A Literature Review on Communication Between Picture Archiving and Communication Systems and Radiology Information Systems and/or Hospital Information Systems

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The purpose of this literature review is to present the concepts surrounding the issue of communication between imaging systems and information systems in radiology and the literature about them. Picture archiving and communication systems (PACS) were developed to combine viewing of modality images, archiving, and distribution of images. When PACS is integrated/interfaced with radiology information systems (RIS) or hospital information systems (HIS), it can merge patient demographics, medical records, and images. To address several issues surrounding communication between PACS and HIS/RIS and to make interface development easier and faster, various organizations have developed standards for the formatting and transfer of clinical data. Additional work continues to better handle these issues. Communication protocol Health Level 7 (HL7) is a standard application protocol used for electronic text data exchange in health care by most HIS/RIS. The imaging communication protocol for PACS is the Digital Imaging and Communications in Medicine (DICOM) standard specification protocol that describes the means of formatting and exchanging images and associated information.

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THE PICTURE ARCHIVING and communication system (PACS) is an imaging management system designed for radiology. Before PACS, images could be viewed only on workstations of the modality on which they were generated. PACS permits acquisition, display, and archiving of images regardless of equipment manufacturer. The communication between different modality devices is defined by a communication protocol developed by the American College of Radiology and National Electrical Manufacturers Association (ACR-NEMA). The initial goal in developing a standard for the transmission of digital images was to enable users to retrieve images and associated information from digital imaging equipment in a standard

format that would be the same across multiple manufacturers.¹ The initial ACR-NEMA standard was replaced by the Digital Imaging and Communications in Medicine (DICOM) standard. Vendors use this standard so their equipment can communicate with PACS.

A major challenge today is to integrate the images of each individual study with other pertinent patient information.² A PACS consists of different components, including technologies for:

- Image acquisition from digital imaging devices including computed tomography (CT), magnetic resonance imaging (MRI), ultrasonography, computed radiography, digital fluoroscopy, angiography, and nuclear medicine
- Archival storage and retrieval from a database management system, including short-term and long-term electronic storage for image information and work-flow management systems
- Display of images on diagnostic and clinical monitors
- Communication through local and wide-area networks (a network physically connects computers)
- Interfacing between PACS and the radiology information system (RIS) to allow the exchange of information and messages³

PACS usually manages only the images and related study text within the system. When a PACS is connected to an RIS or an HIS, it can present patient demographics and medical record information with the images and radiology report. This relationship is called *interoperability*, ie, "the ability to exchange medical information, which has clinical utility on both sides of the connection."⁴

Communication between systems is not always implemented easily. The areas that will be addressed are interfacing, communication protocols, and open architecture integration (Fig 1).

INTERFACING

The Department of Radiology at Georgetown University in Washington, DC, has been researching interfaces between computer systems in radiology since the late 1980s. Levine has published on

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Fig 1. The author's model of connectivity between Information Systems and PACS is a visual interpretation of the relationship between PACS, HIS/RIS, interface, communication protocols, and groups working on communication standards. This model includes the possibility of HL7 and DICOM standard integration.

the subject of interfaces.⁵ She describes three interface design methodologies: unidirectional, bidirectional, and an integrated workstation. A unidirectional interface allows information to flow in only one direction. The disadvantage of this interface is that only one system is updated. The second system must have all information updated manually. This can cause a conflict in database consistency. A bidirectional interface allows information to pass between systems in both directions. This maintains a more consistent information base because both systems can be updated automatically. An integrated workstation is basically a terminal that can access two or more systems separately. The disadvantage is that changes made at a workstation for one system will not be changed automatically in other systems. Each system is updated separately. Levine believes that a bidirectional interface is the best choice for connecting PACS and information systems.

Veader agrees that the interface should be bidirectional.⁶ He explains how the interface allows an image acquisition device on a PACS to receive patient demographics from the RIS and then to send information (eg, location of study, scan done, number of images) back to the RIS for validation.

He believes that a bidirectional interface will eliminate common spelling errors, help scheduling, and facilitate image retrievals.

Most literature supports the virtue of connecting a PACS to an HIS/RIS. This is important because if no RIS or HIS interface can be done, the facility must reevaluate the benefits of implementing PACS. When connectivity between PACS and HIS/RIS is created, entirely new methods of efficiency and effectiveness become possible to help to make it cost-effective. For example, selected images or studies can be made available to an RIS/HIS workstation.⁷ This gives physicians quick access to a patient's medical images without having to travel to the radiology department.

An interface can enable important features such as automatic routing of studies to appropriate workstations, automatic prefetching and routing of previous studies, and the on-screen display of reports.⁸ Erickson claims that it would be hard to underestimate the importance of integrating image information with textual information such as that stored in a typical RIS.⁹

The clinical staff Radiologists at Utah Valley Regional Medical Center in Provo, Utah, list several advantages to acquiring patient management information using PACS.¹⁰ They believe that an integrated radiology network can improve physician efficiency and reduce costs. Secondly, electronic access to images can reduce the number of repeat or unnecessary exams and improve the quality of patient care. Faster access to patient management information can potentially reduce the length of hospital stays, avoid duplication of examinations, and reduce the likelihood of inappropriate care based on inadequate information.

COMMUNICATION PROTOCOL STANDARDS

PACS and HIS/RIS use different communication protocol standards. ARC-NEMA has developed the DICOM communication protocol standard for PACS. Information Systems often are configured with HL7 communication protocol. An interface must interpret and route data between these two communication protocols so that PACS and RIS/HIS can communicate and share information.

Many manufacturers and vendors of imaging equipment claim to be DICOM compliant. They will provide a conformance statement that allows direct comparison between devices using the DICOM communication protocol, but this type of

statement does not guarantee compatibility because manufacturers can interpret the DICOM standard differently. Levine et al from Georgetown University recognize that even when standards are used, one cannot assume plug and play connectivity.¹¹ Their approach is to first determine how, if at all, the interface will work. They begin by examining how each system works independently and then how the two systems will work together. It is important to look at elements such as data flow, triggering events, data elements, and message formatting, and to determine how they will have the same meaning in both systems when interfaced. Their conclusion is that standards alone will not solve the problem of connectivity unless they are widely implemented and interpreted similarly. As far as differences in interpretation of the standard, they believe the standard should be refined by adding specific language to reduce vagueness.

Connors acknowledges that the industry has had limited success using DICOM to integrate imaging systems with the information systems (IS). Without this link, the PAC system is incomplete. Connors addresses the concern that DICOM may not be working toward the support of connectivity with HIS/RIS.¹²

In the initial release of DICOM, there were several service classes that support information systems. They are:

1. *Patient Management*: This service class handles the patient status from admission to discharge.
2. *Study Management*: This service class creates schedules and tracks studies. It follows the patient and complements the patient management class.
3. *Results Management*: This service class gives access to radiology reports of the patient's study.

The Basic Modality Worklist Management service class, in the latest supplement to DICOM 3.0, defines a worklist object influenced by the ISIS (Information System—Imaging System) model and incorporates the recommendations and experiences of a number of medical informatics committees, including HL7.¹² The result is a worklist that can be filtered by different criteria such as modality type, anatomy, time of day, and name of patient or physician. It keeps important patient medical information with the study. The technologist or radiolo-

gist can use this information to better serve the patient.

Connors explains that modality manufacturers may release this new supplement, but the information system manufacturers must support the DICOM service class. He notes that several information system-to-DICOM modality worklist interfaces already are in use. Connors believes this mechanism will bridge the gap between now and the point in the future at which modality and IS manufacturers communicate via a direct interface.

Otte states that DICOM standard implies universal interchangeability, availability, and applicability of digital image data between vendors and radiologists using different computer equipment.¹³ He quotes Dr Joseph Gitlin, who chaired the DICOM session at the meeting of the Radiological Society of North America (RSNA) in 1994. Dr Gitlin believes that the manufacturers are making connectivity easier through compliance with the DICOM standard.

Sabatini explores the issue of connectivity between DICOM and HL7.¹⁴ She believes the interface between PACS and HIS/RIS could be more efficient if the method of communication between them was more standard. Sabatini reports that HL7 is being used within the imaging world of radiology to improve the efficiency of the department. Some hospitals are using the HL7 standard to interface PACS with RIS. She quotes Dr Jost, a Professor of Radiology at the Mallinckrodt Institute of Radiology, as saying "This process of linking the images with the rest of the hospital information environment is not being done very effectively." The HL7 standard is being implemented through alliances between a PACS vendor and an information systems vendor. They work out their own communication protocol to exchange information. This special type of alliance is a proprietary approach.

Kales sees the challenge facing medical imaging as the seamless integration of imaging systems and HIS/RIS.¹⁵ One issue he discusses is the HL7 and DICOM standard. Kales states "While it is possible to display an image with the medical record, the background management of the image that makes it possible to intelligently move it across the hospital enterprise is lacking."

Kales uses excerpts from interviews with professionals in the imaging systems field. From the user side, he quotes Karen Waninger, a clinical engineering supervisor at the St Elizabeth Medical Center,

as saying "DICOM interfacing is much more complex than simply asking if a system is DICOM 3.0 [current revision] conformant, compliant, or compatible."¹⁵ Kales's advice is to find a consultant fluent in DICOM or a company that specializes in it, such as DeJarnette Research Systems (Towson, MD) or Merge Technologies Inc (Milwaukee, WI). Kales mentions that Stuart Gardner believes the integration of PACS and HIS/RIS will be essential in developing the electronic radiology practice. He claims that IS people do not understand the clinical needs of the radiology department or how to plan to utilize diagnostic images.

Kales also comments on the rapid growth of vendors trying to get a piece of the integration pie. This mass entry has served to complicate the connectivity process. The proliferation of vendors confuses the end-user because each advertises its ability to provide total solutions for everybody's integration problems. Kales believes that the HIS and film vendors do not comprehend the clinical environment of radiology.¹⁵ On the other hand, imaging vendors do understand how images need to be viewed and stored. Many HIS and RIS vendors already are creating alliances with PACS manufacturers to position themselves more favorably in the market.

HL7 and ACR-NEMA DICOM committees are continuing to work toward new versions or supplements to their respective standards. There are other organizations that are trying to increase connectivity through these standards. There is significant interest in this area because the product that can interface any vendor's application will be highly marketable.

One group is the HL7 Image Management Special Interest Group (IMSIG). The purpose of this group is to focus on the convergence of the standards HL7 and DICOM. The immediate goal of IMSIG is to provide a standard for the interoperability of HL7 v.2.2 and DICOM 3.0.¹⁶ To achieve this goal, five steps are required:

1. Define a common model for exchange of orders, results, and status information between the HL7 and DICOM systems over an ISIS interface.
2. Understand mapping of HL7 trigger events, segments, and messages to DICOM event types, SOP classes, and messages.
3. Use a common model (#1) and the mapping (#2) to specify HL7 and DICOM messages

that convey the identical content for a set of ISIS transactions.

4. Understand the other technical factors involved in linking ISIS. Explore mechanisms for exchanging images between HL7 systems and DICOM systems.
5. Develop HL7/DICOM application profiles that specify all parameters and conditions necessary to achieve specified levels of interoperability in well-defined ISIS contexts.

The convergence of the two standards will concentrate on creating a subset of all transactions involved in the Imaging System and Information System interface. This can create compatibility because the standards will be defined explicitly. IMSIG is one of the few committees attempting to get all relevant parties involved in creating a nonproprietary solution to interoperability.

Cannavo discusses the standard HL7 and mentions three groups that are working on the issue of connectivity.¹⁷ The ActiveX for Healthcare Working Group from Redmond, Washington, CORBAMED (Common Object Request Brokering Architecture) of Framingham, Massachusetts, and the Andover Working Groups established in 1996 by Hewlett Packard from Andover, Massachusetts are focused on connectivity issues that allow RIS a means of exchanging data between different enterprises. He states that DICOM service classes can address the connectivity to an HIS/RIS on the PACS end.

The goals of the Andover Working Group (AWG) are to improve and enhance the existing information interchange standard HL7. The AWG has developed an Enterprise Communication Framework (ECF).¹⁸ The ECF is an object-oriented software technology that already encompasses standards-based health care data interchange, but not the DICOM standard. The ECF can be embedded into many products. Because the software already incorporates the standard for data exchange, ISIS interface developers will save time and effort when dealing with interpretations of the standard. This software would allow interoperability between disparate systems within the health care enterprise. The AWG also plans to work on other standards such as DICOM in the future.

Microsoft's Healthcare Users Group (MS-HUG) has formed an affiliation with the AWG by sharing the HL7 ECF specifications with MS-HUG's ActiveX for Healthcare Committee.¹⁹ The compo-

nents of ActiveX can be written in any language and can work in any operating system. ActiveX does not define any particular information content. It does provide the ability to define objects, then concentrates on support for object sharing and interaction.

Another group, entitled Common Object Request Broker Architecture (CORBA), allows different applications to communicate with each other transparently. CORBA uses Object Request Broker (ORB), a middleware that establishes client-server relationships between objects.²⁰ ORB provides flexibility when designing systems and allows integration of existing components. CORBAMED is a vertical domain task force of the OMG. It uses CORBA technology in the health care environment. DICOM is the prevailing message standard for biomedical imaging. To ensure compatibility between message-based and object-broker mediated systems, CORBAMED plans to specify that CORBA-conformant imaging applications conform to the DICOM information model.²¹

Some work is being conducted between DICOM and HL7 standards. IMSIG is working on an information model that maps DICOM Information Model to Versions 2.x of the HL7 standard. IMSIG has suggested that HL7 carefully consider using the DICOM Information Model as the imaging component of HL7 Version 3.0.²¹ This would close some gaps between these standards.

The products that these groups are developing will help create a more homogeneous computing environment. The similarity between these groups is the strict adherence to standards, or more clearly defining existing standards. The common goal is seamless integration of systems within the health care environment. With the exception of IMSIG, these solutions are proprietary in some way.

OPEN ARCHITECTURE INTEGRATION

Cannova also suggests three different ways to integrate clinical information systems.²² The first is using Web browsers like Microsoft's Internet Explorer or Netscape's Navigator. The second is a global integrated system solution with common interface and software applications built in. (This is costly and time-intensive to implement). The third, an offshoot from the second, allows the electronic medical record (EMR) system to act as a core system that builds everything else around its graphical user interface (GUI). Cannova believes that each choice has its own benefits. He describes a

trend toward the use of web servers. Many vendors are now offering this latest technology to integrate systems. CompuRad's ClinicalWare and Autocytgroup's AMICAS are two approaches to web technology. ClinicalWare offers full integration of images from any clinical information system. AMICAS is designed to address the integration of DICOM-compliant devices with electronic medical records. It also uses a wavelet compression algorithm (compresses files) to reduce file sizes.

Cannova expresses some concern with the GUI and EMR systems because the interface engine may be limited to a single application. Expanding to a more widespread application will increase the cost of the system. He believes that Web servers may be a cost-efficient way to integrate clinical information. Web servers are not as robust as other applications, but they are considerably cheaper. They can provide a means to request data from multiple sources, compile the data into a usable form, and then deliver the data to the user. Most Web servers are being installed as intranets for security and faster transfer speeds. Cannova explains how "managed care" and "capitated contracting" are forcing hospitals economically to become more efficient and cost-effective. To create a more efficient environment, medical images and patient records must be made available to clinicians in close to real-time. Integrated imaging and information systems can deliver this goal.

There are some new developments already affecting radiology. These include distributed computing, web technology, component-based software, and object-oriented technology. Cooke discusses these subjects briefly.²³ He sees a new distributed computing model that will put rings of resolution around the radiology department. The center will encompass radiology, and information will radiate outward using distributed computing. Radiology, using web technology, will be able to distribute information throughout the enterprise network. Object-oriented technology may appear more frequently, depending on its success in being implemented into clinical systems. Fault-tolerant architecture (redundancy built in the system) also will impact the PACS/HIS/RIS connection.

Mulvaney sees three approaches to the solution of connectivity.²⁴ The first is a PACS broker product like that used by DeJarnette or Mitra. The second approach would be to define a stricter HL7 standard with compliance from vendors. The third approach might be a new type of technology or

system that would incorporate PACS and RIS into a single product.

Connors believes the solution to the interoperability issue is standardization.²⁵ He admits that standardization might not solve the problem immediately, but that it is the shortest path to the best solution. He states "Companies that map out a smooth migration path from the current implementations to a compliant final solution with intermediate stops along the way for proprietary solutions and working relationships will likely outperform those that jump from one quick fix to another, as many companies are currently doing." He explains that "Until the imaging companies, the information system companies, the networking companies and the professional organizations all get together, the models used to define the standards will not coincide."

Amos believes that, in the long run, it probably would be wiser to use DICOM as a subset of HL7

to handle images, and use HL7 for the ADT and orders with which it originated.²⁶ He states "It is not hard to imagine a schema that would use the two protocols in compliment rather than in contrast and conflict."

Samuel J. Dwyer III, PhD, Professor of Radiology at the University of Virginia, also believes that the standards DICOM, HL7, and CORBAmed are the key to connectivity.²⁷ He sees object-oriented technology and client/server systems becoming more popular. Dwyer recommends getting "acceptance testing" when implementing a PACS system. This procedure measures throughput and workstation display protocol (among other items) and can ensure that a good system will work within the standards.

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