Can Radiologic Images be Incorporated Into the Electronic Patient Record?

Keith J. Dreyer, Amit Mehta, and James Thrall

As radiology makes advances toward filmlessness, all of medicine is headed, just as rapidly, toward paperless transmission of patient information. While there are obvious advantages to this electronic approach, and several standards to conform to for the transmission of textual (Health Level 7 [HL-7]) and image (Digital Imaging and Communications in Medicine [DICOM]) data, it is the integration of these two data sets that is clinically essential and yet poorly defined. This report defines an approach for, and the successful implementation of, the integration of radiologic image data with textual data contained within the electronic patient record (EPR) through the use of standard internet protocols. Incorporation of medical images in the EPR has proven to be critical to the successful deployment of picture archiving and communications systems (PACS) and the reduction of film consumption at Massachusetts General Hospital (MGH). Since the installation of the first internet-based Image Data Repository (IDR) at MGH in 1995, the system has adequately served to meet the needs of clinical requests by both radiology-only browser users and users of the EPR. It has drastically reduced the need for film and provided concurrent display of images and text throughout the institution and beyond.

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patient's electronic medical record, through the use of standard internet protocols.

TERMINOLOGY

There are many terms in medical informatics and, unfortunately, many are used interchangeably. Throughout this report, we will use many commonplace and emerging terms, and acronyms, which are fully defined in Table 1. Furthermore, a flow diagram (Fig 1) illustrates the communication and connectivity for many of these various data containing entities.

METHODS

A department-wide radiology picture archiving and communication system (PACS) was installed at Massachusetts General Hospital (MGH) from 1996 through 1999. Over the same period of time, the department of information services at MGH created a clinical data repository (CDR) for the purposes of electronic result reporting of all text-based result data recorded by departmental information systems. These data were made available to thousands of physicians via thousands of personal computers throughout the MGH enterprise via its electronic patient record (EPR) system.

As the MGH radiology PACS system began to contain more and more critical imaging data, the need became apparent for the radiology department to electronically deliver not only text results of radiology examinations, but to include the image data as well. Several methods of providing this necessary digital image transfer were explored.

First, was the option of treating the image data like text data in that it could be moved to the CDR and stored, awaiting clinical retrieval. This approach was quickly excluded at our institution for several reasons. The current CDR was not capable of expanding to the massive data requirements of medical images without re-architecture of the entire design, including hardware and database structure. Also, the CDR access application had no mechanism for the display of medical image data on the client's computer.

Since the images contain a unique ID in the DICOM header, and are all retrievable from the departmental PACS system, a second option was explored. If the images were too large to be contained on the CDR, the images could remain on the PACS and through the use of DICOM unique ID pointers, the CDR could forward requests to the PACS for images that came from the CDR users. These images could then be displayed to the client through a viewer application. Again, several issues prevented this approach. First, the existing network infrastructure (a variety of bandwidth ranging from 10 Mbyte shared to 100 Mbyte switched) could not support potentially thousand of requests for the transfer of minimally compressed medical image data (PACS 2:1 lossless JPEG). Also, the PACS could not

From the Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, MA.

Address reprint requests to Keith J. Dreyer, DO, PhD, Vice Chairman of Radiology, Massachusetts General Hospital, Zero Emerson, Suite 3E, Boston, MA 02114. Dreyer.Keith@MGH.Harvard.edu.

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Table 1. Definitions—Medical Informatics Terminology

Electronic Medical Record (EMR)	—The portion of the patient encounter not captured by conventional information systems, typically ambulatory data including chief complaint, progress notes, medications, allergies, history and physical, etc. Commonly referred to as the EMR. Often times, this term is used to connote the entire set of electronic medical data on a patient.
Electronic Patient Record (EPR)	—The combination of conventional medical information systems data (lab, radiology; admit, transfer, discharge [ADT], etc) and the (ambulatory) electronic medical record.
Longitudinal Medical Record (LMR)	—See Electronic Patient Record.
Electronic Health Record (EHR)	—The combination of the Electronic Patient Record with data entered by the patient including symptoms reactions to treatments and other historical events.
Medical Content Trusted Authority	—Internet publishers of medical data that have been deemed trusted for patient use, the method for validation of these sources is currently poor defined.
Clinical Data Repository (CDR)	—A database of information gathered by querying the various medical information systems of a provider, for the common presentation of electronic medical results.
Image Data Repository (IDR)	—A database of information gathered by querying the various medical imaging systems of a provider, for the common presentation of medical image data.
Interface Engine	—A device used to allow for the communication of disparate medical information systems, typically within one provider. Such a systems is necessary for the common delivery of Electronic Order Entry and Results Reporting of heterogeneous information systems.
Hospital Information System (HIS)	—The conventional information system of a hospital system used to register patients and contain, at least, data regarding their admit, discharge, and transfer (ADT) history.
Medical Record Number (MRN)	—A unique number used to identify and track a patient throughout a single provider.
Accession Number	—The number used to identify and track a specific test, procedure or examination of a patient. While the accession number alone may not be unique, the combination of MRN and accession number should be unique with in a single provider.
Master Patient Index (MPI)	—When 2 or more hospitals share patients, there is a need to find a common and unique numbering system for these individuals. Since each patient will have a different MRN at each hospital, a new numbering system must be created with links back to each hospital's MRN data. This new overarching medical record number (and the computer system that generates it) is commonly referred to as the master patient index.
Departmental Information Systems	—The information systems used to schedule, track, order, report and bill for procedures within various departments of the hospital. The radiology information system (RIS) is an example.
Radiology Information System (RIS)	—The departmental information system for radiology that contains information used to track patients, examination status, orders, results, films, schedules, personnel, billing and charges. It is typically devoid of images, even for filmless departments.
Electronic Order Entry	—The entering of medical orders through the use of a computer. A doctor, nurse, or other designate typically performs the entry.
Electronic Result Reporting	—The display of medical test results through the use of a computer, as opposed to paper or film.
ADT	—Abbreviation for Admit, Transfer and Discharge (the data typically contained by the hospital information system, or HIS).
Picture Archiving and Communication Systems (PACS)	—A computer system used for the digital acquisition, storage, transmission, display, and distribution of medical image data. While commonly synonymous with radiological imaging, the term applies to all medical subspecialties where images are stored digitally.
The Internet	—A method communication between all computers that allows for the sharing of data through various protocols such as the world wide web.
Browser	—A software program that is used to interpret and display data imbedded within messages sent over the Internet.
Hypertext Transport Protocol (HTTP)	—The communication protocol used to transmit data over the Internet. The data transmitted is commonly referred to as the world wide web.
Hypertext Markup Language (HTML)	—A language, or format, used to define the appearance of web pages as they appear within Internet Browsers.
Extensible Markup Language (XML)	—A newer language of the Internet that does a much better job than HTML of separating data from presentation. As such, XML is better suited for computer to computer communication or electronic data interchange.
Electronic Data Interchange (EDI)	—The ability for two computers to communicate information independent of human intervention. There are various protocols used for EDI, one of the most promising is extensible markup language or XML.
Virtual Private Network (VPN)	—A tunneling protocol used to secure the transmission of private data (such as confidential medical information) on public lines (ie, the internet).

Fig 1. Medical patient information flow. VPN, virtual private network.

support thousands of requests to its database server without serious performance degradation. Finally, there was no viewer application in existence native to the PACS system that was "thin" enough to execute on the thousands of personal computers throughout the hospital.

The elimination of these two options created the necessity to construct a new data repository, the Image Data Repository (IDR).

Image Data Repository

It was quickly decided that the IDR be internet-based with the capability of DICOM communication and include clinically acceptable, lossy image compression. It was preferred that expansion of the system, as needed, would occur through a distributed architecture versus monolithic expansion of a single server. With performance requirements defined as sub-second image access for potentially several hundred simultaneous users, it was determined that Microsoft, Inc (Redmond, WA) products, including the NT 4.0 operating system and IIS (Internet Information Server), were fully capable of delivering these performance requirements with excellent support and pricing.

Initially, the IDR application was executed using server hardware containing an Intel (Santa Clara, CA) Pentium 90-MHz processor with 128 Mbytes of RAM and 40 Gbyte of level V redundant array of inexpensive disks (RAID). This original single server system has evolved into nine distributed Intel based servers from various vendors to allow for increasing performance demands and to take advantage of the decreasing cost of increasing computing power.

At its core, the IDR is essentially a relational database and internet web server. It communicates with the PACS system via DICOM and is set as a storage class provider (SCP) to receive all image data that the PACS receives from modalities. This image data is then wavelet-compressed (at various compression ratios ranging from 10:1 to 20:1 depending on modality type) and stored in the database along with DICOM header information (image type, series details, and unique IDs), including medical record number (MRN) and accession numbers received by the PACS from the radiology information system (RIS) during examination validation.

Prior to EPR integration, a stand-alone browser-based view application was written to support the decompression and display of this server-based image data for clinical review. This application is used separate from the EPR as essentially a digital lightbox for the display of radiology-only medical data. Since the clinician may only know the patient's MRN, accession number, or last name, a query mechanism was included in the browser application to search for image data based on any one of these parameters. It is this query mechanism that was used to interface the existing text based EPR to the IDR.

While using the EPR, when the clinician is viewing a radiology report, the EPR knows the MRN and the accession number of the patient's examination being viewed. Using this information, the EPR opens a browser and requests for the IDR to display the image data associated with the accession number of the specific examination that the clinician is viewing. The HTTP request is similar to the manual request sent by the radiology-only digital lightbox browser (described above) to the IDR. An example of such an automated query is as follows: <http://radiology.mgh.partners.org/?AN=1234567>.

RESULTS

Once integrated in 1997, the IDR and EPR have served the MGH clinical community with very few technical problems. Unlimited concurrent user access to image data has been occurring for several years and appears to be without serious limitation to clinical needs with few exceptions. These exceptions are as follows:

No accession number. Often times, examinations are performed without knowledge of the patient's MRN (eg, trauma patients with no identification). The images of these examinations can enter the PACS, although prior to accurate MRN data, and can be retained there until the RIS MRN and accession number is assigned. Without an accession number, the current system will not allow for viewing of image data; therefore, the images of these patients are not made available until MRN validation.

IDR archive limitations. Since most clinical data requested are that which is most recent, the image archive of the IDR has been limited to maintain compressed image data for approximately 6 months. Any information requested before 6 months from the current date is sent to another browser application that allows the user to request the data from deep archive (ie, the PACS). Since this request can take several minutes (depending on the load of the PACS), the clinician has the option to enter his or her pager number so he or she may be notified when the images are ready for viewing. It was noticed that the majority of these requests were needed for conferences or clinical trials, where a

bulk request with time delays of several minutes was acceptable.

Workstation limitations. With the addition of image display on thousands of end user workstations, it was noticed that many of the installed personal computers used for clinical review were limited in their display capabilities due to limitation of their video subsystems. Being that certain video modes are not capable of displaying medical image data acceptably, the video capabilities of the end user's machine had to be detected by the software. If it was determined that the machine's video system was not capable of acceptable display, the images were not shown and a message was dis-

played instructing the user to contact the help desk for upgrade options.

CONCLUSIONS

Incorporation of medical images in the EPR has proven to be critical to the successful deployment of PACS and the reduction of film consumption at MGH. Since the installation of the first internet-based IDR at MGH in 1995, the system has adequately served to meet the needs of clinical requests by both radiology-only browser users and users of the EPR. It has drastically reduced the need for film and provided concurrent display of images and text throughout the institution and beyond.