Continuing Quality Improvement Procedures for a Clinical PACS

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The University of California at San Francisco (USCF) Department of Radiology currently has a clinically operational picture archiving and communication system (PACS) that is thirty-five percent filmless, with the goal of becoming seventy-five percent filmless within the year. The design and implementation of the clinical PACS has been a collaborative effort between an academic research laboratory and a commercial vendor partner. Images are digitally acquired from three computed radiography (CR) scanners, five computed tomography (CT) scanners, five magnetic resonance (MR) imagers, three digital fluoroscopic rooms, an ultrasound mini-PACS and a nuclear medicine mini-PACS. The DICOM (Digital Imaging and Communications in Medicine) standard communications protocol and image format is adhered to throughout the PACS. Images are archived in hierarchical staged fashion, on a RAID (redundant array of inexpensive disks) and on magneto-optical disk jukeboxes. The clinical PACS uses an object-oriented Oracle SQL (systems query language) database, and interfaces to the Radiology Information System using the HL7 (Health Languages 7) standard. Components are networked using a combination of switched and fast ethernet, and ATM (asynchronous transfer mode), all over fiber optics. The wide area network links six UCSF sites in San Francisco. A combination of high and medium resolution dual-monitor display stations have been placed throughout the Department of Radiology, the Emergency Department (ED) and Intensive Care Units (ICU). A continuing quality improvement (CQI) committee has been formed to facilitate the PACS installation and training, workflow modifications, quality assurance and clinical acceptance. This committee includes radiologists at all levels (resident, fellow, attending), radiology technologists, film library personnel, ED and ICU clinician end-users, and PACS team members. The CQI committee has proved vital in the creation of new management procedures, providing a means for user feedback and education, and contributing to the overall acceptance of, and user satisfaction with the system. Well developed CQI procedures have been essential to the successful clinical operation of the PACS as UCSF Radiology moves toward a filmless department. Copyright © 1998 by W.B. Saunders Company

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THE UNIVERSITY of California at San Francisco (USCF) Department of Radiology currently has a clinically operational picture archiving and communication system (PACS) that is thirty-five percent filmless, with the goal of becoming

seventy-five percent filmless within the year. Operational concerns with PACS implementations elsewhere, have been raised at all stages of the process from the design specifications, to installation, training and acceptance.¹ Quality control procedures necessarily become modified in the digital radiology department, and new processes must be put in place.^{2,3}

The design and implementation of the UCSF Clinical PACS has been a collaborative effort between an academic research laboratory and a commercial vendor partner. Images are digitally acquired from three computed radiography (CR) scanners, five computed tomography (CT) scanners, five magnetic resonance (MR) imagers, three digital fluoroscopic rooms, an ultrasound mini-PACS and a nuclear medicine mini-PACS. The DICOM (Digital Imaging and Communications in Medicine) standard communications protocol and image format is adhered to throughout the PACS, utilizing interfaces for non-DICOM-compliant legacy devices. Images are archived in hierarchical staged fashion, on a 126 gigabyte (GB) RAID (redundant array of inexpensive disks) for "near-line" storage, and on a half terabyte (TB) magneto-optical disk jukebox for permanent long-term archival. Access to the 3.9 TB UCSF historical archive with four years of prior CT and MR exams is available through DICOM query and retrieve. The clinical PACS uses an object-oriented Oracle SQL (systems query language) database with its own 37 GB RAID, and interfaces to the Radiology Information System (IDXRad) using the HL7 (Health Languages 7) standard. Components are networked locally using a combination of 10 mega bits per second (Mbps) switched and 100 Mbps fast ethernet, and 155 Mbps ATM (asynchronous transfer mode), all over fiber optics. The wide area network

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consists of a 622 Mbps sonet ring linking six UCSF sites in San Francisco. Teleradiology applications include both domestic and international sites. A combination of high resolution (2K by 2K) and medium resolution (1.5K by 1.5K) dual-monitor display stations have been placed throughout the Department of Radiology, the Emergency Department (ED) and Intensive Care Units (ICU).

METHODS

A continuing quality improvement (CQI) committee has been formed to facilitate the PACS installation and training, workflow modifications, quality assurance and clinical acceptance. This committee includes radiologists at all levels (resident, fellow, attending), radiology technologists, film library personnel, ED and ICU clinician end-users, and PACS team members.

The total committee met monthly with the radiology subset, including radiologists, technologists, film library personnel and PACS team members meeting weekly. More frequent meetings were held on an as-needed basis. Information was communicated to and assimilated by the PACS Clinical Coordinator using several methods, including the committee meetings, users' groups and training read-out sessions. Problem descriptions, questions and suggestions for improvement were also transmitted as they occurred via telephone voicemail, electronic mail and RIS messaging, as well as by written records in PACS logbooks placed throughout the clinical environment at every display station, input modality, output device, etc.

The form in Table 1 was utilized for recording errors in the PACS logbooks. It documented what the problem was and when it occurred, who reported the event or how it was detected, and what corrective action was taken, when and by whom. The information listed in Table 2 was used to ascertain a global assessment of errors in the system, in operations, workflow, etc.

RESULTS AND DISCUSSION

Although UCSF is currently only thirty-five percent filmless in terms of continuing to print film, the radiology department is closer to fifty percent filmless functionally; that is, approximately fifty percent of imaging exams are read softcopy. This includes primary diagnosis as well as image review with, for, and by the referring, non-radiologist

Table 1. PACS Error Logbook Format

When:	Date and time problem became known by the PACS group
How:	Who reported the problem or how the problem was detected
Timing:	How long did the problem exist before it was reported/detected
What:	Problem description
When Fixed:	Date and time
How Fixed:	Corrective action taken including any outside service vendor contacted
Who Fixed:	Name(s)

Table 2. Error Assessment Documentation

Cause:	Cause of the problem if known (hardware, software, personnel)
Frequency:	Has the problem occurred before, and if so, how often
Evaluation:	Could the problem have been anticipated Could the problem have been prevented, and if so, how Is the problem likely to recur (is the fix permanent) Is there a better fix than the one implemented What steps must be taken to put a more permanent fix in place
Outside Service (if used):	Who called the service vendor Did the Vendor respond adequately

clinician. The main barriers to printing less film are digital display of images in the operating room environment, provision of additional display stations to clinicians for softcopy review of imaging examinations in locations outside of radiology, and access to radiological studies for conferences. These impediments to going totally filmless should be overcome in the next phase of display station roll-outs which includes dissemination of PC-based workstations for intranet web access to radiology exams. Regardless, much has been learned by having a CQI committee in place at the beginning stages of (partial) filmless operation. Many new workflow and quality control procedures have been defined and implemented, better preparing radiology for the total digital clinical department.

SuperVs and Troubleshooting

A large majority of acute issues raised requiring urgent attention, could be resolved by additional/continued end-user training. These were not system errors or operational malfunction, but rather, user lack of understanding about how the system worked. It was determined that many of these problems could be handled by specially trained X-ray technologists and film library personnel, one designated per shift as a "SuperV." They have become the first line of defense for end-users to notify. If they are unable to resolve the incident on their own, they notify the on-call PACS group member. Service vendors were called as needed, initially by the PACS team. SuperVs became able to sufficiently troubleshoot problems quickly to determine whether service needed to become involved in problem resolution.

Acquisition

The imaging modality is the first entry point into the PACS and any errors in data input here, can propagate throughout the system. This input data is verified by comparison of pertinent demographic data (name, date, time, medical record number, accession number, exam type) at the acquisition gateway with the data recorded in the RIS. Thus, any imaging exam entering the PACS is RIS-verified prior to archival and distribution. Several imaging modalities are tightly coupled with the RIS (ie, some CR manufacturers) and provide automatic downloading of demographic information from the RIS, via barcode readers, to the modality, and hence the DICOM header. This eliminates the highly error-prone manual entry of data at acquisition. Unfortunately for manual data entry devices, any errors in data results in the image being held in a queue pending manual (human) inspection and resolution. Continuous feedback was given to technologists making repeated errors in data entry. In addition, a bi-directional interface was developed to provide an automatic image audit. Listings of exams scheduled in the RIS were matched to exams received into the PACS.

Some DICOM transfer of imaging exams (i.e., from CT and MR scanners) to the PACS require autosend-networking pathways to be enabled at the scanner. Unfortunately, these features can easily be turned off (frequently by the service manufacturer) resulting in missed real-time transfer of images to the PACS. Stressing the importance of having the autosend enabled at the time of imaging to the imaging technologists, as well as the manufacturer's service personnel reduced this problem.

Display

Monitor luminance calibration and matching was done monthly to maintain image output quality. Continuous feedback occurred between the CQI committee members and system end-users regarding ease-of-use and suggestions for improvements of the image display stations. Much valuable information was gained by observation of imaging readout sessions.

Networks, Database, and Archival

Network monitoring software was created to verify all systems were communicating, and to visually notify the PACS system manager when

networking failed. Routine database back-up is performed daily, weekly and monthly.

PACS Specifications Planning Phase

During the PACS planning, specifications and lab testing phases it was extremely beneficial to involve users. User awareness of the goals of a PACS implementation and its system features prior to clinical installment proved critical to the overall success of the system. Installation of system components was most successful when scheduled during low-volume periods and when all affected users were notified well in advance of the install date. Backup contingency plans must be in place prior to going live in the clinical environment.

Training

Extensive formal training sessions were held at set times prior to, during and immediately after display station roll-out. The most successful training took place when systems were clinically operational and users could view their own clinical cases. Initial training covered just the basics of calling up a specific patient's imaging exams and relevant data, viewing the images, doing some image manipulation and getting out of the system. Advanced training on more involved capabilities of the system were best communicated after the user had some experience interacting with the system. In our academic environment, personnel rotate through clinical services and locations very frequently. Thus, formal training for everyone is not possible. Training of the constants in the system, for example nursing staff in the ICU and attendings and fellows in radiology, who could then train new users, proved successful.

QA/QC

Maintenance, quality assurance/quality control (QA/QC), and workflow procedural modifications continue to be developed as incidents occur and system trouble shooting is carried out. Documentation of events, and CQI committee review and analysis of system functioning in conjunction with review of user suggestions is extremely important to the successful clinical operation of the PACS.

The CQI committee has proved vital in the creation of new management procedures, providing a means for user feedback and education, and contributing to the overall acceptance of, and user satisfaction with the system. Well developed CQI procedures have been essential to the successful

clinical operation of the PACS as UCSF Radiology moves toward a filmless department.

REFERENCES

1. Honeyman JC, Staab EV: Operational Concerns with PACS Implementations. *Applied Radiology* August: 13-16, 1997
2. Honeyman JC, Frost MM, Staab EV: PACS Component Testing: Beta and Acceptance Testing. *SPIE Medical Imaging 1997: PACS Design and Evaluation* 3035:405-412, 1997
3. Honeyman JC, Jones D, Frost MM, et al: PACS Quality Control and Automatic Problem Notifier. *SPIE Medical Imaging 1997: PACS Design and Evaluation* 3035:396-404, 1997