Information Systems Integration in Radiology

Janice C. Honeyman

Advances in information systems and technology in conjunction with outside forces requiring improved reporting are driving sweeping changes in the practice of radiology. In most academic radiology departments, there can be at least five separate information systems in daily use, a clinical picture archiving and communication system (PACS), a hospital information system (HIS), a radiology information system (RIS), a voice-recognition dictation system, and an electronic teaching/research file system. A PACS will have incomplete, incorrect, and inconsistent data if manual data entry is used. Correct routing of studies for diagnostic reporting and clinical review requires accurate information about the study type and the referring physician or service, often not easily entered manually. An HIS is a hospital-wide information system used to access patient information, reports from various services, and billing information. The RIS is typically a system specifically designed to place radiology orders, to receive interpretations, and to prepare bills for patients. Voice-recognition systems automatically transcribe the radiologist's dictation, eliminating transcription delays. Another system that is needed in a teaching hospital holds images and data for research and education. Integration of diverse systems must be performed to provide the functionality required by an electronic radiology department and the services it supports. Health Level 7 (HL7) and Digital Imaging and Communications in Medicine (DICOM) have enabled sharing of data among systems and can be used as the building blocks for truly integrated systems, but the user community and manufacturers need to specify the types of functionality needed to build clinically useful systems. Although technology development has produced the tools for interoperability for clinical and research/educational use, more work needs to be done to define the types of interaction that needs to be performed to realize the potential of these systems.

ADVANCES IN INFORMATION systems and technology in conjunction with outside forces requiring improved reporting are driving sweeping changes in the practice of radiology. Access to the right information in a timely manner is crucial to patient care and it is easy to project that in the future it will be considered the standard of care. Since radiology studies are part of the patient history, images must be available whenever and wherever they are needed. In this new environment, requirements for integration of information from diverse systems need to be defined and implemented.[1-5]

In most academic radiology departments, there can be at least five separate information systems in daily use, a clinical picture archiving and communication system (PACS), a hospital information system (HIS), a radiology information system (RIS), a voice-recognition dictation system, and an electronic teaching/research file system. Many times, these systems are distinct, separate systems with little or no communication among them. The lack of integration leads to duplicate data entry tasks, inconsistencies, and inadequate functionality.

A PACS will have incomplete, incorrect, and inconsistent data if manual data entry is used. Correct routing of studies for diagnostic reporting and clinical review requires accurate information about the study type and the referring physician or service, often not easily entered manually. Most modalities do not have the required fields available on the consoles to enter the data required for routing studies to appropriate archives, diagnostic workstations, and clinical locations. In addition, data entry by technologists hard pressed to complete a clinical schedule may have numbers transposed in the medical record number and inconsistent spelling of names which results in database entries that make it difficult to find a specific patient. Comparison studies are frequently required during the diagnostic process. Three problems can occur; first, inaccurate entries will result in difficulty finding thehistorical studies; second, on-demand retrieval can result in delays and time wasted by radiologists; and third, it will be difficult to match a report with its associated imaging study. It would be better if comparison studies and their reports were made accessible to the workstation prior to the reading session. One of the potential benefits of PACS is the elimination of lost studies, but with manual data entry, electronic filing is no better at making files accessible than the old film library.

An HIS is a hospital-wide information system used to access patient information, reports from

From the Department of Radiology, University of Florida, Gainesville, FL.

Address reprint requests to Janice C. Honeyman, PhD, Department of Radiology, University of Florida, PO Box 100374, Gainesville, FL 32610.

0897-1889/99/1202-1070$10.00/0

various services, and billing information. In some cases, an electronic patient record gives clinicians an overview of a patient's care. These systems rarely have access to radiology images, nor do they have a user interface capable of displaying the images and navigating through a large, complex, multiimage study.

The RIS is typically a system specifically designed to place radiology orders, to receive interpretations, and to prepare bills for patients. This system can provide historical reports for radiologists and usually transmits the final reports to the HIS, but in most cases, does not interface easily with the PACS.

Voice-recognition systems automatically transcribe the radiologist's dictation, eliminating transcription delays. The only way these systems can work effectively is to communicate with the RIS to receive patient demographics, to order information, and to send the final report. During diagnostic interpretation, these systems should be able to display previous reports as requested and in fact to inform the radiologist that previous reports exist. If a previous report exists, it is desirable to have the corresponding study available to be reviewed at the time of the interpretation. This requires an integration of the RIS, the PACS and the voice-recognition system.

Clinicians caring for the patient need to review the report and may need to see the relevant images from the study. This requires an interface between the HIS and an image archive. In addition, the radiologists must be able to mark the relevant images to be included with the report. It may be desirable to print the images with the report to be sent to physicians who may not have access to the information systems in the hospital.

Another system that is needed in a teaching hospital holds images and data for research and education. The data may include study specific findings, measurements, trends, medical history, and treatment methods in addition to the information stored in the HIS and RIS. Coding methods may be incorporated into this system to facilitate research protocols. This system will need to integrate some or all of the data stored in the PACS, RIS, and HIS.

BACKGROUND INFORMATION

Integration of diverse systems must be performed to provide the functionality required by an electronic radiology department and the services it supports. A variety of standards groups have emerged to define methods to provide the interoperability demanded by customers and an emerging industry has developed tools to facilitate the integration. Two of the most common standards used today in the United States are Health Level 7 (HL7) and Digital Imaging and Communications in Medicine (DICOM).[6]

A user/vendor committee on HL7 was formed in 1987 with the goal of simplifying the implementation of interfaces between computer applications from different, and often competing, vendors. This committee, known as the HL7 Working Group, is developing standards for the electronic interchange of clinical, financial, and administrative information among computer systems, such as HIS, pharmacy systems, lab systems, and the RIS. It is not uncommon for a hospital to have installed computer systems to handle admission, discharge, and transfer; clinical laboratories; radiology; pharmacy; etc. Each of these systems may have been developed by a different vendor and have different data formats different communication protocols, if any, and were never intended to transfer information to other systems. Now customers need interoperability among these systems in the course of performing routine procedures. A typical interaction between the HIS and the RIS might include and order for a study with patient demographics, insurance coverage, study requested, scheduling information, allergies, reasons for the study, and a preliminary diagnosis. The RIS may in turn send the diagnostic report back to the HIS. The HL7 standard is an evolving standard undergoing rapid change, although there is a lag time between accepted changes in the standard and adoption of the changes by large information systems companies, due to the time required to develop and test new implementations. For more information on HL7, visit the Duke University web site at: dumccss.mc.duke.edu/standards/HL7/sigs/image-management/im-home.html.

The DICOM standard includes the architecture for exchange of information between imaging modalities, as well as a communication definition. DICOM is an object-oriented standard defining information objects, services, and classes of devices to perform these services. For example, a storage class provider should be able to receive and store a DICOM object. Each device has a set of

defined objects it is prepared to handle, as well as the services it will provide, and negotiation between two devices must be performed before a successful DICOM image transfer. Prior to the adoption of DICOM by most imaging and PACS vendors, each vendor had a proprietary image format and communication protocol, which made it difficult if not impossible to interface equipment in a multivendor environment. DICOM facilitates the development of departmental-wide archives and output (display and printing) devices. The committee responsible for defining this standard includes members from the American College of Radiology (ACR) and the National Equipment Manufacturers Association (NEMA). For more information on DICOM, visit the Pennsylvania State web site at: www.nema.org/nema/medical/dicom/.

HL7 and DICOM have different goals and therefore do not necessarily contain the same date elements nor do they provide the same services. For example, it is unnecessary for HL7 to define radiology study specific details such as the slice thickness of a computed tomography (CT) image or the pixel size of a computed radiology (CR) image. DICOM does not implement an order entry function. An electronic radiology department requires the functionality of both systems and a level of interaction between them.

REQUIREMENTS FOR INTEROPERABILITY

HL7 and DICOM have enabled sharing of data among systems and can be used as the building blocks for truly integrated systems, but the user community and manufacturers need to specify the types of functionality needed to build clinically useful systems. If we examine the workflow associated with a radiology study, we can see where improvements in the systems can be made.

When a patient is scheduled for a radiology study, the technologists and support staff need to know the location of the patient, the requesting service, allergy and medication history, insurance carrier, reason for the study, and preliminary diagnosis. Some of this information is needed to qualify the patient for the study given his or her insurance coverage, some will help determine if the appropriate study was ordered, and some is used to avoid administering a contrast agent that may cause an allergic reaction or may be contraindicated. In addition, the location of the patient and the requesting service may help route images and results to physicians and clinics where they can be used for patient care.

During the radiology procedure, information about the patient and study must be attached to the images. The technologist using the modality operator's console usually performs this. If DICOM modality worklist is implemented for the specific unit, the technologist will either choose the patient and study from a list or use a bar code reader to enter a unique identifier from a radiology request form to query the RIS for the information on the patient and study. This identifier is frequently called an accession number. One of the functions of an RIS is patient tracking where the location of a patient is noted during various stages of the radiology study, such as in transit, in the waiting room, having the study performed, and study completion. This information is used by management to determine equipment usage, technologist performance and to be able to model the day to day operation of the department. Tracking requires data entry, usually by bar code, at each stage of the procedure cycle. If the DICOM modality worklist returned information to the RIS about the status of the study, such as start and completion, the technologist would not be required to duplicate the task of bar-coding the accession number. Marking the completion of the study on the modality would serve to both indicate the end of image acquisition for PACS and closing the study for the RIS. Modality worklists help assure accurate and complete information about the study and provide a direct link between the images associated with a study and the information in the RIS and HIS.

After a study is complete, given the correct information provided by modality worklists, the study can be routed to one or more workstations or to a central PACS server, depending on the PACS architecture. Radiologists are faced with two problems, identifying that there is work to be done that has not been dictated, and avoiding duplicate dictations. Radiologist worklist management is a concept that is being developed by a number of manufacturers and allows a radiologist to select a study for reporting and block other radiologists from opening the study for reading. If the radiologist is using a voice-recognition system, at the same time a study is opened for interpretation, the voice-recognition system needs to get the study information from the RIS. Since voice recognition is currently a separate product from a PACS

workstation, it has not been well defined which system should lead the task. One way to implement this is to have the radiologist worklist part of the voice recognition, which would pull patient information from the RIS, which in turn would signal the PACS that a study should be displayed. Since the RIS will probably not be able to determine where the study should be displayed, this may not be the best option. If the radiology worklist was part of PACS, the PACS workstation could signal the RIS that a packet needed to be sent to the voice-recognition system. This could be sent to a central server, but again, it would be difficult to tell which voice-recognition workstation should receive the information. An ideal solution might be to have the voice recognition and PACS workstation integrated so the study could be selected from the worklist, which would open the images and prepare for dictation on the same workstation.

During the interpretation process, previous studies and/or reports are frequently needed and should be immediately available on demand. This means some preparation should be done beforehand, and should be automatic. At the time a study is ordered or scheduled, if the RIS sends the information about the intended study, the PACS can automatically retrieve or prefetch relevant previous studies based on a set of rules. If a study is changed immediately prior to performance, or is added as an emergency, the new information can be sent to the PACS for additional retrievals.[7] At any time during the interpretation, the radiologist should be able to request and view previous reports for the patient from the PACS workstation.

Radiology studies should be available to the treating physicians along with the dictated report. The implications of this are that the treating physicians should have a way to view the images on a computer with the report and should be able to navigate through the images easily. Ideally, the radiologist should be able to annotate the images with graphics, text, or voice to help the clinician understand the findings. Since many radiology studies have tens to hundreds of images, some with very high spatial resolution, the radiologist should select relevant images, annotate if desired, and save this smaller set of images for subsequent review by other physicians. The display requirements for the image review computers may be somewhat less that those of the diagnostic PACS workstation, but should be able to display the set of relevant images and in some cases, in a reduced spatial resolution.

Routing to treating physicians is a complicated problem. Since it is difficult to predict which physicians will need the images in the future, routing toevery potential treating physician is impractical and would probably result in network bandwidth requirements that are impossible to attain. However, in the case of a patient being seen in a clinic or an inpatient, it might be practical and desirable to send the relevant images and report to that clinic or hospital location for quick and easy access. The patient location and requesting service information included in the initial order information sent to the PACS can be used for this routing. Additionally, when a patient is scheduled for a clinic appointment or admitted to the hospital, a message from the HIS to the RIS could prefetch previous images and reports to the appropriate system, or they should be part of an electronic patient record (EPR). The EPR is an evolving part of an HIS, which includes the patient medical history with reports from all services such as laboratory results, admission and discharge notes, and radiology results. Images should be part of the EPR, including those from radiology. Although some vendors have starting including the radiology images, many have not.

In addition to the clinical systems discussed above, many teaching institutions accumulate teaching files for research and education. In the film world, these are large jackets of images sometimes collected by a specific faculty member according to his or her interests. It is difficult to catalog these studies in a way to make them accessible to a wide audience. With the introduction of electronic data, an archive or collection of teaching files can be built with different functionality than that of the clinical archive. When the data are part of a research protocol, the images, reports, and associated data can be coded for access using different criteria than patient name or medical record number. In fact, the patient information can be hidden to protect patient confidentiality and to reduce bias introduced by recognition of the patient by the researcher. Since these files including images and text or graphic data may be used by students and systems that do not have the capability of handling DICOM, they can be converted to different formats such as Joint Photographic Experts Group (JPEG)

or tag image file format (TIFF) on demand and retrieved using file transfer protocol (FTP). Data for these studies may include selected information from the HIS such as a medical history, medication history, patient age, sex, and race. In addition, data from the RIS might include a diagnostic report. Information from the PACS would include study parameters such as slice thickness, protocol used, and resolution for measurement or reprocessing purposes.

SUMMARY

Although technology development has produced the tools for interoperability for clinical and research/educational use, more work needs to be done to define the types of interaction that needs to be performed to realize the potential of these systems. A planning committee on Integrating the Healthcare Enterprise (IHE) has been formed as an initiative of the Healthcare Information and Management Systems Society (HIMSS) and the Radiological Society of North America (RSNA). The IHE mission statement reads, in part: "With the continued growth of medical knowledge, data from many sources are needed to make optimal patient-care decisions. Gaining the full benefit of this growing stock of information will require complete integration of medical information systems. These systems must be able to communicate patient data dependably to healthcare providers upon demand to support medical decisions." This initiative will not define new standards, but will support the use of existing standards to provide interoperability among systems. For more information on the IHE, visit the web site at: www.rsna.org/IHE/ihemiss.html.

REFERENCES

1. Boehme J, Choplin RH: Systems integration: Requirements for a fully functioning electronic radiology department. Radiographics 12:789-794, 1992

2. Halloran M, Harrington J, Selinger R, et al: Accelerating the movement toward standards-based interoperability in health care. A white paper by the Clinical Information Systems Subcommittee of the IEEE-USA Medial Technology Policy Committee. www.ieee.orb.usab.DOCUMENTS/FORUM/LIBRARY/PAPERS/interop.html, 1996, pp 1-10

3. Martens FJ, van den Broeck R, Dicke P, et al: HIPIN—A generic HIS/RIS-PACS interface based on clinical radiodiagnostic procedures. Eur J Radiol 17:38-42, 1993

4. Tiara RK, Breant CM, Chan HM, et al: Architectural design and tools to support the transparent access to hospital information systems, radiology information systems, and picture archiving and communication systems. J Digit Imaging 9:1-10, 1996

5. Kuzmak PM, Dayhoff RE: The Department of Veterans Affairs integration of imaging into the healthcare enterprise using the VistA hospital information system and digital imaging and communications in medicine. J Digit Imaging 11:53-64, 1998

6. Oosterwijk H: DICOM versus HL7 for modality interfacing. J Digit Imaging 11:39-41, 1998

7. Siegel EL, Reiner BI: Recommendations for image prefetch or film digitization strategy based on an analysis of an historic radiology image database. J Digit Imaging 11:94-99, 1998