Implementation of a Filmless Mini Picture Archiving and Communication System in Ultrasonography: Experience After One Year of Use

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This article details our experience in developing and operating an ultrasound mini-picture archiving and communication system (PACS). Using software developed in-house, low-end Macintosh computers (Apple Computer Co, Cupertino, CA) equipped with frame-grabbers coordinate the entry of patient demographic information, image acquisition, and viewing on each ultrasound scanner. After each exam, the data are transmitted to a central archive server where they can be accessed from anywhere on the network. The archive server also provides web-based access to the data and manages pre-fetch and other requests for data that may no longer be on-line. Archival is fully automatic and is performed on recordable compact disk (CD) without compression. The system has been filmless now for over 18 months. In the meantime, one film processor has been eliminated and the position of one film clerk has been reallocated. Previously, nine ultrasound machines produced approximately 150 sheets of laser film per day (at 14 images per sheet). The same quantity of data are now archived without compression onto a single CD. Start-up costs were recovered within six months, and the project has been extended to include computed tomography (CT) and magnetic resonance imaging (MRI).

KEY WORDS: Ultrasound, PACS, filmless radiology, recordable CD.

THIS ARTICLE describes our experience in developing and operating a mini picture archiving and communication system (PACS) in our ultrasonography department. The system was built on an existing departmental Ethernet network with 35 Macintosh computers (Apple Computer Co, Cupertino, CA), but has grown to more than 60 computers, along with seven Unix-based workstations. The decision to pursue development in-house began several years earlier but stalled before suitable means of image management and archival were found. During this time, various archive media were tried, including optical disks, digital tape, and removable cartridges. Data compression

hardware also was tried but proved to be more limiting than beneficial. Films continued to be used for image archival purposes until it was decided that we would explore the use of compact disk recordable (CD-R) technology, which precipitated a re-engineering of the existing software.

METHODS

Previous System

The system in existence prior to the re-engineering was Macintosh-based and comprised software that coordinated the entry of patient information along with image capture (via framegrabbing), and included basic viewing tools. A single-image-per-file format was used with a simple database to maintain a record of the studies on the local disk. The most significant deficiency with the system was the lack of a convenient means to archive and retrieve data. All of the Macintosh computers required periodic monitoring and off-loading of files to maintain sufficient disk space for new studies. This was a manual operation that occupied a technician for a significant portion of the day. Because hardware compression was performed during archiving, and the media were poorly indexed, image retrieval was problematic. As a result, data were retrieved only when films were lost.

Re-engineering

The first three modifications we implemented were to eliminate compression, automate downloading of images from the Macintosh computers used for acquisition, and use a central database to facilitate archival and retrieval. The compression, which was hardware-based, limited retrieval to the one computer that was used for archival purposes. Once we settled on recordable CDs as our archive medium, it became possible to retrieve data from any computer in the department. Automated image off-loading was accomplished using the ability of Macintosh computers to share the hard disks of other computers on the network. This allowed us to set up a central "archive server" to receive images from every Macintosh used for acquisition at the time of the examination. This server also maintained a database to keep track of every examination. Queries of the database and access to the images then became possible from any computer on the network. At first, the database served only as a means to facilitate recovery of the archived data, but later incorporated pre-fetch capabilities.

To retain the ability to view cases performed throughout the day (and to allow access to images from previous days), additional modifications were made to permit viewing across the network. By design, this function did not require that the data first be downloaded to the local disk. This eliminated the need to monitor the availability and usage of local disk space.

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Storage and Archival

Primary storage of the data was provided by the archival server on three 9-GB disks. This allowed the most recent 8 weeks of data to be kept "on-line" for immediate access from anywhere on the network. For long-term archival, we introduced the use of CD-R technology. The attraction of recordable CDs, aside from their low cost, is their robustness and portability. The ability to use any common CD-ROM drive to restore the archived data is a benefit that is typically unavailable with other media. CD-R technology, however, has certain technical limitations that, in our case, required modification of the system to allow the recording process to be automated. In the end, it was necessary to replace the Macintosh-based archival server with a Unix workstation capable of recording CDs unattended.

Retrieval and Pre-Fetching

With a permanent database residing on the archive server, it was a simple matter to add the ability to execute searches. This, in turn, provided the ability to generate retrieval requests. A function to perform both of these tasks was added to the software used for acquisition and viewing. The user then was able to search for any given patient (by name, requisition number, and so on), then submit a "request" electronically for retrieval of the data. All such requests include a user-specified destination for the data to be sent. Each request first is processed automatically to determine if the data are still on-line. If so, they are copied automatically to the desired destination (provided the user has write-permission). Otherwise, the request is forwarded to a MacIntosh workstation in the filing room (where the CDs are stored) for manual retrieval. When this occurs, a continuously running application generates an audible alert to notify the clerical staff that a retrieval request has been received. This application simply prompts the clerk to load the required CD into the CD-ROM drive, then transfers the desired images to their destination.

This same scheme is used for pre-fetching. Twenty-four hours in advance, a clerk receives a list of patients who are scheduled for examinations the following day. Using the search and request functions described previously, the clerk selects all previous examinations and submits a request for them to be copied to a directory on the archive server called "tomorrowUS." Over night, after the data acquired during the day have been recorded onto CD, the directory "tomorrowUS" is renamed to "todayUS" and becomes available for review the following morning. This scheme results in the prior examinations of every patient being included on the same CD as the current examination. This provides some storage redundancy and makes future retrieval considerably more efficient.

RESULTS AND DISCUSSION

This system has been in filmless operation for more than 18 months at the time of this writing. Our ultrasonography department performs an average of 95 examinations per day on nine ultrasound machines. Prior to going filmless, an average of 19 images per patient were acquired, which resulted in an average of 128 14- × 17-inch films being

produced on a laser camera each day at 14 images per film.

We estimate that less than 2 hours per day are spent on pre-fetching and miscellaneous retrieval operations. An average of 54 examinations are requested for retrieval per day; 42% of these are serviced automatically because the data are still on-line, while the remaining 58% require retrieval from the CD. These figures would change if our primary storage disk space were increased or decreased. It is also worth noting that the number of examinations requested does not necessarily correspond to the number of CDs they are stored on. In fact, the latter number is likely to be much lower because of our policy of including all prior examinations for a given patient with the newest one.

Because our radiological staff and technicians were already familiar with the software in its original form, minimal training was required. The application used by the clerical staff is straightforward, so training there, too, was minimal.

Because the archival system has been automated completely and films have been eliminated, the position of one filing clerk was re-allocated and one film processor was shut down. The cost of a single CD is equivalent to three sheets of 14- × 17-inch film, yet the CD is sufficient to store more than 2100 images (at 640 × 480 × 8 bits). For our purposes, this is adequate to store one full day of examinations without compression, even when including the prior examinations of those patients having multiple visits.

Implementation required the purchase of a new MacIntosh with a framegrabber for each ultrasound scanner, plus one Unix workstation, one CD recorder, and three 9-GB hard disks. These costs were recovered within 4 months.

CONCLUSIONS

The success of this mini-PACS spawned a formal project within our department to pursue similar goals in computer tomography (CT) and magnetic resonance (MR) imaging (see our companion articles in this issue^{1,2}). We recently have eliminated film in these modalities as well, but have used a different approach to do so. The key difference lies in our use of the DICOM standard to transmit and store all image data between acquisition devices, archive servers, and diagnostic review workstations. Although our ultrasonography mini-PACS does not use DICOM, it makes use of several

similar concepts that should make its conversion (planned for the future) straightforward.

Not surprisingly, the experience we gained in developing the mini-PACS was applied to our design of the larger PACS with much success. This new system also uses CDs for archival purposes and has a retrieval request mechanism that closely mimics its counterpart in ultrasonography. An added feature of both systems is a means to access the image data (and submit retrieval requests, and so on) via the World Wide Web. This facility, although not used as much for ultrasonography, was deemed necessary before eliminating films in CT and MR imaging.

During the first year of filmless operation in ultrasonography, that branch of our department was the leading example of what could be achieved in pursuing digital PACS technology. Despite being overshadowed by the larger PACS currently being operated in CT and MR imaging the ultrasonography mini-PACS continues to fulfill its original promise.

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