Enterprise-Scale Image Distribution with a Web PACS

Adrian Gropper, Sean Doyle, and Keith Dreyer

The integration of images with existing and new health care information systems poses a number of challenges in a multi-facility network: image distribution to clinicians; making DICOM image headers consistent across information systems; and integration of teleradiology into PACS. A novel, Web-based enterprise PACS architecture introduced at Massachusetts General Hospital provides a solution. Four AMICAS Web/Intranet Image Servers were installed as the default DICOM destination of 10 digital modalities. A fifth AMICAS receives teleradiology studies via the Internet. Each AMICAS includes: a Java-based interface to the IDXrad radiology information system (RIS), a DICOM autorouter to tape-library archives and to the Agfa PACS, a wavelet image compressor/decompressor that preserves compatibility with DICOM workstations, a Web server to distribute images throughout the enterprise, and an extensible interface which permits links between other HIS and AMICAS. Using wavelet compression and Internet standards as its native formats, AMICAS creates a bridge to the DICOM networks of remote imaging centers via the Internet. This teleradiology capability is integrated into the DICOM network and the PACS thereby eliminating the need for special teleradiology workstations. AMICAS has been installed at MGH since March of 1997. During that time, it has been a reliable component of the evolving digital image distribution system. As a result, the recently renovated neurosurgical ICU will be filmless and use only AMICAS workstations for mission-critical patient care.

MATERIALS AND METHODS

Hardware

Four Dell 2200 Servers, 128 MB RAM, 4 GB internal SCSI disk, 23 GB external SCSI disk, 100Base-T Ethernet, V.34 Modem.

Software

Windows NT Server (Microsoft), AMICAS Web/Intranet Image Server (Autocyt Group, Inc. Watertown, MA), Java (Sun Microsystems), Wavelet image compression, (Aware Inc.), DICOM library (University of California Davis and Michigan State University).

Communications

DICOM network communications were isolated by a 100Base-T Ethernet switch, one port of which connects to the MGH Ethernet backbone. Internet connection to teleradiology sites is provided via the MGH backbone. Web image clients typically access AMICAS via 10BaseT Ethernet. Some radiologists connect to AMICAS via Centrex ISDN (Bell Atlantic) at 128 Kbps while others use MediaOne cable modems (Continental Cable) at speeds of 1.5 Mbps using PPTP virtual private networking (Microsoft). Analog modem communications is enabled in all AMICAS servers for teleradiology backup and service.

High Performance Client (ICU Workstation)

266 MHz Pentium II (Dell), 96 MB RAM, 4 GB disk, 10/100Base-T Ethernet, 8 MB Imagine II video card (Number Nine). 24″ W900 Color Monitor (Sony) operating at True Color, 1920 × 1080 resolution, 72 Hz refresh. Windows NT Workstation 4.0 or Windows 95 (Microsoft), Communicator 4.04 Web browser (Netscape).

ENTERPRISE ELECTRONIC MEDICAL RECORDS

The integration of images with existing and new health care information systems poses a number of challenges in a multi-facility network: image distribution to clinicians; making DICOM image headers consistent across information systems; and integration of teleradiology into PACS.

As part of the multi-year plan to convert MGH to filmless operation and improved integration with affiliated hospitals and clinics, the availability of radiology images to all of the 28,000 desktop workstations in the Partners Health Care system came to be considered a priority. Apart from anticipated benefits in patient care, broad access to radiology images helps justify the large investment in technology for filmless radiology (Fig 1).

Four AMICAS Web/Intranet Image servers were installed as part of the initial phase of the project in March 1997 along with 6 radiologist workstations and a M/O disk library from Agfa. All images available in digital form were routed to both the Agfa PACS and the AMICAS enterprise distribution system. For maximum speed, AMICAS stores images in a wavelet-compressed format directly in the Web server's file structure. With the addition of 23 GB magnetic drives to each AMICAS, the on-line cache currently goes back approximately 12 weeks (Table 1).

The AMICAS technology is designed to facilitate hyperlinks between medical records (Fig 2) and images by combining Internet query and re-

From Massachusetts General Hospital and Autocyt Group, Inc.

Address reprint requests to Adrian Gropper, M.D., 52 Marshall St., Watertown, MA 02172.

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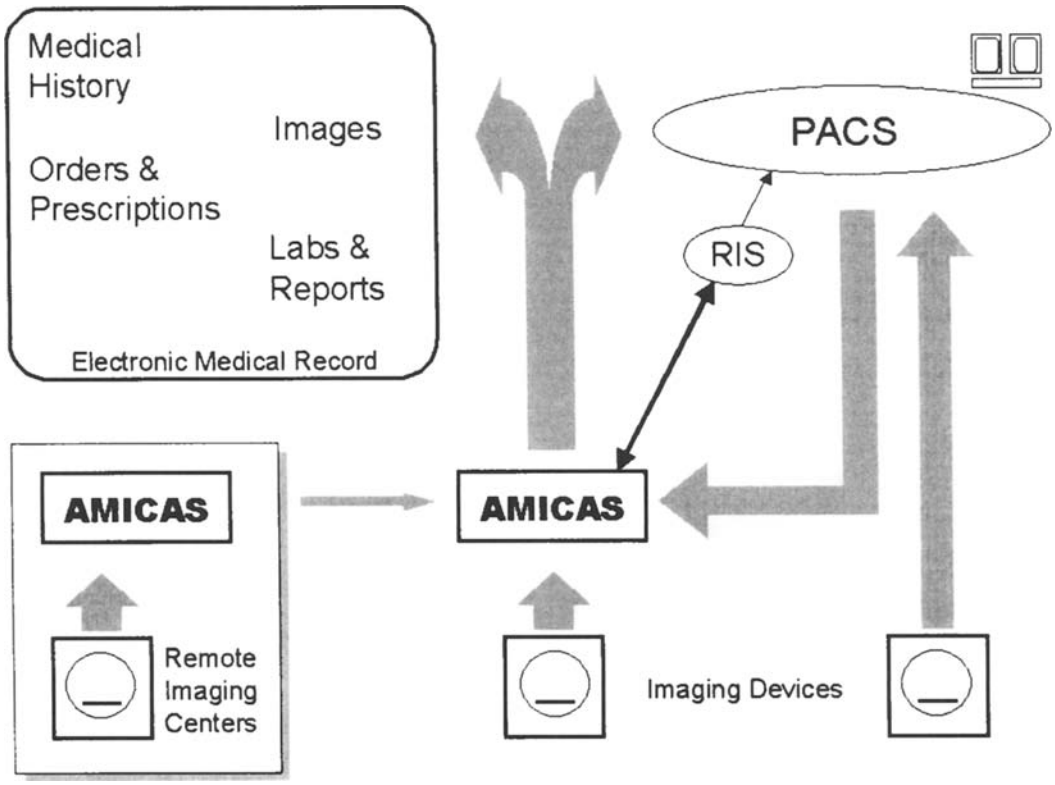

Fig 1. Digital image flow at MGH.

trieve standards, a real-time search engine interface and RIS interface technology.

Hyperlinks enable the system to scale to the full scope of the medical records system by allowing images to be rapidly requested on-demand (Table 2). Hyperlinks avoid the need for the medical record system to have a copy of the image data.

A key innovation in AMICAS eliminates the need to store the hyperlinks in the medical record system. AMICAS typically responds to Internet-style queries in 0.1 seconds and provides the current hyperlink along with key study information (Fig 3). This real-time response is parsed by the medical record software and provides the image links for clients that are based on either Web browser or traditional software components such as the CAS (Fig 2). By redirecting image links though this real-time query retrieve process, AMICAS avoids the problems of "stale" or disconnected links and retains full freedom to move images for load balancing, archiving or teleradiology purposes. For example, a HTTP GET to URL: http://amicas01.mgh.harvard.edu:80/servlet/StudiesWithID?patientid=5551212 returns a HTML table in 0.1 seconds by querying the AMICAS database (Fig 3).

DIRECT LINKS TO AMICAS IMAGES FROM IDXRAD SCREENS

Reliable image access, like any other form of medical information, requires correct patient identifiers. Unfortunately, the medical record, study

Table 1. Digital Imaging at Massachusetts General Hospital

Server	Modalities	Load (Studies/Yr)	Patients	Studies	Images	Latency (Weeks)
AMICAS-1	CT-1, CT-2, Fluoro	9,996	2,235	2,970	181,089	13.6
AMICAS-2	CT-ER	15,948	1,854	2,281	170,479	10.5
AMICAS-3	MR-1, MR-2, CR-1, CR-2, US, Teleradiology	22,080	4,231	5,335	401,022	13.3
AMICAS-4	CT-3, CT-4	22,032	2,152	2,938	204,818	9.2
Total		70,056	10,472	13,524	957,408	12.0

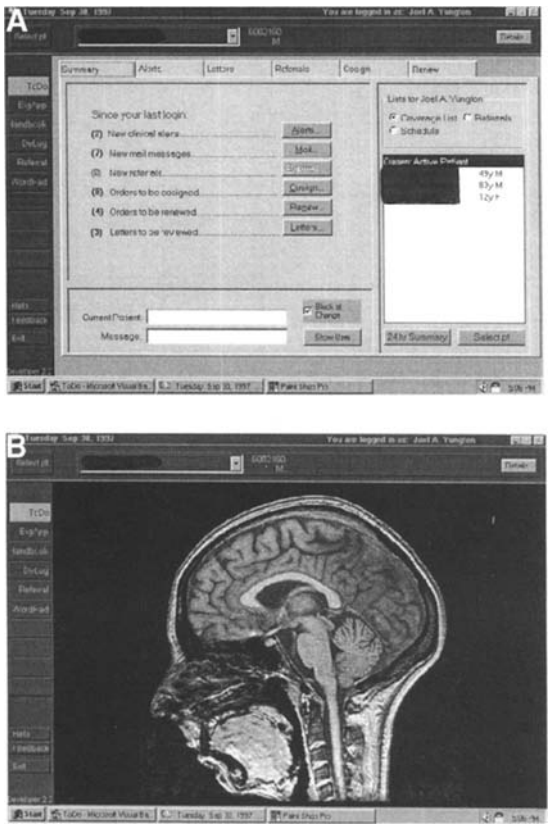

Fig 2. (A) Clinical Applications Suite (CAS) and (B) AMICAS Image Link in CAS.

tracking (accession) number, patient name and date of birth are not always correctly entered into the DICOM source modalities. Although the DICOM HIS/RIS classes solve much of this problem, as of this writing, only two of 10 data modalities on the MGH PACS support this feature. For the rest, AMICAS provides another innovation that enables the automatic transfer of patient identifiers from the IDX RIS to the DICOM header. This feature not only assures valid image links to AMICAS but also avoids routing problems in the Agfa PACS and enables a single imaging study to be assigned multiple accession numbers. This also resolves a critical, yet subtle, problem with modern PACS and their integration with multiprotocol procedures (such as Spiral CT, abdomen, chest, pelvis) common to modern radiology departments.

We have solved the problem of making data in DICOM headers consistent with the RIS. An AMICAS-enhanced terminal emulator allows the scan technician to transfer demographic and study information directly from IDXrad to the DICOM header without re-keying. The terminal emulator is deployed in the form of a Java applet from any Netscape browser. Hyperlinks to AMICAS images from IDXrad Report, Resource and Exam Inquiry screens are also provided. (Fig 4).

WEB IMAGE VIEWER AND TOOLS

The AMICAS Web server enables sub-second, on-demand image distribution without any impact on PACS resources. Wavelet compression preserves 12-bit data and allows interactive window/level and magnification control within standard Web browsers using a Netscape plug-in. An auto-layout capability initially displays CR and digitized film at a reduced resolution to desktops with smaller screens while making full resolution available on demand. Although every desktop PC with a modern Web browser has access to the full suite of image display and manipulation tools, a high-resolution, 2 K × 1 K monitor facilitates reference to side-by-side images in a critical care unit (Fig 5).

The image display and manipulation tools for the AMICAS ICU Workstation in Fig 5 are: Automatic Layout Based on Display Size; Window and Level Presets; Interactive W/L Adjustment and Magnifying Glass; Flexible Image Layouts with Magnification Display; Direct Random Access to Images; Comparison Mode with Linked W/L and Scrolling; Image Save in JPEG, Bit Map or Wavelet Format; Direct Email of Images in Wavelet Format; Color Ultrasound and Nuclear Medicine Images; and Radiology Report, Help, Transmission and Log Frames.

INTEGRAL TELERADIOLOGY

Using wavelet compression and Internet standards as its native formats, AMICAS creates a

Table 2. Access Speed of Image Screens from Information System Hyperlinks

Example	Images on Screen	Image Resolution	Image Size	Network Speed	Screen Drawing Time (Typical)
CT	2	512 × 512 × 12 bit	512 × 512 × 12 bit	10 Mbps	1.8 sec.
MR	8	256 × 256 × 12 bit	256 × 256 × 12 bit	10 Mbps	2.2 sec.
CR	1	2,010 × 1,670 × 12 bit	1,005 × 835 × 12 bit	10 Mbps	2.9 sec.

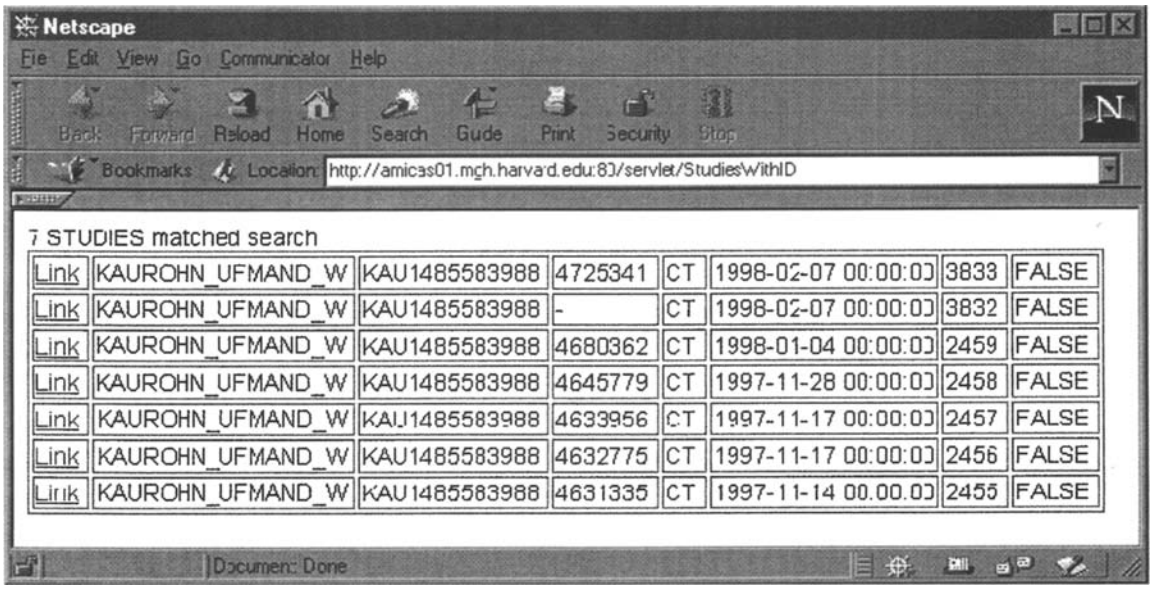

Fig 3. AMICAS database query result.

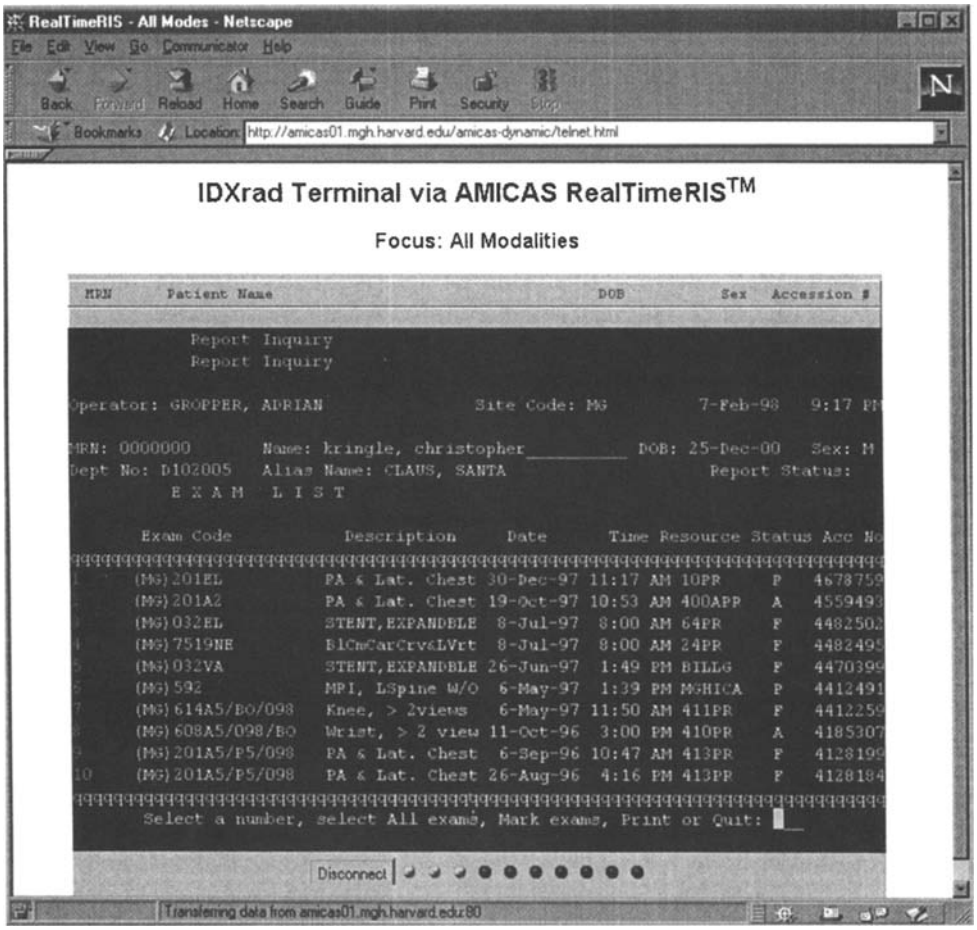

Fig 4. Hyperlinks to AMICAS from IDXrad Report, Resource and Exam Inquiry screens.

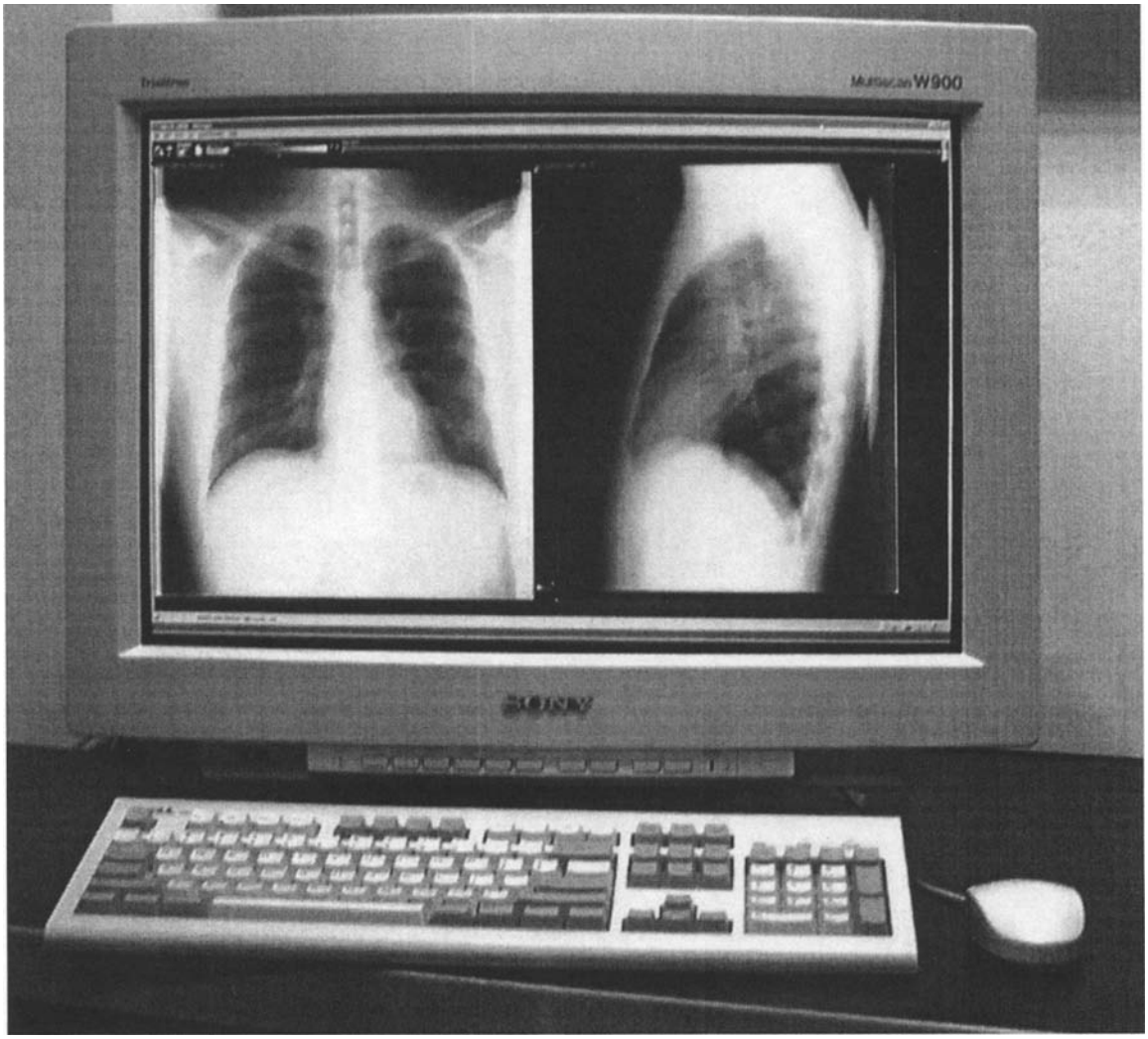

Fig 5. AMICAS ICU workstation picture and key tools.

bridge to the DICOM networks of remote imaging centers via the Internet. This teleradiology capability is integrated into the DICOM network and the Agfa PACS thereby eliminating the need for special teleradiology workstations (Fig 6). AMICAS currently receives studies from three affiliated imaging centers located in Istanbul, Turkey, Yonkers, New York, and Dartmouth, Massachusetts on a daily basis. The Massachusetts site communicates over a shared Partners Healthcare T1 link. The Turkey and NY sites communicate via the Internet using the FTP protocol. In these cases, the use of the Internet has reduced monthly operating costs by many thousands of dollars.

CONCLUSION

An image server based on Web standards and architecture provides a reliable complement to a DICOM PACS by placing 100% of digital radiology studies on-line. The AMICAS system has demonstrated more application flexibility as compared to the DICOM PACS. The servers and their wavelet-based image representation provide images to a broad range of clients ranging from DICOM radiologist workstations to simple desktop PCs with standard browsers. Direct links to images are provided from both the IDX RIS and the Clinical Applications Suite (electronic medical record system) at Partners Health Care. The system

Fig 6. AMICAS Images on Dicom Workstation.

has also reduced costs when compared to a full DICOM PACS solution. The AMICAS system has reduced teleradiology communications cost by employing the Internet to international and out-of-state imaging centers. Further savings were achieved by using AMICAS in a new ICU in place of DICOM workstations that would each have cost at least $25,000 more.