Picture Archiving and Communication System—Asynchronous Transfer Mode Network in a Midsized Hospital

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This article describes the pathway to full implementation of a hospital information system—picture archiving and communication system—wide area network (HIS-PACS-WAN) in a 300-bed acute care hospital, and the linking of that system to two other off-site medical centers. The PACS included direct digital capture of computed tomography (CT), magnetic resonance (MR) imaging, nuclear medicine, and ultrasonography images into an Olicon archive. Plain radiographs and fluoroscopy images were digitized manually and archived into an Olicon system. The active archive included current images on each Olicon workstation and the juke box. Long-term archiving of the images on removable optical discs, which would be loaded manually by an operator every time a request for one of these studies appeared on the operator's monitor, also was implemented. Ability to store, retrieve, and display simultaneously the physician's report of each procedure along with the images was an ultimate goal. The WAN is to be used for teleradiology and teleconferencing among the three medical centers involved in this study as well as other off-site locations. Phase I included the design and installation of the local area network (LAN) in the Department of Radiology at Olive View—UCLA Medical Center. This included the clinics and the inpatient and hospital-wide fiber-optic network and its linkage to the local telephone company. Phase II involved linkage of the Olicon workstations to imaging equipment. This implementation has been delayed significantly because of inadequate needs assessment, absence of planning for forward-compatibility to imaging equipment, and incompatibilities in DICOM conformance among vendors. Every PACS project must include an in-depth needs analysis, which should be updated yearly because of rapid turnover of technology. Although this analysis should have a heavy emphasis on clinical needs, it must incorporate the hospital-wide needs for an integrated information systems network. Integration of PACS, HIS, RIS, and a dictation/transcription system is a complex task that requires a full-time, clinically oriented project officer for successful completion.

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PICTURE ARCHIVING and communication systems (PACS) are still in their early stages of evolution. The standards of image acquisition, transfer, archiving, and retrieval being developed by the National Electrical Manufacturers Association (NEMA) still are not widely applicable. The next few years will see incorporation of microcom-

puter-based multimedia systems into PACS and the convergence of radiology information systems (RIS), radiology dictation and transcription systems, and teleradiology systems. The separate effort by hospital information systems (HIS) departments to develop an integrated electronic medical record (EMR) of the future will pose new challenges for PACS in radiology. Use of PACS by other departments is likely to increase. Already, images of histopathological slides can be transmitted over high-speed lines through asynchronous transfer mode (ATM) switches. With the expansion of teleradiology in other disciplines (e.g., dermatology) in which an image conveys more information than a narrative description, PACS is likely to play a major role in diagnosis by a specialist in a location remote from the patient. We describe here the difficult road to full implementation of a PACS in a mid-sized hospital, and provide a checklist (see Conclusions) for those who wish to embark on a similar mission in the future.

BACKGROUND AND CURRENT SYSTEM

The Department of Radiological Sciences at Olive View—UCLA Medical Center has had a Raytel (Sunnyvale, CA) PACS System in operation since 1991. This system consisted of direct capture of computed tomography (CT) (GE 9800; General Electric, Milwaukee, WI) and magnetic resonance (MR) (Picker HPQ; Picker, Cleveland, OH) images, and manual digitization of ultrasonographic, nuclear medicine, radiographic, and fluoroscopic images. The images were archived on an optical disk storage juke box. The display and review

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stations consisted of four $1K \times 1K$ monitors in the radiology file room and four single $1K \times 1K$ workstations in the operating room, inpatient wards, and outpatient clinics. The Dupont (Wilmington, DE) LINX system design interface (SID) was used to transmit CT and MR images from the technologist console to the Raytel archive. Although more than 300,000 images had been archived in the system, it was used sparingly by the clinicians because the image retrieval process was not user-friendly. Olicon (San Clemente, CA) was selected as the vendor for the upgrade of the Raytel System. A limited assessment of needs of the hospital and the department of radiology was performed by the vendor to help with design of the new system. To further delineate the needs, a consultant was recruited. This clarified clinical needs, but the issues related to hardware incompatibilities were never brought to light during these planning stages. The original design of this upgrade included (1) a SUN-SPARC 5 server, (2) a 32-platter optical juke box (38-GB storage capacity), (3) an Olicon gateway (80486 microprocessor-based PC), (4) eight new 80486-based Olicon workstations, and (5) the existing Konica digitizer. The existing Dupont SIDs and the existing hospital-wide network would be used to install the new network. No provision was made for DICOM conformance and the need for Merge Communications Technology interfaces between the imaging equipment and the Olicon system. The system was ordered and delivered 6 months later. A Newbridge Networks ATM switch had been installed as part of a General Telephone and Electric Company (GTE) sponsored trial. The radiologists in the ultrasonography section desired to go "film-less" by directly archiving into the Olicon server and by reviewing and interpreting active studies on the PACS monitors. Transmission of images during off-duty hours to the radiologists' residences emerged as a new need in view of budget curtailments. The Olicon system was to be interfaced with the existing Siemens (Iselin, NJ) Magnetom Vision 1.5 T MR imaging and post-processing workstation, a new CT Scanner (Picker PQ 5000), and the two new 3M-Imation DryView laser printers (Minneapolis, MN). Compatibility with a to-be-installed nuclear medicine local area network (LAN), which included a PET System, SPECT, and mobile gamma cameras, also was desired. The Olicon system was based on the American College of Radiology/National Elec-

tronic Manufacturers Association's (ACR/NEMA 2.0) specifications for image acquisition, transfer, and printing. All of the newer imaging equipment conforms to NEMA's Digital Imaging and Communication in Medicine (DICOM) 3.0 protocols. The newer DICOM 3.0 compatible modalities, therefore, needed to be interfaced to an Olicon gateway that accepts DICOM 3.0 protocols and converts to ACR/NEMA 2.0 for archiving to Olicon. Transmission of images from the ultrasonography equipment to Olicon, from MR imaging to Olicon, and from the Olicon archive to laser printers required either a dedicated Olicon gateway for each device or a Merge Communications Technology interface. The total cost of these devices would have added 50% to the cost of the original system. The current configuration of the LAN and the wide area network (WAN) of the PACS shown in Fig 1, therefore, represents a compromise solution without inclusion of the Merge Communication Technology interfaces.

In the present configuration, the four-port digital image capture system will acquire the ultrasonographic images for archiving to Olicon. The existing GE 9800 CT would use one of the four ports of the image capture system, and the new Picker PQ 5000 system is expected to be DICOM 3.0 compatible and, therefore, interface via the Olicon gateway. DICOM 3.0 software was made available by Siemens, which allowed its MR imaging Magic-View Workstation to be interfaced to an Olicon gateway. All radiographic and fluoroscopic films will be digitized manually. The Imation laser printers will be wired directly to the ultrasonography, CT, and MR imaging. The archived Olicon images, therefore, no longer can be printed on the laser printers. The ATM switch has been installed, and pilot tests have demonstrated successful instantaneous and simultaneous transmission of audio, video, and live ultrasonography studies to the off-site medical centers with no delay in transmission and no "drag" or "ghost" artifacts on the images. In view of the non-Olicon PACS at the two remote facilities (UCLA and Veterans Administration, West Los Angeles), however, transfer of images from the Olicon archive to the remote sites' PACS archive has yet to be demonstrated. The merging of physician's report with the images in Olicon archive is still in development.

Fig 1. PACS network architecture. The thick line represents the fiber-optic backbone. WAN, wide area network; LAN, local area network; TP, twisted pair; C, coaxial cable; FO, fiber-optic cable; M, modem; JPEG, joint photographic expert group.

CONCLUSION

Picture archiving and communications systems in radiology still are not fully developed. There is a paucity of knowledge among the vendors and the users. Therefore, each facility has to perform its own needs assessment. Moreover, because of the rapid changes in radiological and information technology hardware and software, it is realistic to assume that the system being purchased is only compatible with systems it has been demonstrated to be compatible with. The multiple equipment vendors involved in a PACS make it a necessity to budget for enough third-party interfaces to achieve successful integration of systems from various vendors. The image acquisition, transfer, archiving, retrieval, and printing requirements at each step need to be reviewed in detail with each vendor involved, and written approval from technical experts rather than sales representatives is recommended. This complex task requires the services of a full-time system manager for coordination of the planning and installation of a PACS and its integration with other departments of the hospital: information systems, facilities (electrical and biomedical electronics), communications, nursing, medical records, and the local telephone company. In view of the multiple unforeseen eventualities we had to face, we have developed a checklist for would-be purchasers of PACS.

CHECKLIST

Image acquisition: List of equipment and form of capture of image (digital or analog) from each

system. Are images to be captured from technologist or physician or both consoles? Number of third-party interfaces needed for automatic image acquisition, transfer, and printing.

Image Archive: Which images and how many are to be archived? Which and how many images are to be in short-term and long-term archive? Will video images (eg, Doppler ultrasound) be archived? If so, how? If only selected images are to be archived, who will select and by what criteria? Determine need for on-site and off-site back-up of archived images.

Image transfer: Cables and modems needed within facility, within campus, inter-facility, and to the radiologists' residences. During off-duty hours, how will images be transmitted to radiologist's off-site location? Need for automatic archive and transmission to radiologists' home during off-duty hours.

Read stations: How many monitors are needed at each reading station; what is the desired resolution?

Review stations: How many and where? If PCs are to be used to review, how will they be integrated?

Reports: Will they be merged with the images, if so how? Will only the impression or the entire report be archived? Where will hard copies of reports be printed, if any?

Retrieval: How many and location of stations for clinicians and radiology staff?

PACS CPU/archive: Location (radiology versus

HIS), who will pull daily statistics and reports? Who will back-up, who will purge, how often?

Interfaces: For acquisition from each modality to PACS archive, from PACS to laser printers, HIS, RIS, ATM switch, telephone company lines, individual or centralized modems, and so on.

Digitizer: Needed for digitizing old films and analog modalities. If all digital acquisition is desired, how many modalities need to be upgraded to digital format?

Hard copy: Are hard copies still needed, for what? On what kind of printer will these be printed? (Laser/transparency printers, plain paper, or color.)

Old Films: What will be done with old films on active or inactive patients?

Training: Radiologists, file room staff, technologists, clinicians, nurses, and ward clerks.

Security issues: Who will have access to images and reports? How will this access be granted? Are policies on electronic signature in place? How will access to images in PACS on legal

cases be limited? How will confidentiality of images transmitted off-site be guaranteed? Need for off-site back up of radiology reports and images.

Maintenance: Problems of maintaining off-site equipment (especially radiologists' homes), including installation of software upgrades. Who will pay for this? Issues of liability for interpretations performed off-site, e.g., the radiologist's home.

HIS: Download of patient demographics from HIS to PACS. Compatibility of radiology-generated demographics to those saved in HIS. Frequency and nature of upload of radiology reports—batch or on a case-by-case basis, automatically vs. manually driven. Provision for access to clinicians and residents.

Medical records: Security issues including electronic signature, import and export of images or reports, automatic printing/faxing of reports/images in unattended locations, and confidentiality agreements with receiving locations.