Filmless Medical Imaging: Experiences of the Massachusetts General Hospital

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As the concept of picture archival communication systems (PACS) gathers momentum, the vision of a filmless digital department and digital image management has become a reality. This report will discuss the experiences of a major health-care institution with implementation of a large-scale PACS. Specifically, we discuss success with a modular, nonproprietary, multivendor solution that offers flexibility and state of the art functionality at our institution.

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IN EARLY 1995, the Massachusetts General Hospital (MGH) embarked on eliminating film consumption in an attempt to reduce departmental operational costs. Central to this strategy was the installation of a departmental picture archival and communication system (PACS) and deployment of the necessary infrastructure to allow electronic transmission of radiographic images throughout the Partners HealthCare System (PHS) enterprise. A multiphased, multivendor modular approach, instead of a single overarching solution, was proposed. Essential core components were identified before generation of our phase I request for proposal. These key components were identified as the archive, the network, acquisition devices and DICOM modifications, workstations, intranet distribution, and voice recognition.

We began by describing and defining the current radiology delivery system (Fig 1). Next, we defined the proposed electronic radiology delivery system (Fig 2), as well as the proposed enterprise-wide digital infrastructure (Fig 3) that would allow the radiology department to deliver images and reports electronically throughout our healthcare enterprise.

In order for a filmless radiology department to deliver images within its health care institution, a fully functional digital infrastructure is required. While our initial investigations concluded that there was no single vendor strategy that would provide a complete solution to our vision of filmless medical imaging, we recognized that the

market and the technology was evolving rapidly and in search of an enterprise solution. At that point we explored vendor partnerships and internally defined a complete proposal to our administration covering all aspects of development, funding, and implementation of a multivendor, modular framework for enterprise-wide filmless medical imaging.

Our implementation has thus far involved four phases. Phase I was installed in March 1997 and consisted of softcopy interpretation, archival and limited intranet distribution of urgent computed tomography for neuroradiology. Phase II involved expansion of the neuroradiology interpretation area, while phases III and IV involved the installation of additional modalities and subspecialties with further expansion of intranet distribution.

The current PHS provides our multiple hospitals affiliates, and thousands of physician affiliates, enterprise-level information access via 28,000 Intranet-attached personal computers (PCs). The radiology departments in total have conducted approximately 875,000 examinations in 1997 with an expected capacity of more than 1,000,000 exams by the year 2000. Our ultimate goal is to allow any physician within our network to be able to quickly and easily access radiology images and reports, regardless of where they are conducted within the PHS enterprise.

While similar deployment strategies are planned for all of our affiliated institutions, this report will only discuss the experiences surrounding the MGH filmless radiology efforts. At MGH alone, the 1997 annual radiological examination volume exceeded 400,000 (Table 1). The MGH radiology department employs close to 400 individuals who work in 17 separate interpretation areas divided by modality and subspecialty, including several outpatient facilities.

ACQUISITION DEVICES

Image acquisition is the first point of entry into a PACS. As mentioned above, MGH's current filmless medical imaging effort began with computed tomography (CT) neurological examinations performed in the emergency room with subsequent distribution and archiving. Currently, all CT examinations, since April 1998, have been archived.

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Fig 1. Current radiology delivery system within the MGH.

In phase II of our implementation, two remote-site computed radiography devices were added. We began prospectively storing all studies 2 months before their local softcopy interpretation. In phase III of our installation, three magnetic resonance imaging (MRI) and five inpatient ultrasound (US) units were added. Next, we integrated our digital radiography unit, computed radiography at Boston Shriners' Children's Hospital, as well as a MRI unit at the Massachusetts Eye and Ear Infirmary. Phase IV provided the integration of two computed radiography processors within the main department for portables and multimodality gastrointestinal and genitourinary examinations (Fig 4).

ARCHIVE

An accurate archival site analysis includes an evaluation of storage capacity, cost, and retrieval requirements. A review of the current literature demonstrates a void in the area of clinical evaluation of modern, nonproprietary, multidevice archives and their response times. Our archive selection focused not only on storage and cost, but also on speed of access to previously stored examinations and capacity for modular expansion. Phase I

Fig 2. Proposed radiology delivery system after PACS deployment within enterprise.

Fig 3. Proposed digital infrastructure within proposed radiology delivery system.

of our archival subsystem began in March 1997 with the implementation of a 256-platter, 2.6 GB magneto-optical disk plasmon jukebox employing 2:1 lossless JPEG compression providing 1.3 terabytes (TB) of image storage. As expected, this initial device filled within 9 months of installation, at which time a second identical unit was added. Archival subsystem phase II consisted of the installation of a 9710 Agfa/StorageTec DLT (Agfa, Ridgefield Park, NJ), capable of lossless storage for 40 TB of image data. A current study is underway at MGH to evaluate the responsiveness of a single DLT/RAID device within our department. If a DLT/RAID only solution proves adequate, retrospective transfer of image data from MOD to DLT with subsequent removal of MOD jukeboxes will ensue.

NETWORK

Network services are consistently being expanded beyond the scope of the radiology department. The MGH has an existing Ethernet-based (TCP/IP) network, which is used by clinical teams for information transfer. Due to the high requirements of the radiology services, a 100-Mb-

Table 1. 1997 MGH Annual Examination Volume

Modality	Exams/Year
Computed tomography	55,000
Magnetic resonance imaging	17,000
Ultrasound	32,000
Plain film	175,000
Portable examinations	80,000
Angiography	12,000
Nuclear medicine	7,000
Nuclear cardiology	5,000
Mammography	24,000
Total examinations	407,000

Fig 4. Current MGH PACS implementation.

switched Ethernet was installed as an expansion of the institutional supported TCP/IP backbone. In addition to the physical wiring, several other devices were installed, including the following:

- **Agfa Network Gateways:** Phase I began with a single such device to handle DICOM traffic to and from modalities, archives, workstations and web servers. When additional CT, MRI, and US services were integrated, DICOM traffic overwhelmed the single gateway and two additional network gateways were added. Our current design has a total of five network gateways through which we are able to adequately load-balance all existing DICOM network traffic.
- **Agfa HIS/RIS Broker:** The radiology information system (RIS) broker is responsible for all demographic data transfer to the PACS, including examination codes and intelligent routing tables from our IDX RIS system. The Mitra RIS broker (Mitra Inc, Waterloo, Canada) is also responsible for providing demographic data to certain acquisition devices such as computed radiography, digital radiography (Thorovision; Philips Electronics, New York, NY), and DICOMIT-based US devices. The next implementation will include transmission to existing CT and MRI devices. We have learned that a robust RIS interface is integral to the efficient functioning of a department PACS system (Fig 4).

WORKSTATIONS

As we foresee large changes and developments in the content and platforms of workstations, phase I began with a two-monitor, one $1K \times 1K$ Agfa workstation within our neuroradiology department for CT studies solely. With phase II and integration of more acquisitions devices, we added three more such Agfa workstations in the neuroradiology department for nonemergent CT and MRI interpretation. In addition, a two-headed $2K \times 2K$ workstation was installed in the emergency room to review computed radiography cases from remote clinical sites. Next, we installed a single station in the main interpretation area of the radiology department, which gained much popularity with our radiologists and led to the installation of three $1K \times 1K$ workstations for the gastrointestinal and genitourinary subsections. Once these workstations were in place, US interpretation was added, and subsequently inpatient US became completely filmless. Last, chest division filmless conversion began with the installation of a single two-headed $1K \times 1K$ workstation for chest CT interpretation. The strategic installation of workstations solely on an as needed basis saved costs through several recent technology price reductions. It will further serve to limit the number of costly UNIX workstations installed with a predicted impending platform migration to PC-based NT systems for primary interpretation (Fig 4).

INTRANET-BASED ENTERPRISE IMAGE DISTRIBUTION

From the onset of our filmless effort, web-based image distribution was cited as integral to the acceptance of a filmless radiology department to our enterprise. Thus, four Amicas (Autocyt, Inc, Waltham, MA), PC-based, Web servers were installed that systematically receive all cases from the department PACS and make them available for enterprise viewing on standard PCs using web browsers. Currently, hundreds of users access thousands of images daily over the intranet throughout the PHS.

These web servers were also recruited to solve departmental PACS issues. After the first 3 months of the project, PCs were added in the technologist's control areas in CT and MRI to allow for the validation of transmission to the PACS and intranet via web browsers. The installation of these units has allowed for a decrease of 10 to 20 nonvalidated cases (those that do not reach the PACS due to demographic errors) a day to only one or two per day.

VOICE RECOGNITION

From the origin of our filmless efforts, we have cited voice recognition (VR) as essential to soft-copy primary interpretation. To achieve this task,

we employ IBM's MedSpeak/Radiology (IBM, White Plains, NY) version 1.4. With sequential deployment, we have installed 35 PC-based VR workstations, representing 50% penetration of our department. Our radiologists currently dictate more than 400 reports per day through VR and these numbers are rising as we continue to phase out traditional dictation stations.

CONCLUSION

For a successful implementation of filmless medical imaging, one's vision must be larger than that of traditional PACS and RIS systems. While these two subsystems are essential, VR, intranet-based image distribution, modular archival subsystems, and a fast enterprise-wide network infrastructure are equally critical for success. While no single vendor provides such an all-encompassing product, a multivendor solution is currently available from several sources that require moderate internal integration efforts.

Viewing our implementation strategy retrospectively, our modular, nonproprietary, multivendor solution has proven to provide the correct framework for enterprise-wide, filmless medical imaging. Further, it has offered the flexibility, state-of-the-art functionality and cost savings necessary for continued financial and clinical support.