SESSION III

The Archiving Decision: A Balance of Time, Money, and People

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HENNEPIN COUNTY MEDICAL CENTER (HCMC) is a public teaching hospital in downtown Minneapolis staffed by approximately 360 physicians and dentist members of Hennepin Faculty Associates who supervise the advanced medical training of approximately 220 resident physicians. Staff physicians are also members of the University of Minnesota Medical School faculty.

Hennepin County Medical Center occupies five city blocks near the Metrodome and also operates primary care clinics in south Minneapolis, in the southern suburb of Richfield, in north Minneapolis, and in the northern suburb of Brooklyn Center. The downtown location has 434 hospital beds (more than 100 intensive care), 16 operating rooms, four primary care clinics, and scores of specialty clinics and outpatient programs. In 1997, these clinics recorded more than 313,600 patient visits and counted more than 124,300 unduplicated patients.

Hennepin County Medical Center was named Minnesota's first Level I Trauma Center in 1989. Hennepin County Medical Center's Emergency Department is the most active in the state, experiencing approximately 85,000 patient visits and 48,000 ambulance runs annually.

STARTING THE ARCHIVING PROCESS

A Picture Archiving and Communication System (PACS) without an archive component is in essence an electronic over-read service. Therefore, for the sake of this paper, it will be assumed that the archive decision is not one of, "if," but rather one of, "how and when."

The initial decision of an archive strategy is to determine the depth of the historical archive to be converted to digital form prior to commencement of other PACS processes such as soft copy reading. Distribution of digital images, except for maybe the Emergency Department (ED), whose patient mix is normally skewed to first-time patients, is usually held back until sufficient comparison studies can be offered digitally as well. Basically, it comes down to the degree by which the radiologists will interpret studies "soft copy" (ie, on a workstation) while using a hard-copy film for comparison.

At Hennepin County Medical Center, our experience with a "hybrid" reading process was not very successful. The jacket, which needed to be prepped and routed to the Reading Workstation for comparison report purposes, also contained the films for the current study. It was too easy for the radiologist to simply continue interpreting the current study from film and then handle PACS workstation tasks as an after-thought (or not at all). During this period, the technologist usually ended up signing-off the digital studies as part of the quality control (QC) process. This at least ensured that the digital archive would continue to grow with correctly "stated" studies, independent of the radiologists' actions regarding their use of the PACS workstation for interpretation.

Early in the PACS implementation, computer radiographic (CR) images were being being distributed to workstations in the Intensive Care Unit's (ICU's) for clinician viewing independent of whether the radiologists read the study soft-copy or not. These stations were primarily "receive only" workstations because the ICU clinicians rarely had a need to query for historical studies beyond the current admission.

For handling digital archiving of historical studies on an "on-request" basis, multiple DeJarnette digitizers were installed in the department. In addition, a custom developed DICOM interface to an earlier digital archive system from Eltrax (now Emerald Archiving, Inc.), would enable the studies stored on these optical disk platters to be transferred to the new PACS (archive) and be distributed to PACS workstations.

At Hennepin County Medical Center, this initial phase of digital capture and archiving with limited soft copy reading by the radiologist continued for

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approximately 12 months. During this time, the technologist fulfilled the radiologist's role regarding the study sign-off. A special soft copy reading committee was formed to finalize the new workflow processes in preparation for a fully filmless environment. Representatives from the radiologists staff, the technologists, the file room, department supervisors, the computer support team, and the PACS vendor comprised the committee.

DEFINING THE ARCHIVING STRATEGY FOR HENNEPIN COUNTY MEDICAL CENTER

The archiving decision process is a balance of time, money and human resources. It primarily revolves around the nature and number of comparison studies required for the soft copy reading activity and the patient care practices of the clinicians. The higher the number of comparison/historical studies required, the more "fast response" archive is required on the system. As the proper balance is achieved, any shortfall in providing studies on-line must be covered by the support personnel in terms of responding to "load requests" for off-line, optical disk platters. Determining this balance is usually an iterative process and may be effected by the delivery cycle of the vendor's equipment. As a result, the vendor needs to be an integral partner in the archive development process.

The multi-tier archive architecture deployed at Hennepin County Medical Center is outlined in Fig 1. As might be expected, the access characteristics identified in this diagram are affected by the size of the study or studies being retrieved.

At this time, the PACS configuration at Hennepin County Medical Center only has a single

work-group and therefore the Redundant Array of Inexpensive Disks (RAID) installed is actually associated with our central or "historical" level device. A special functionality of the PACS workstations installed from Siemens at Hennepin County Medical Center, called "shared worklist," permits each "personal" level workstation to access and interpret studies physically stored on another individual's workstation. This provides a "pseudo work-group" environment for the radiologists to efficiently complete their soft copy reading workload.

The "Study Volume Capacity" entries in Fig 1 reflect the following design axioms applied for Hennepin County Medical Center:

- The 1-2 day personal workstation volume reflects that the radiologist schedule would provide a worst-case coverage to interpret and sign-off the studies within this time-frame.
- The 1-2 day personal workstation volume is the volume for a single workstation only which is approximately 1/7th of the total daily departmental volume for HCMC.
- The 5-7 day work group volume reflects a capacity sufficient to cover the average daily stay for inpatients.
- The 12 month on-line historical volume reflects a coverage of approximately 80% of the estimated queries for historical studies (see Fig 2). This percentage would likely need to be higher at non-teaching hospitals.

All personal and work group workstations are set to auto-purge their own archives based on the status of the study, the length of time it's been stored on that workstation and the particular type of study (eg, CT, MR, CR, etc). The historical archive devices also retain the integrated patient directory. They manage the contents of both the "fast response" RAID and the optical disk platters dynamically. Studies required from off-line OD (optical disk) platters are loaded via a separate OD drive and do not require a permanent re-configuration of the jukebox.

ARITHMETIC OF PACS ARCHIVING AT HENNEPIN COUNTY MEDICAL CENTER

The procedure volume analysis for Hennepin County Medical Center is summarized in Table 1.

The archive devices deployed on the workstation were typically 1 and 2 GB hard drives, providing almost instantaneous seek and retrieval times. The

Fig 1. Multi-tier archive architecture.

Fig 2. Percent of Historical Studies Requested by Age of Study.

RAID arrays were configured in 24 GB Type 5 blocks. (New product offerings in this area however have 80 GB RAID now achieving equivalent price performance ratios).

The optical disk jukeboxes deployed at Hennepin County Medical Center are 160 platter systems utilizing OD media with a capacity of 1.7 GB/platter. The drives are expected to perform at a transfer rate of approximately 1 MB/sec. yielding an average estimated transfer time for a 25 MB study of about 30 seconds from initiation of request to completion of delivered study to the archive processor.

Table 1.

Type of Study	Annual # of Proc.	Average Images/Proc	Average MB/Proc	Average MB/Day
CT	9,990	32	16	608
MRI	2,434	123	16	145
NM	2,793	25	3	36
US	11,828	30	18	819
Rad	87,075	2	20	6,046
Spec/Angio	1,823	29	58	403
			Total	8,057

OPERATIONAL WORKFLOW ISSUES EFFECTING THE ARCHIVE STRATEGY

Since the archive solution is at the heart of the PACS configuration, it is imperative that the workflow and process change that were necessary as part of the PACS implementation reflect a recognition of this critical resource. Some of these workflow issues which were the subject of considerable discussion are:

1. *How and who will be responsible for responding to load requests for off-line studies?* If the historical archive component is under-sized for the query distribution for your institution, the result is a backlog of load requests. This translates to very long response times for the requesting clinician or radiologist. It is important to remember that this requirement is a 7×24 hour responsibility, so scheduling of support staff must take this into consideration. At Hennepin County Medical Center, this task is handled by the computer support team during normal operating hours and after-hours, the responsibility has been assigned to the over-night technologist staff. In

the future, the File Room staff will handle this operational support staff during whatever shifts they are present.

2. *The timeliness and quality of the query requests originating from the clinics has the greatest impact on the overall response time of the historical archive.* The clinic staff previously received the entire patient's medical imaging jacket in accordance with their patient schedule. Requests to the file room were done many hours ahead of time to allow for standard retrieval and distribution procedures to be completed. With a PACS system, the specificity of the requests is significantly higher and the proximity to the actual time of the patient visit significantly closer. Overall, the request integrity and the efficiency of the clinic-to-Medical Imaging interaction improves substantially. To leverage this improvement properly, however, the awareness of the archive as an enterprise-wide critical resource must be embraced by the clinic staff. This should be reinforced regularly through follow-up training sessions and by focused, immediate feedback to improper query requests. To minimize inconsistencies in response times in the future, Hennepin County Medical Center is planning to install work group level archives for one or more of the higher volume clinics. These work group servers would then be populated by queries initiated at pre-set times based on a specific patient visit schedule.
3. *The number and type of comparison studies required by the radiologists has a measurable impact on the size of both the personal reading workstations and the "fast response" RAID resource.* Each radiologist has a particular style when interpreting imaging studies. This translates into differing requirements for each of the staff radiologists, as well as for any residents being mentored by them. Most variations in comparison study requirements could be accommodated by the 12 month on-line historical archive. However, if the comparison study requirements routinely include the first study *ever* for a previously treated patient, the demand for offline "load requests" could impact the size/number of the optical disk platters retained online. This was not the situation at Hennepin County Medical

Center. Currently at HCMC, the automated pre-fetch processing for retrieving comparison studies is in the discussion stage. Once implemented, this functionality will automate the current function performed by the Image Control Tech of "assembling" the package for soft copy reading. As a result of the number of iterations experienced at Hennepin County Medical Center to finalize these pre-fetch requirements, it is highly recommended that one conduct a technologist-driven prefetch process prior to installing any "electronic rules" to accomplish this task in a fully automated fashion.

4. *Early in the archiving decision process, the choice of how the pre-PACS films would be incorporated into the new environment had a substantial impact not only on the operational workflow requirements, but on the archive sizing as well.* The key variable is the amount of "on demand" digitizing the Medical Imaging Department wanted to support. This answer, coupled with the choice of whether the start-up environment would utilize hard copy film or pre-digitized PACS files for comparison, determined from day one the type and size of the PACS archive we needed. For radiologist interpretation tasks at Hennepin County Medical Center, the previous "90-day file" was determined to be the critical time frame for the general mix of patient studies ordered. Rather than undertaking a "mass digitizing" of patient films, it was decided to let this file "build" through the routine digital capture workflow. Since the initial patient population being migrated to the PACS was from the ICU's, the critical comparison studies were actually covered by a 30-day time-frame. Sufficient "fast response" storage was then configured into the design to cover this comparison study volume requirement.

FUTURE CONSIDERATIONS REGARDING PACS ARCHIVING

Now that the PACS system has stabilized in terms of soft copy interpretation and distribution to key clinician areas, Hennepin County Medical Center is keeping an eye on the next generation of archive solutions and other technological develop-

ments which could enhance the current PACS environment.

A computerized patient record (CPR) initiative containing an electronic medical record (EMR) and a clinical data repository (CDR) and a new integrated clinician workstation solution is currently underway. One option for the CPR could be a shared "deep archive" with the PACS system. In this regard, digital tape sub-systems from companies such as Emass or Storage Technology are being investigated. Some preliminary performance data for these types of systems are listed in Table 2.

Other alternatives for the archive solution being investigated are jukeboxes based on the DVD storage format. Besides the clinical data repository issue, methods to leverage the web server and browser technology offer potential for efficient image distribution to a wide audience. Although this technology is not applicable as a replacement to the custom application software used by the radiologist, it appears to offer substantial benefits and efficiencies for distributing medical images and results to the clinicians (and to patients).

To utilize the web client/server model effectively, however, a prerequisite of routinely "tagging" specific images in studies containing numerous images and/or series (eg, CT, MR, US) as being "clinically significant" would probably need to be

operationalized. These sub-sets of full patient studies could then be archived separately on a web server for efficient browser access. Pilot projects for intra-, inter-, and extra-net solutions for distributing the PACS images are currently works-in-progress at Hennepin County Medical Center.

CONCLUSION

The archive solution is the lynch pin to a successful PACS implementation. It is, however, by far the most expensive component of the PACS as well. It is therefore imperative that the workflow issues related to the archive save and retrieval processes, a number of which were delineated in this paper, are openly discussed and documented *before* hardware is installed.

Like most of the technology components of the PACS, the archive will need to migrate to next-generation hardware and software at regular intervals. However, unlike, the rest of the PACS devices, the archive has a historical aspect to it which mandates that the data must also have a proper migration plan. This plan must be finalized jointly with the vendor(s) and reflect the historical study request curve applicable to your institution.

Digital tape solutions noted herein would in essence create an environment of 100% of historical studies being on-line. This would eliminate the need for any back-end human resource support for load requests. However, this depth of historical study automation must also be accompanied with a solution for generating a redundant copy of the image files. In other words, the PACS archive management issue will have made the transition to a full information management system. As such, it should be physically relocated and functionally supported by the Information Systems Department (as opposed to Medical Imaging Department), including being incorporated into the institution's disaster recovery plan for computerized information.

Table 2. Performance Characteristics for Various Deep Archive Solutions

	Optical Disk	Digital Tape (8590)	Digital Tape
Drive Ready	1 sec	20 sec	45 sec
Search	1 sec	30 sec	100 sec
Transfer	31 sec	6 sec	10 sec
Capacity (per media)	2.6 GB	10-20 GB	35 GB
Transfer Rate	1 MB/sec	9 MG/sec	5 MB/sec
Drive Cost	x	5x	1x
Media Cost	2y	y	y
Cost GB	28z	2-3z	z