dictation time and distraction during image viewing. With standalone SR, several easily accessible techniques can minimize these disadvantages. When SR is combined with PACS on an integrated platform, greater efficiency and potential timesavings are possible.

***JDI* asked Steven C. Horii, MD, Professor of Radiology and Clinical Director of the Medical Informatics Group, Department of Radiology, University of Pennsylvania Medical Center in Philadelphia:**

JDI: What workflow-enhancing strategies can radiologists adopt in dealing with the ever-increasing data sets associated with new imaging technologies such as multislice computed tomography (CT)?

Dr. Horii: The full image sets produced by multislice CT machines, magnetic resonance (MR) imaging, angiographic studies, cine (multiframe) ultrasound, angiography, and fluoroscopy all have in common very large numbers of component images. An important common aspect is that they form the first group of examinations that cannot practically be printed to film for interpretation. Even with a 15-on-1 image format on a printer, a 1,000-image examination would require 67 sheets of film to print. That would fill 17 panels of a four-lightbox mechanical film changer. Trying to read the examination on film would very easily result in a loss of the radiologist's spatial memory, that is, the process of remembering for later review where in the anatomy an abnormality was seen. In addition to display features of workstations that can improve productivity, PACS can also contribute to major changes in logistics (or workflow).

Display Features. Reading studies with large numbers of images can be streamlined through softcopy review; that is, reading the studies on a PACS workstation. This may not be true for all studies with large numbers of images. The most useful advantage that workstations provide over film for these studies is the availability of "stack viewing," in which images are electronically "stacked up" and viewed in sequence in the space of a single image rather than displaying a number of images across the monitor.[12] The rate at which the images are shown is usually controlled manually with whatever control device (mouse or trackball) the workstation uses. This allows variable rate movement through the image stack. This sort of display is useful when there is either a spatial or temporal relationship between the images. For CT and MR, this would mean a sequential series of images through some portion of the anatomy. In some fluoroscopic applications (dynamic gastrointestinal contrast studies, cardiac studies, and many angiographic examinations), the images are sequenced in time with a fixed view of an organ or area of anatomy.

The display of multiple images on workstation monitors is sometimes referred to as "tile mode," because the pattern of the display is similar to a series of tiles on a wall or floor. This is analogous to displaying multiformat films on a lightbox. When large numbers of images are displayed this way, viewing them involves considerable eye and head movement.[13] This movement is significantly reduced with stack viewing. Although some MR display methods involve multiple stacks with different pulse sequences set up in each stack,[14] many systems allow for the synchronizing of stacks that show the same anatomy in the same planes but with different techniques of acquiring the images. The different MR pulse sequences are one example, and noncontrast/with contrast CT scans are another.

Stack viewing also permits a radiologist to maintain his or her gaze on a specific spatial location while images change. This is very difficult to accomplish in tile mode as the gaze is shifted from image to image. Many radiologists believe that stack viewing allows for a better interpretation of the three-dimensional relationship of various structures.[15] Whether these advantages of the stack viewing method translate into faster reading times remains to be broadly demonstrated, although Reiner et al.[16] have reported productivity improvement with PACS-based CT reading (note that this also incorporates improvements as a result of faster or automated retrieval of prior studies).

In addition to the stack viewing mode, another major advantage of workstation interpretation is the ability to adjust window width and level values. For CT studies in particular, most examinations are viewed with the window width and level values set to show lung, soft tissue, and bone in an optimum fashion.[17] In film-based viewing, the multiple window width and level viewing require that the same images be printed with the different settings, resulting in a further increase in the number of images.

The ability of workstations to process the multiple images from CT or MR studies also can be used to generate three-dimensional volumetric or two-dimensional multiplanar reconstructions. These alternative ways of viewing datasets can reduce reading time by providing views of anatomy that are difficult to synthesize mentally.[18] Examples of the utility of such computer graphics applications include vascular (for three-dimensional) and spine (for two-dimensional multiplanar) examinations.

Workflow Enhancement. A major factor in productivity improvement through using PACS workstations is in the logistics surrounding the interpretation process.[19,20] Two areas are important in this regard. The first is automation. In many high-volume film reading environments, the radiologist's time is optimized if all she or he is doing is interpreting examinations and generating reports. To support these tasks, motorized film changers (alternators or multiviewers) are preloaded by film library clerks so that the radiologist does not have to search through stacks of film to find the study to be read. The preloaded films usually include any prior studies for comparison or correlation, and a copy of the printed report is either attached to the paperwork accompanying the films or placed on the alternator with the films. The film library clerks usually know who is going to be reading studies and will arrange the films to that radiologist's customary specifications. (For example, one radiologist may prefer having the current exam on the right and the prior on the left, whereas others may prefer a different configuration.) On workstations, the automation of "hanging protocols" provides the electronic equivalent of a film library clerk. Through the workstation login, the radiologist is known to the PACS, so that individual display preferences are automatically set up. These displays also may vary by examination type for the radiologist who reads examinations of multiple types. The automation of the display layout is a tremendous time saver when compared with situations in which the radiologist must search through the electronic patient "folder" (much as would be done with a film jacket if the films were not prehung).

The second area important in workstation logistics improvement is in the integration aspects of the PACS. In film-based operation, the preloaded film alternator is usually either accompanied by a "directory" consisting of slips of paper or by cards bearing the patient name and location on the alternator. The paperwork also may be sorted by the examination location. This saves the radiologist time, because there is no need to inquire about what studies are to be read or where they are. PACS workstations also can support worklists. These are lists of examinations to be read, the analogs of the paper "directories" used with film alternators. PACS workstations also have the ability to generate different types of worklists and to prevent an examination from being read twice by locking that study when it is opened for reading on a workstation. Another radiologist may view the study but would be notified that it is being read. Worklists may also be set up for different specialties, for "overreading," or for resident review in teaching institutions. To generate the work lists, the PACS often has to interact with the RIS, because this is the system that usually carries examination schedule, start, and end information. However, the end exam "signal" may pass through the PACS to get back to the RIS. The radiologist typically marks the examination as having been "read" at the workstation, although this may happen automatically in a digital dictation or SR system. This event then usually results in the examination being removed from the worklist so that the radiologist can keep track of studies read.

The combination of display techniques unique to workstations and improvements in workflow resulting from PACS use can have important effects on radiologist productivity. In my experience, workload in both body CT and ultrasound has increased since PACS was installed, yet the number of radiologists reading these studies has not changed. Also, the number of technologists in ultrasound has decreased since PACS was installed, whereas the daily workload has increased by approximately 17%.[21,22]

It is important to note that a PACS without the automation or integration features described will contribute far less to productivity improvement and may actually reduce efficiency.

It matters little if the radiologist saves time through stack viewing of large-image-number studies if that time gain is given up in searching for examinations to be read, setting the display layout for each study, or having to request comparison examinations to be fetched from storage.

***JDI* asked Eliot L. Siegel, MD, Director of Imaging for the Veterans Affairs (VA) Maryland Healthcare System and Vice-Chair of Information Systems at the University of Maryland School of Medicine, Baltimore:**

JDI: How do PACS and the electronic medical record EMR affect workflow on an enterprise-wide level?

Dr. Siegel: The use of a PACS and an EMR can have a major effect on workflow at the enterprise-wide level. Unfortunately, this relationship has not been well documented in the radiology or hospital information technology literature.

In 1989, the Baltimore VA Medical Center performed a workflow analysis to study the process of ordering an inpatient chest radiograph, acquiring the images, and reporting the results to the referring clinician. We found that this process required 59 major steps. Of these steps, 18 were performed by personnel outside the radiology department. These included the referring clinician, ward clerk, nurse, and medical clerk. After re-engineering our workflow and integrating our information systems, we were able to reduce the 59 major steps to only 9. In addition, the number of steps performed outside the radiology department was reduced from 18 to only 2: the ordering of the study by the clinician using the EMR and access by the clinician to the results, also using the EMR.[23] The elimination of the many manual steps inherent in a paper- and film-based enterprise and, more important, the improvement associated with integration of the various enterprise information systems have resulted in substantial gains in study turnaround times and cost savings.[24]

In addition to the administrative and clinical processes of ordering and reporting imaging studies, the use of a PACS and EMR has resulted in many other major workflow changes in our health care enterprise. A survey of physicians in the medical center indicated that the average amount of time saved associated with the PACS and EMR was estimated to be 50 to 60 minutes per day.[25]

We also studied the frequency with which various medical teams in the VA Maryland Healthcare System reviewed radiology studies requested on their patients and found that they had reviewed approximately twice as many images after the introduction of PACS and EMR than they had previously reviewed using film. This more frequent review of images was probably related to the increased accessibility (using PACS and EMR workstations in their team rooms and patient care areas).

The more frequent review of images may also have resulted in substantial decreases in direct in-person consultation by clinicians with radiologists in the radiology department. The in-person consultation rate for general radiography, for example, decreased from one consultation for every 7.5 studies to one consultation in 42 studies.[26] The ability of clinicians to remain in patient care areas and not make time-consuming trips to the radiology department has significantly changed workflow and has changed the direct consultation process to an electronic process that relies to a greater extent on digital annotation of images viewed at workstations, access to digital dictations over the telephone, and increased use of electronic mail and physician alerts available in the EMR.

The increased frequency of image review by physicians was associated with an unexpected increase in radiology utilization rates. The number of studies per patient admission increased by 43%, compared with 0% increase for the rest of the VA hospitals throughout the country during the same time period. Outpatient utilization similarly increased 21%, whereas national VA hospital utilization decreased during the same interval.[27]

Although less dramatic, substantial changes in workflow related to the transition to the use of PACS and the EMR have been observed in a number of clinical areas, such as the intensive care unit, the emergency room, and the operating room.[28-30] In general, studies of these areas have documented improved report and image turnaround times resulting in the potential for improved patient care. In our facility, primary and specialty clinics have become more efficient as a result of the elimination of manual processes, such as the need to pull films before clinics. The clinics also have benefited from decreased waiting times for images and universal access to current and historic imaging reports directly from the PACS and the EMR.

The high level of integration required to achieve major improvements in enterprise workflow has historically been difficult to achieve in the absence of standards for communicating demographic, ordering, scheduling, status, and exceptions information among various hospital information systems (HIS). Until recently, the only way to obtain this degree of integration was to create custom interfaces among the various radiology modalities, RIS, HIS, PACS, and other information systems—an expensive and time-consuming process. The Radiological Society of North America (RSNA) and the Healthcare Information and Management Systems Society (HIMSS) have formed a partnership to form consensus on the use of existing standards, such as Digital Imaging and Communication in Medicine (DICOM) and Health Level 7, to minimize or eliminate the need for these custom information system interfaces. Radiology is uniquely situated among the various clinical subspecialties because of the high degree of utilization of imaging services by clinicians and the need for rapid communication of images and reports between radiology and the rest of the enterprise. Further, radiologists themselves need to have as much clinical information as possible to optimize their ability to assist the clinicians and care for patients. In my opinion, therefore, it is no coincidence that radiology has led the way among the clinical specialties in forging close alliances with information technology health care professionals in an effort to enhance integration to optimize workflow.

***JDI* asked Paul Nagy, PhD, Director, Radiology Informatics Laboratory, Medical College of Wisconsin, Milwaukee:**

JDI: What is the role of technology in monitoring workflow in radiology?

DR. NAGY: Simply put, workflow is the number of steps it takes to get your job done. Workflow monitoring is the attempt to understand the process and remove non-value-added components that delay service and introduce errors. The opportunities that workflow monitoring presents to radiology and all of health care are significant, because most workflow within medicine was never consciously designed.[31] This has been confirmed by researchers who found as many as 59 steps being conducted in the routine operation of radiology.[32] The results of neglected workflow design are poor and inconsistent delivery of timely service, errors, costly inefficiencies, user fatigue, and demoralization. Physicians are generally skeptical of information systems and efficiency engineering, seeing them as attempts to reduce costs without regard for physician workload or even quality of care.[33] Good engineering is not a tradeoff. It should be no surprise that good engineering could improve report turnaround, the productivity of the radiologist and technician, and the quality of service.[34–36] Sixty to eighty percent of mistakes in health care involve human error.[37] The more steps, the higher the probability for an error. As an example, errors in typing patient demographics at the radiology modality have been associated with a 15% clerical error rate.[38] With the introduction of the DICOM Modality Worklist, the patient name could be selected from a list, and that reduced the number of keystrokes and the error rate went down to 1.5%. Workflow re-engineering should be viewed as a survival trait in this time of radiologist and technologist staffing shortages.[39,40] The RSNA and HIMSS have joined forces to promote good workflow in their Integrating the Healthcare Enterprise (IHE) initiative?[41,42]

Information technology facilitates the ability to measure quality in the delivery of health care.[43] When information is entered into a computer (eg, when a patient arrives to register or a report is signed of by a radiologist), that information is recorded into a database. Reports can be generated to query the database and analyze specific elements of the department's operation. Common reports analyze patient wait times[44] and report turnaround times.[45] These types of reports have been around for many decades within the RIS. Although these metrics are helpful, they capture only the most basic information about workflow. PACS has the potential to help create an even better understanding of workflow. A PACS can record when a clinician logs in to look at pertinent images and assess how quickly those images are made available and how they are being utilized.[46] A PACS also can directly capture a great deal of the radiologist's workflow, by determining how long it takes to log in, pull up a worklist, receive the first image, receive the entire study, close a case, and move on to the next one. A PACS can analyze how many times and in what capacity a radiologist looks at previous images, thereby yielding valuable understanding about which kinds of images are relevant to diagnosis.[47] Today there is little workflow monitoring in PACS.[48] As the worlds of RIS and PACS collide, however, opportunities arise to obtain a clear picture of the ways in which the entire department operates and delivers services to the enterprise.

An inclusive approach to workflow involves looking at the ordering physician, radiologist, technologist, and the patient as their needs and actions revolve around the overall workflow of the study. One of the challenges to workflow within radiology is that it is dependent on the nature of the service and the status of the patient. Workflow patterns in inpatient and outpatient facilities can differ markedly. Table 1 is a first pass at useful metrics for measuring radiology workflow. To capture these statistics, a universal method for logging and transmitting these metrics would need to be developed and agreed upon by vendors.

Health Insurance Portability and Accessibility Act (HIPAA) legislation requires that PACS record who is looking at what data and when. This centralization of usage statistics actually provides an ideal framework for monitoring workflow. All that is missing is recording how well the system provides that information to users. To address HIPAA compliance, IHE in year 4 has developed the concept of the audit record repository (ARR).[49] The audit record repository utilizes SYSLOG, a computer industry standard transport mechanism, to transfer messages between back-end server systems and central collection servers. SYSLOG transports HIPAA information contained within an extensible markup language message. For the audit record repository, vendors came together and agreed on 18 different message types to fully describe the auditing of patient information. My recommendation to develop workflow monitoring as a standard would be to employ the infrastructure and framework of the ARR and simply define messages that can help analyze workflow. Once this information is stored in a central repository, reporting tools can be developed to help trend the data and even build real-time reporting and alerting systems.

Conclusion: Today, workflow monitoring is conducted at the level of the RIS. As the PACS industry matures, workflow monitoring offers significant potential for understanding and improving workflow. Workflow redesign is the next evolutionary step in the PACS/RIS industry. Improved workflow has been demonstrated to dramatically enhance the productivity of radiologists and technologists. Metrics should be developed and agreed upon by vendors to define workflow based on user acceptance criteria. Methods should be developed to exchange this data among different information systems to collect a complete picture of workflow. A methodology has been proposed to accomplish workflow monitoring, employing existing standards and methodologies.

***JDI* asked Bill Rostenberg, FAIA, FACHA, vice president in the San Francisco, California, office of SmithGroup Architects and Planners:**

JDI: How important are environmental factors and design on workflow within the filmless imaging department?

MR. ROSTENBERG: It often appears that some of the nation's best medicine is practiced in some of our most aging medical facilities. This, however, does not suggest that the physical environment has a limited effect on workflow and productivity. On the contrary, one can only imagine how much better medical care would be in a properly designed facility. High-quality medicine provided in suboptimal environments is a testimony to the inventiveness and flexibility of those who practice within these spaces. Medical imaging focuses on information management, specifically on the timely dissemination of valuable knowledge that beneficially influences patient outcomes. As such, efficient workflow is key to the design of any imaging

Table 1. Metric Suggestions

Workflow actor	Possible metrics
The study	• Time the order was written • Time the patient came to registration • Time the examination began • Time the examination was completed • Time the study was dictated • Time the study was transcribed • Time the study was verified • Time the physician received the results • Current Procedural Terminology codes (CPT) • International Classification of Diseases (ICD-9) codes
Patient and technologist	• Time of registration • Wait time • Examination time • Quality control time • Patient acuity
Radiologist	• Time to login to the PACS • Time to pull up the worklist • Time to retrieve the first image • Performance of the workstation (images/second) • Number of images in the study • Time to read case • Number of mouse clicks or keystrokes necessary to manipulate the images • Demographics about relevant priors • Time to close the case and move to the next one
Clinician	• Time of writing order • Time to viewing images • Time to reading report • Time to login to the PACS • Time to pull up the worklist • Time to retrieve the first image • Performance of the workstation (images/second)
Archive	• Time the study was received from the radiology modality • Study statistics • Number of times the study was sent out to be reviewed • Performance and loading metrics of the system and network

facility. Several types of workflow must be considered in imaging facility design, including the flow of patients, staff, information, and equipment and supplies.[50] Some types of flow (such as those of patients and equipment) obviously benefit from a quality environment. Others (such as the flow of information) may appear to be influenced more by equipment than by environmental design. However, when one examines the process in which radiologic information is managed, design plays a significant role.

Impact of Filmless Imaging on Workflow and Productivity. Workflow within the digital department differs from that within traditional film-based facilities. The physical flow of information is changed, as is the overall job of the radiologist. In many digital facilities, radiologists are more productive and experience fewer interruptions than in film-based facilities. "One thing we found interesting was that when we do time/motion studies from the time the radiologist pulls up the image to the time he or she completes the dictation, there is an 8% to 25% time savings," said one member of an expert panel discussing the transition to filmless work. "Radiologists are not interrupted as much. Technologists become more efficient, not having to interact as often with radiologists. And clinicians can access images and reports anywhere throughout the enterprise."[51] Fewer images are read in batch mode, with a move to more continuous reading. In addition, digital imaging allows greater decentralization without necessarily reducing efficiency, as often occurs in film-based practices.

Few radiologists have the luxury of making the transition from film-based to digital practice overnight. Unless a new facility is built from the ground up or an entire department is renovated, most practitioners experience a gradual transition (often lasting many months or years) before operations are completely digital. Even with new construction, some practices elect to maintain certain modalities as hybrids in which images may be acquired digitally but are stored traditionally as hardcopy. Others are unwilling to relinquish multiviewers and film illuminators for comparing new digital images with previous films.

To accommodate hybrid processes in which film and digital images coexist, the new environment must be designed to gradually change without disrupting ongoing services. For example, as the need for film storage decreases and eventually disappears, the massive space allocated for this purpose can be converted to a new use. Equally important, the new use should be properly suited to the location. For example, a new interventional suite may not be appropriately located in a converted film file room if that room is surrounded by unrestricted foot traffic that could disrupt the interventional procedures.

Environmental Requirements Change Over Time. The physical needs of digital departments change rapidly over time. For example, a central PACS archive designed 5 or 10 years ago would have required several hundred square feet of space, a raised computer floor, and an industrial-quality, environmentally air-conditioned space. Today, an archive with similar or greater capacity requires a fraction of that area, no raised floor, and air flow equal to that required in a general office space. As an alternative, archiving now can be contracted to a remote location, eliminating the need to dedicate space for this function.

The Reading Room Environment. Perhaps the place in which environmental factors and design have the greatest effects on workflow and efficiency is the reading room. This is true in exclusively softcopy reading areas and of special importance where hybrid hardcopy and softcopy reading coexist. The reading room should be designed for continual modification, without built-in fixtures such as casework and permanent walls, if possible.[52] The digital reading room should be designed for the unique lighting, acoustic, and connectivity requirements of softcopy reading. When hardcopy and softcopy coexist, computer monitors should be protected from the harsh light emitted from film illuminators and multiviewers.

The lighting requirements for working with film and monitors are not merely different, they are incompatible. Reading room designers must accommodate the low-level luminance necessary for computer work and at the same time attenuate scattered light, such as that originating from nearby film illuminators or windows. Lighting suitable for paperwork is too bright for softcopy reading and, thus, should be provided by highly focused and dimmable task lights. Ambient lighting surrounding computer workstations must be controlled so that the contrast between the screen and surrounding surfaces does not create eyestrain, yet the room must be dark enough and sufficiently free of glare to make the screen image readable.[53]

As the use of voice recognition becomes more common, the importance of acoustic control increases. The best acoustically designed spaces tend to be private offices, which unfortunately limit collegial interaction to fewer than three or four people. Some degree of acoustic containment may be provided within larger spaces by movable acoustic partitions, thus maintaining flexibility for workstation modification over time. The configuration of each workstation space should enable two or three radiologists to sit near the monitors and also permit several others to view the images from a slight distance. One prototype reading room under development at the University of California, Los Angeles, configures four workstations in a cruciform arrangement in the center of the room.[54] In this design, light and sound project out toward the room's perimeter rather than into nearby workstations. Radiologists viewing images from a distance are aided by a large, overhead flat-panel monitor.

Continual softcopy reading can be economically more strenuous than batch mode hardcopy interpretation, with eyestrain and repetitive motion injuries reported. Therefore, ergonomically adjustable work surfaces and furniture are essential.

Available Resources. Visits to facilities that have already embarked on the transition from film to digital imaging are among the best resources in planning such a transition. However, because of the inherent time lag between the design of a facility and the time at which it is fully staffed and running, more digital department designs are currently "on the boards" than are fully operational. Those designed with flexibility and adaptability in mind are better prepared to fine-tune their environment as technology and practices change.

Recognizing the importance of facility design on workflow, the Society for Computer Applications in Radiology (SCAR) has begun to develop a "facility planning" track as part of the SCAR University curriculum at the annual meeting. The RSNA offers one or two refresher courses on facility design issues under its Associated Sciences track (courses end with a "24" suffix) at its annual meeting. For several years, the Harvard University Graduate School of Design—Office of Executive Education has offered summer "minisessions" on health facility planning. One such course, focusing on imaging and surgical suite design, includes a section on the transition to digital imaging and its impact on design.

Finally, it is essential that the design team be experienced in designing digital imaging environments. Not all architects specializing in health care have broad experience with imaging facility design. Not all designers familiar with imaging facilities understand the unique planning requirements of digital practices.

Interviews and references can help identify design consultants with relevant experience. It is also worth noting that a new professional organization was created about 2 years ago to board certify health care architects meeting established professional criteria. The American College of Healthcare Architects (ACHA) identifies the specialty experience of its members. This information can be found on the ACHA Web site at www.healtharchitects.org.

***JDI* asked Kenneth C. Johnson, president of Kenneth Johnson Associates, a diagnostic imaging technology consultancy in Columbus, Ohio:**

JDI: As radiologists are being challenged to read more studies that in many cases have more images and are more complex—for less reimbursement—can the design of reading and other spaces and improved workflow help to address this challenge?

MR. JOHNSON: Absolutely. For more than 20 years, we have analyzed workflow in radiology departments across the country and have found that poor space planning is one of the most common factors contributing to less-than-optimal productivity and patient satisfaction. One of the key reasons for this oversight is that space planning needs are generally underemphasized or overlooked altogether during the equipment acquisition phase. In addition, the traditional space planning process used by architects for radiology departments (programming phase, schematic design, construction drawings, etc.) is flawed.

Instead of using the traditional space planning process, we recommend the following four-step process. (Note: The first three steps usually are done simultaneously, not sequentially.)

1. Perform a *functional analysis of the workflow* within your department, tracing the steps taken by radiologists, technologists, other staff, and patients to complete examinations in each section of the department. The goal is to identify what works well and where bottlenecks or opportunities for improvement exist.
2. Seek ways to *minimize the number of steps and time* required to complete examinations in each area of the department by making the best use of key resources (technology, personnel, physical space, time, and money).
3. *Identify existing sites* that can be used to illustrate the changes that *should* be made to workflow, technology, and physical space for your department. Make contact with staff at those sites and, when appropriate, visit them to learn more.
4. *Develop action plans* to move toward the vision that is developed from the previous three steps.

Although each of these steps is equally important, I would like to focus on step 3. When building a new home, the most successful approach is to find a home nearly identical to that which you envision and then to hire that architect and builder to build a home for you that is "Identical to that one, except …." Why not use this process for optimizing the design and workflow within your department? The outcome, based on the experience of others and a careful assessment of your own needs, will be much better.

***JDI* asked Cynthia E. Keen, a PACS consultant with i.t. Communications in Sanibel Island, Florida:**

JDI: What benefits/advantages can an outside consultant provide in the transition to filmless operation?

MS. KEEN: When hospital staff plan the transition from film-based to filmless operation, they should recognize that a PACS provides the power and impetus for change. This is especially applicable to workflow in diagnostic imaging. Although the power of PACS unleashed can be substantial, this potential can be undermined by replicating processes that were originally created for less-than-efficient film-based operations. If the hospital does not have in-house staff who can objectively analyze existing workflow and compare existing processes with an optimized

PACS, hiring a consultant for some or all of this evaluation is an intelligent and financially astute decision.

A PACS is not a panacea for all the problems associated with a radiology department. In one scenario, the objective for implementing PACS was to eliminate what had become a publicly embarrassing delay in imaging emergency department patients. The process simply took too long. A workflow evaluation by a PACS consultant determined that the department worked quite efficiently. The hangup was lack of patient transport staff, resulting in lengthy delays for less critically ill or injured patients. While the emergency department and the radiology departments were pointing fingers, the real issue of insufficient transport staff had not surfaced. This hospital as configured did not need a PACS—it needed people.

In another scenario, the addition of a radiographic room within the emergency room did little to speed the radiology interpretation and reporting process. Film cassettes were processed in the busy main radiology department, where work conditions and workflow offered many opportunities for substantial delays. A workflow analysis combined with a hard/soft dollar financial analysis led to the immediate acquisition of a computed radiography miniPACS instead of the budgeted CT and MR miniPACS. Funding was limited to only one miniPACS configuration. Although more difficult to implement, the business case made by workflow analysis was to support the emergency department.

A knowledgeable consultant is an unbiased observer who is not involved in turf protection and is being paid to speak candidly. The consultant has a breadth of knowledge about ways in which a PACS can be used to its fullest capabilities—and whether it is being used well at all. A consultant should be able to rapidly identify operational flaws and the methods by which the client can correct them when a PACS is deployed. The consultant is an island of neutrality when mediating between conflicting departments.

By their very nature, people and institutions form habits. Some habits and behaviors are the result of well-thought-out protocols; others are workarounds to deal with or even offset the impact of less than ideal conditions, personalities, or situations. A consultant can ask, again and again, "Why are you doing this? What would happen if you could achieve the same result but in a different way? Would any clinical or administrative activity be compromised?"

Most diagnostic imaging departments are capable of forming teams (if they can carve out the time to do so) to identify each and every process. A very effective way of doing this is on a day-long weekend retreat with representation from everyone—from the warehouse film processor to the film library clerk to the radiologist to knowledgeable representatives of departments heavily dependent on diagnostic images. People who work within an environment know their own habits and needs.

The careful analysis and dissection of film work habits enables a consultant to identify where a PACS can make improvements. Workflow patterns may determine where PACS components are placed for optimum effectiveness and may contribute to purchasing decisions in minor or major ways. Identification of such patterns can help establish protocol standards with a level of neutral credibility. A consultant may say, "Doctor, you may think that you need to see the entire contents of each and every patient's imaging records, but this is not what is done at most hospitals with PACS. Here is what will happen and what you need to spend to achieve this capability. Now let's talk details about what you really need to see so that we can create realistic prefetch protocols!" The consultant can say this to the chair of the radiology department, whereas a network analyst in the information technology department with the same concerns might not. The need for additional one-on-one applications training can be identified in advance and diplomatically planned for to help overcome perceived problem areas.

A PACS can create efficiencies so profound that unexpected bottlenecks are created that did not exist before. A single digital radiography room replacing a conventional radiography room has the potential to double patient throughput. The workflow of the technologists should be rethought and scheduling may be affected. The consultant can recommend behavior modifications that will facilitate success in the transition. Radiologists have preferences for interpretation workflow. A consultant can assist in identifying which user interfaces of various vendors may bring the highest comfort and efficiency levels for reading proficiency.

Consultants look for opportunities to make PACS excel in efficiencies that film cannot provide. If listened to, they can help prevent mistakes. Selecting a consultant is a matter of preference in working with experienced independents or a large team. The SCAR Web site (www.scarnet.org) is good place to start. Make calls, talk to knowledgeable people with strong credentials, and, most of all, find someone with whom you are comfortable. The transition from a film-based to a filmless department is not easy. It helps to have a professional friend and experienced guide.

REFERENCES

1. Gale B, Safriel Y, Lukban A, et al: Radiology report production times: voice recognition vs. transcription. Radiol Manage 23:18-22, 2001
2. Hayt DB, Alexander S: The pros and cons of implementing PACS and speech recognition systems. J Digit Imaging 14:149-157, 2001
3. Hundt W, Stark O, Scharnberg B, et al: Speech processing in radiology. Eur Radiol 9:1451-1456, 1999
4. Langer S: Impact of tightly coupled PACS/speech recognition on report turnaround time in the radiology department. J Digit Imaging 15(suppl 1):234-236, 2002
5. Ramaswamy MR, Chaljub G, Esch O, et al: Continuous speech recognition in MR imaging reporting: advantages, disadvantages, and impact. AJR Am J Roentgenol l74:617-622, 2000
6. Houston JD, Rupp FW: Experience with implementation of a radiology speech recognition system. J Digit Imaging 13:124-128, 2000
7. Heilman R: Voice recognition transcription: surely the future but is it ready? RadioGraphics 19:2, 1999
8. Langer S: Radiology speech recognition: workflow, integration, and productivity issues. Curr Probl Diagn Radiol 31:95-104, 2002
9. Wickstom TK: Gradient headset microphones—history and performance. Emkay Innovative Products, January 24, 2002. Available at: www.arraymicrophones.com/html/wp_8_99.htm. Accessed 19 December 2002.
10. Sistrom CL, Honeyman JC, Mancuso A, et al: Managing predefined templates and macros for a departmental speech recognition system using common software. J Digit Imaging 14:131-141, 2001
11. Weiss DL, Hoffman J, Kustas G: Integrated voice recognition and picture archiving and communications system: development and early experience. J Digit Imaging 14(suppl 1):33-235, 2001
12. Horii SC: Workstations. In: Dreyer K. Mehta A. Thrall J eds. Springer-Verlag, New York, 2002; p 201
13. Beard DV, Hemminger BM, Denelsbeck KM, et al: How many screens does a CT workstation need? J Digit Imaging 7:69-76, 1994
14. Chang PJ, Hoffman E: Multimodality workstation featuring multiband cine mode and real time distributed interactive consultation. InfoRAD Exhibit 9507WS. Presented at the annual meeting of the Radiological Society of North America, Chicago, IL, December 1993
15. Mathie AG, Strickland NH: Interpretation of CT scans with PACS image display in stack mode. Radiology 202:709-711, 1997
16. Reiner BI, Siegel EL, Hooper F, et al: Effective productivity of PACS in the interpretation of CT exams. Proceedings of the Society for Computer Applications in Radiology, 1996. Reston, VA, SCAR; 399–402, 1996
17. Horri SC: Workstation functions and system capabilities. In: Siegel EL. Kolodner RM eds. Springer-Verlag, New York, 1999; pp 277-294
18. Calhoun PS, Kuszyk BS, Heath DG, et al: Three-dimensional volume rendering of spiral CT data: theory and method. RadioGraphics 19:745-764, 1999
19. Reiner BI, Siegel EL: PACS and productivity. In: Siegel EL. Kolodner RM eds. Springer-Verlag, New York, 1999; pp 103-112
20. Horri SC, Kundel HL, Feingold E, et al: What do we need to advance PACS workstations: a critical review with suggestions. Proc SPIE [PACS Design and Evaluation] 3035:6-14, 1997
21. Horii SC, Feingold E, Coleman B, et al: Use of a miniPACS for printing in ultrasound: potential for improved productivity. Proc SPIE [PACS: Design and Evaluation] 2435:257-262, 1995
22. Horii SC, Coleman B, Mezrich R, et al: Experience report: a multi-vendor ultrasound miniPACS, engineering and clinical issues. Proc SPIE [PACS: Design and Evaluation] 3035:380-388, 1997
23. Siegel EL, Reiner BI: Work flow redesign: the key to success when using PACS. AJR Am J Roentgenol 178:563-566, 2002
24. Siegel EL, Diaconis IN, Pomerantz S, et al: Making filmless radiology work. J Digit Imaging 8:151-155, 1995
25. Protopapas Z, Siegel EL, Scanlon M, et al: Experience with comparative picture archiving and communication system baseline data collection at four Veterans Affairs medical centers: methodology, lessons learned, and suggestions for improvement. J Digit Imaging 10(3suppl 1): 161-164, 1997
26. Reiner B, Siegel E, Protopapas Z, et al: Impact of filmless radiology on frequency of clinician consultations with radiologists. AJR Am J Roentgenol 173:1169-1172, 1999
27. Reiner BI, Siegel EL, Flagle C, et al: Effect of filmless imaging on the utilization of radiologic services. Radiology 2l5:163-l67, 2000
28. Pomerantz S, Siegel E, Protopapas Z, et al: Experience with PACS in the operating room in a filmless hospital. In: Proceedings of the 1995 Image Management and Communications Conference. New York, NY: IEEE Computer Society Press; 238–242, 1995

29. Protopapas Z, Siegel EL, Pomerantz SM, et al: PACS in the emergency room: experience at the Baltimore VA Medical Center and design considerations for the future. In: Carlsbad CA ed. Symposia Foundation, Carlsbad, CA, 1996; pp 412-414

30. Kundel HL, Seshadri SB, Langlotz CP, et al: Prospective study of a PACS: information flow and clinical action in a medical intensive care unit. Radiology 199:143-149, 1996

31. Bates D: The quality case for information technology in healthcare. October 2002. Available at: http://www.biomedcentral.com/1472–6947/2/7. Accessed 19 December 2002

32. Siegel E, Reiner B: Work flow redesign: the key to success when using PACS. AJR Am J Roentgenol 178:563-566, 2002

33. Treister N: Physician acceptance of new medical information systems: the field of dreams. CIO Mag 1999 Available at: http://www.cio.com/research/healthcare/field_of_dreams.html. Accessed 19 December 2002

34. Siegel E, Reiner B, Hooper FJ, et al: Radiologists' productivity in the interpretation of CT scans: a comparison of PACS with conventional film. AJR Am J Roentgenol 176:861-864, 2001

35. Siegel E, Reiner B, Hooper F, et al: Effect of film-based versus filmless operation on the productivity of CT technologists. Radiology 207:481-485, 1998

36. Dreyer K, Mehta A, Thrall J: PACS: A Guide to the Digital Revolution. Springer-Verlag, New York, 2002, p. 183

37. National Academy of Sciences, National Institute of Medicine: To Err Is Human: Building a Safer Health System. National Academy Press, Washington, DC, 2000, p. 53

38. Dreyer K, Mehta A, Thrall J: PACS: A Guide to the Digital Revolution. Springer-Verlag, New York, 2002, p. 170

39. Howell J, Simon C, Sum A: Massachusetts Medical Society Physician Workforce Study. 2002. Available at: http://www.massmed.org/pages/workforce.asp. Accessed 19 December 2002.

40. First Consulting Group: The Healthcare Workforce Shortage and Its Implications for America's Hospitals. 2001. Available at: http://www.fcg.com/webfiIes/pdfs/FCGWorkforceReport.pdf. Accessed 19 December 2002.

41. Siegel E, Channin D: Integrating the Healthcare Enterprise: a primer: part I. Introduction. RadioGraphics 21:1339-1341, 2001

42. Channin D: Integrating the Healthcare Enterprise: a primer: part 2. RadioGraphics 21:1343-1350, 2001

43. Bates D: The quality case for information technology in healthcare. 2002. Available http://www.biomedcentral.com/1472–6947/2/7

44. Sack D: Increased productivity of a digital imaging system: one hospital's experience. Radiol Manage 23:14-18, 2001

45. Seltzer S, Kelly P, Adams DF, et al: Expediting the turnaround of radiology reports in a teaching hospital setting. AJR Am J Roentgenol 168:889-893, 1997

46. Mattern CWT, King Jr BF, Hangiandreou NJ, et al: Electronic imaging impact on image and report turnaround times. J Digit Imaging 12:155-159, 1999

47. Andriole KP, Avrin DE, Yin L, et al: Relevant priors: prefetching algorithm performance for a picture archiving and communication system. J Digit Imaging 13(suppl 1):73-75, 2000

48. Nagy P, et al: PACSPULSE: A Web-based DICOM network traffic monitor analysis tool. Radio Graphics, (in press), 2003

49. Integrating the Healthcare Enterprise: Technical Framework version 5.3, 2002. Available at: http://www.rsna.org/IHE/. Accessed 19 December 2002

50. Rostenberg B: The Architecture of imaging. American Hospital Publishing, Inc, Chicago, IL, 2002, pp 173-181

51. Abella H, et al: Going filmless: panel describes how: radiology's work changes. Diagn Imaging 24:33-40, 2002

52. Rostenberg B: Reading rooms should be designed to accommodate future changes. Diagn Imaging 24:11-15, 2002

53. Rostenberg B: Success by design: maximizing your digital environment. Advance Admin Radiol Radiat Oncol 8:1, 1998

54. Page D: How not to design a reading room. SCAR News 13:4, 2001