Basics of Imaging Informatics:  
Part 2

Part 1 of this review on the basics of imaging informatics discussed the elements that make up a picture archiving and communication system (PACS), as well as some of the useful software that can be used to enhance PACS performance. Part 2 will focus on the impact of informatics in the radiology reading room and on recent technologies that may be unfamiliar to residents and practicing radiologists outside the informatics community.

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Workflow Analysis

Workflow analysis is a type of workflow analysis in which an individual is videotaped and each movement is analyzed for efficiency. It is even possible to deconstruct the workflow of an entire radiology department (Fig 1) (2). The major goals of workflow analysis are to eliminate interruptions, remove bottlenecks, and appropriately incorporate out-of-band tasks.

Out-of-band tasks.—Out-of-band tasks are nonmemorable events that are easily forgotten in the stream of a normal workflow. Examples might include preparing scanning protocols for the next day’s cases or checking for older, undictated cases that do not appear on the PACS work list. Out-of-band tasks are particularly troublesome when they may be accomplished by several different people, and thus no one person is required to take responsibility. Proper workflow incorporates out-of-band tasks in a manner that makes them logical and memorable. Dynamic alerts incorporated into the PACS can help to control errant out-of-band tasks.

Load balancing.—Film-based radiology departments often clustered radiologists into large arena-like reading rooms. This was useful because all the radiographs could be brought to one place and overburdened radiologists could be relieved by their less busy colleagues. In a PACS environment, however, radiologists are often distributed across the hospital or even at different hospitals because PACS allows the images to follow the radiologists to virtually any location. In this setting, it may become difficult for radiologists in one location to assess the workload of radiologists elsewhere in the enterprise. This results in an unbalanced workload and decreases the efficiency of the department as a whole.

Load balancing refers to the ability of the PACS to alert less busy radiologists to the needs of their busier colleagues and to establish mechanisms to correct the discrepancy. (The term load balancing is similarly used when assigning tasks to network components to ensure that no one component is overburdened.)

Digital dashboards.—The dashboard in a car summarizes the state of a complex machine in a few key metrics. Similarly, digital dashboards can summarize the state of a PACS from the perspective of a radiologist, a radiology administrator, or PACS support personnel (Fig 2) (3). Dashboards are useful, when incorporated into a PACS, for alerting radiologists to forgotten out-of-band tasks or for load balancing between radiologists. Digital dashboards are a dynamic means of rapidly correcting workflow inefficiencies.

Very large data sets.—The explosion of data in radiology presents a challenge not only for data storage, but also for interpretation (4). Radiologists confronted with examinations consisting of thousands of images need to find different ways to evaluate the huge amounts of data. Potential solutions include different tools for human-computer interaction, software that presents the images in different ways, and departmental policies regarding the need to examine every image in a study. Such innovations will require focused research for discovery and validation lest the workflow improvements of the digital environment be lost to an overload of data.

Quality Assurance and Quality Control

The terms quality assurance (QA) and quality control (QC) are often used interchangeably (or in tandem), but they have different meanings. QA is an assessment of the process by which a product (“deliverable”) is created. QC is an assessment of the deliverable itself. In the setting of radiology, QC refers to the final quality of either the images or

Essentials

- When radiology departments move from a film-based to a digital environment, radiologists’ workflow must be reengineered to achieve maximum benefit from the digital technology.
- Quality assurance is the responsibility of every interpreting radiologist, and the quality assurance needs of a digital radiology department are different from those of a film-based department.
- The advent of additional informatics technologies is inevitable; radiologists should be aware of recent technologic developments that will affect the way they interact with patients and other physicians.

Informatics in the Reading Room

Workflow Analysis

Workflow analysis is a means of deconstructing the complex tasks that professionals perform as part of their everyday work. Workflow analysis usually involves listing tasks, measuring the time required to perform them, and quantitatively valuing the tasks. Redundant or inefficient tasks may then be eliminated or reengineered. Time-motion analysis

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Abbreviations:
CPOE = computerized physician order entry
CR = computed radiography
DR = digital radiography
EMR = electronic medical record
PACS = picture archiving and communication system
QA = quality assurance
QC = quality control

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the radiologists’ reports. QA refers to the policies and processes of the radiology department and thus is related closely to workflow.

Further confusing the semantics are the less well-defined terms quality assessment and quality improvement. Quality assessment is used as a generic term for both QA and QC. Quality improvement expands on QA and QC by including a feedback mechanism to improve the system (feedback is implied, but not explicit, in QA and QC).

Although QA and QC were critical to any radiology department in the film era, the advent of PACS has produced unforeseen categories of potential errors that need to be addressed with QA and QC systems. Digital images are created and processed with different parameters that must be continually assessed, different artifacts are possible from the digital processes, and complex computer systems can fail in subtle ways. Radiology departments need to incorporate appropriate QA mechanisms to account for recently adopted technologies.

Fortunately, informatics also provides a means of collating and analyzing QA data, along with more rapid and less intrusive ways of providing feedback.

Ergonomics and Reading Room Design

A digital radiology environment may provide increased efficiency for the radiologist, but it also carries risks such as eye strain and repetitive motion injuries. Often, when radiology departments convert from film to PACS, the radiologists continue to use the same workspace, rather than changing the physical environment to suit the revised workflow. Failure to redesign the workspace can result in discomfort and decreased satisfaction among radiologists (5).

Ergonomics is a field of study that focuses on the redesign of work environments to better suit human body mechanics. The goals of ergonomics in imaging informatics include improving radiologist comfort, preventing repetitive stress injuries, reducing eyestrain, and improving efficiency. This is accomplished by creating workstations that adapt to individual users and are designed for specific tasks (6,7). Lighting considerations are of particular importance in a radiology reading room—glare on computer screens and excess ambient light can diminish diagnostic accuracy.

The layout of the radiology reading room should be tailored to the digital environment. It is counterproductive to use the same room that was optimized

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**Figure 1**

Radiology department workflow. In this diagrammatic representation of workflow, personnel are represented by boxes, and each task performed by an individual is listed inside his or her box. (Reprinted, with permission, from reference 1.)
for films and alternators after moving to computer workstations. The positions of personnel and equipment need to be carefully considered to minimize interference and maximize productivity. Specialized chairs, specialized desks, arm or hand supports, and policies regarding continuous use of computer displays are all helpful to improve radiologist ergonomics.

**Teleradiology**

Because PACS allows worldwide distribution of images, there is no absolute need for the radiologist who is interpreting the images to be in the same building (or even the same country) as the imaging modality equipment. Teleradiology is the interpretation of images at sites outside the hospital at which they were obtained.

Teleradiology is most commonly applied to overnight interpretation of urgent studies within a hospital system. One example is a single radiologist covering many hospitals within an enterprise to reduce the total number of radiologists on call. Another example is radiologists reading films from their homes, usually when a trainee needs assistance or when a particularly complex case arises. Smaller practices, with few overnight studies, may use exclusively at-home teleradiology after hours. Teleradiology may also be used for subspecialist consultation, as when general radiologists at a community hospital request assistance from a subspecialist at an academic center.

Less common, but receiving greater attention, is the practice of international teleradiology (8). In this scenario, radiologists in other countries read images, usually in American patients. There are several advantages to this model: Because of differing time zones, international radiologists can be on daylight shifts when overnight examinations are performed in the home country. Not only does this make overnight call responsibilities less burdensome for the home radiologist, it diminishes sleep deprivation as a cause of interpretive errors. Although technical barriers to teleradiology were numerous in the past, they have now been almost completely surpassed (9).

Nevertheless, many ethical and practical issues remain (8).

It is worth reinforcing that teleradiology in any form requires high levels of network security. Because patient data are being transmitted outside the physical boundaries of the hospital enterprise, robust security formats such as virtual private network, or VPN, are necessary.

**Recent Technologies**

Most of the technology discussed so far in this article is found in the majority of academic medical centers. There are other technologic advances that are only now becoming part of mainstream radiology practice. Radiology residents should be familiar with these technologies, not only so that they are prepared when the technology is introduced, but also so that they can be aware of potential improvements to the workflow of their departments.

**Interacting Information Systems**

Radiologists are exposed to a myriad of acronyms for the information systems that store medical data. Besides the PACS, there is the radiology information system, or RIS, which is designed for scheduling patients, storing reports, and patient tracking; the hospital information system, or HIS, which keeps track of patient demographic data and locations; and the electronic medical record (EMR), which is designed to organize all medical data from an entire enterprise.

These different data systems, and a variety of other systems tailored to individual departmental and administrative needs, often exchange information. Communication standards have been developed to facilitate this exchange. Frequently used communication standards include Digital Imaging and Communications in Medicine, or DICOM, and Health Level 7, or HL7.

Integrating the Healthcare Enterprise, or IHE, is an initiative that strives to establish criteria by which different medical information systems can work together efficiently (10). IHE breaks down the actions of any software sys-
tem so that each system can claim the tasks at which it excels. This reduces redundancy and ensures that responsibility for critical tasks is well-defined.

Computed Radiography versus Digital Radiography

Computed radiography (CR) and digital radiography (DR) are competing technologies that replace conventional radiographs (11). CR is similar to traditional imaging with film except that a storage-phosphor imaging plate replaces the traditional combination of fluorescent phosphor screen and film. The cassette around the phosphor plate is essentially the same as for film, and the cassette generally incorporates a scatter grid. Thus, the CR cassette can be used with the same x-ray source equipment and tables that were used in the film era. This substantially decreases the cost of upgrading from film to CR.

CR phosphor storage plates are processed differently than film. Because the phosphor storage plate is not light sensitive, darkrooms are no longer necessary. The cassette around the phosphor plate is essentially the same as for film, and the cassette generally incorporates a scatter grid. Thus, the CR cassette can be used with the same x-ray source equipment and tables that were used in the film era. This substantially decreases the cost of upgrading from film to CR.

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The DR panels are fixed to a wall or table and do not use cassettes. Thus, DR is somewhat less flexible than CR for unusual projections and portable radiography. DR image quality is somewhat higher than CR image quality, but the clinical impact of this difference remains unclear.

The major advantage of DR over CR is that DR does not require processing of cassettes or plates. DR images are immediately available on the computer once the patient has been irradiated. This allows for greater patient throughput, since technologist time is spent processing and storing images. The major disadvantage of DR, compared with CR, is increased cost. To take advantage of the increased throughput of DR and thus offset its higher cost, radiology departments must redesign their workflow to remove other system bottlenecks (11).

One of the major advantages of both CR and DR systems is the wide dynamic range of the medium compared with film. Increased dynamic range allows the technologist or radiologist to adjust the visible image (akin to the use of windows and levels at computed tomography), correcting for overexposure or underexposure after the image has been stored.

To summarize, CR provides an inexpensive, low-impact transition from screen-film technology to digital technology. DR is a more efficient system in the long run, but it is more expensive initially and requires an overhaul of the workflow in the radiology department.

Enhanced Radiology Reports

Traditional radiology reports consist of unstructured free-form text. There are a variety of ways that these bland reports can be enhanced to better convey information, educate, and ensure that critical information is not overlooked.

**Structured reporting.**—Only minimal structure (eg, history, findings, impression) is imposed on most radiology reports. One of the major drawbacks of this free-form approach is the inability to reliably search radiology reports for specific diagnoses or findings. Another concern with free-form text is that clinicians who skim the report may not understand the critical aspects of the interpretation or may overlook important findings or recommendations. Clinicians consistently report a preference for a more structured radiology report to avoid these errors.

Structured reporting, or SR, results in a different output format for radiology reports (Fig 3). The content of the report is codified to provide consistency between different radiologists. This allows the data contained in the report to be retrospectively analyzed in a more reliable fashion.

The major drawback of SR is that it requires radiologists to learn another method of authoring reports. This results in a different output format for radiology reports (Fig 3). The content of the report is codified to provide consistency between different radiologists. This allows the data contained in the report to be retrospectively analyzed in a more reliable fashion.
in decreased radiologist efficiency, at least during the transition to SR, with potential permanent efficiency losses. Software that automatically converts free text to structured reports may overcome this barrier and permit greater radiologist acceptance of SR (13).

**Radiology lexicon.**—Another important aspect of consistent radiology reporting is the development of a complete radiology lexicon (14). Mammography remains the only radiology subspecialty with a universally accepted set of terms to describe radiographic findings. Extending this lexicon to the rest of radiology would provide consistency for both referring clinicians and radiology researchers. Unfortunately, given the vast vocabulary found in modern radiology reports and the difficulty of achieving terminology consensus among radiologists, a complete and universally accepted radiology lexicon remains a daunting task. The Radiological Society of North America has begun to address this issue with its RadLex initiative (15).

**Multimedia reports.**—The incorporation of select radiologic images into reports can improve the radiologist’s ability to communicate complicated findings. To be useful, the images must be associated with specific words or phrases in the text. Ideally, the incorporated images can be presented to referring clinicians in an electronic context (such as the EMR) and can serve as a launch point for review of the entire study in the PACS.

Other multimedia content, such as ultrasonographic or fluoroscopic movies, links to teaching files or reference cases, and educational links, can similarly aid in enhancing the quality of the radiology report. Such enhancements will become of increasing importance as images are widely distributed and radiologists are pressured to demonstrate their added value to patient care.

**Physician Order Entry**

Computerized physician order entry (CPOE) is the electronic equivalent of a prescription for a radiologic test (16). By allowing (or forcing) referring physicians to use a computerized ordering system, the radiology department can ensure that sufficient patient history is provided and that appropriateness criteria are met. Alternative diagnostic tests can be suggested at the time of ordering (decision support). The challenge for successful CPOE lies in making the system convenient enough for the ordering physician, so that CPOE is not seen as burdensome. One of the major benefits of CPOE is the ability to track ordering patterns, which can be of interest to hospital administrators and third-party payers, as well as radiologists.

**Data Exchange between Hospitals**

Patients are frequently treated at more than one medical enterprise, either within the same geographic region or in different parts of the world. Ideally, all pertinent patient data, and in particular medical images, would accompany the patient when switching facilities. The Regional Health Information Organization, or RHIO, initiative from the United States Department of Health and Human Services attempts to enhance the secure exchange of patient information within geographic areas (17).

Initiatives are also underway within the radiology community to ensure that imaging data can be easily exchanged. Standards are being created for the formatting of the portable media (such as compact disks) that have replaced conventional film for the storage and transfer of patient images. This will facilitate the evaluation and incorporation of images acquired at outside institutions.

**Imaging Informatics Outside of Radiology**

Because radiology is an inherently data-intensive part of medicine, radiologists have become leaders in medical informatics. But radiologists are hardly the only consumers of imaging within the medical enterprise. For example, dermatologists take pictures of skin lesions, otolaryngologists and gastroenterologists obtain endoscopic images, and pathologists review microscopic images. Many of the advances that have been pioneered in radiology informatics have applications in other parts of medicine. Radiologists should attempt to leverage our experience and assist other physicians in applying informatics to their fields.

**Conclusion**

Imaging informatics is a distinct subspecialty of radiology that endeavors to improve the efficiency, accuracy, and reliability of radiology services within the medical enterprise. Because this is a relatively young field of study, research opportunities abound, and the state of the art is constantly in flux. Imaging informatics may appeal particularly to the computer-savvy members of the radiology community, but there are far-reaching implications for every radiologist, involving every aspect of radiology practice.

Residents and other trainees who are interested in imaging informatics should visit the Society for Imaging Informatics in Medicine, or SIIM, website (http://www.siimweb.org), where there is a resident community that discusses training, fellowship, and research issues.

**Glossary**

Listed below are some commonly encountered imaging informatics acronyms and terms.

**CPOE (computerized physician order entry; also, computerized provider order entry)**

A system by which referring clinicians can order radiologic tests on a computer, rather than by writing prescriptions.

**CR (computed radiography)**

Radiographic technology that replaces traditional film-screen cassettes with digital media. Compare with DR.

**DICOM (Digital Imaging and Communications in Medicine)**

A communication standard for medical imaging devices developed by the American National Standards Institute (ANSI).

**DR (digital radiography)**

A radiographic technology that replaces film cassettes with mounted digital receivers. Compare with CR. (DR was historically used as a generic term that included CR.)
EMR (electronic medical record)
A data collection and distribution system that replaces all paper records in an entire hospital enterprise. Compare with HIS, RIS.

HIS (hospital information system)
A data collection and distribution system that records basic demographic and laboratory information about patients but is not designed to completely replace paper within the enterprise. Compare with EMR, RIS.

HL7 (Health Level 7)
A communication standard for passing data between HIS, RIS, EMR, and similar systems.

IHE (Integrating the Healthcare Enterprise)
An initiative sponsored in part by the Radiological Society of North America that endeavors to improve the ways in which medical computer systems share information.

PACS (picture archiving and communication system)
A computer network dedicated to the storage, retrieval, and display of medical images.

QA (quality assessment; also, quality assurance), QC (quality control), and QI (quality improvement)
Formal methodologies for ensuring delivery of appropriate, efficient patient care.

RHIO (regional health information organization)
A group of health care organizations that electronically exchange health information in a secure format. This allows patients to travel between facilities without misplacing pertinent medical data.

RIS (radiology information system)
A data collection and distribution system that tracks patient data specifically relevant to radiology. Ideally integrated with PACS into a single RIS-PACS system.

SCAR (Society for Computer Applications in Radiology)
In April of 2006, SCAR changed its name to SIIM.

SIIM (Society for Imaging Informatics in Medicine)
The subspecialty society devoted to imaging informatics.

SR (structured reporting)
Predefined formatting of radiology reports that facilitates clinician comprehension and clinical radiology research methodologies. (The acronym SR may also be used for speech recognition; see part 1 of this review.)

VPN (virtual private network)
Security software that allows users outside the hospital environment (e.g., radiologists viewing images from home) to safely view private patient information.

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