The Digital Imaging and Communications in Medicine (DICOM) Archive Is a Dynamic Component of a Clinician Image-Related Workflow Solution

Barton L. Guthrie, Chris Price, Joanna Zaleski, and Eric Backensto

The authors investigated clinician transactions against the Digital Imaging and Communications in Medicine (DICOM) archive within a clinical image management system (CIMS) in support of patient care. A Neurosurgical Oncology practice was audited for image utilization. There were 400 requests for 233 image studies during 297 sessions. Fifty percent were for current studies, and 50% were for historical studies. Current studies alone were requested in 37% of the sessions, current plus historical in 31%, and historical alone in 32% of the sessions. Seventy percent of studies were within 8 weeks old and were rapidly available from the CIMS disk cache without an archive image transaction. Conversely, 30% were older than 8 weeks, requiring a clinician transaction against the archive for image retrieval. Approximately 25% of studies were older than 3 months and 10% older than 6 months. Clinician image needs are complex and any CIMS solution must include a DICOM archive that can support clinician-based transactions.

Copyright © 2001 by W.B. Saunders Company

EARLY COMPUTER-BASED image management systems were developed within radiology environments. These traditional picture archiving and communication systems (PACS) consisted of an archive layered with workflow software to support radiology's need to rapidly interpret large numbers of modality-specific image studies. These "central archives" were built for primarily for storage. User-based archive transactions were minimized by off-line prefetching rules like "retrieve the most recent prior image related to this current image."

From the Computer-Assisted Neurosurgery (CANS) Facility, Division of Neurosurgery University of Alabama School of Medicine, Birmingham, AL.

Supported by a grant from the University of Alabama Health Services Foundation General Endowment Fund.

B.L.G. has a financial interest in Emageon, Inc, which has licensed a portion of the CIMS software from UAB.

Address reprint requests to Barton L. Guthrie, MD, Computer-Assisted Neurosurgery (CANS) Facility, Division of Neurosurgery, University of Alabama School of Medicine, M001 RAC, 1813 6th Ave S, Birmingham, AL 35294. E-mail: bguthrie@uabmc.edu.

Copyright © 2001 by W.B. Saunders Company

0897-1889/01/1402-1051\$35.00/0

doi:10.1053/jdim.2001.23868

Clinician patterns of medical image and radiology reports are more complex. Clinicians are often required to see patients on an ad hoc basis such as in the emergency room, as random consults, via a telephone call, etc. They routinely use multimodality historical image studies for patient care. Rules for prefetching are often inadequate due to case complexity or not possible due to ad hoc nature of encounters. For these reasons, it may be impossible to establish rules that protect an enterprise archive from user transactions for real-time image retrievals.

It is the goal of this report to examine clinician user transactions of the Digital Imaging and Communications in Medicine (DICOM) archive component of the Clinical Image Management System (CIMS). CIMS services the image needs of the clinical neurologic services and is representative of the utilization of an enterprise clinical imaging solution. Utilization patterns of an image-intensive clinical service (Neurosurgical Oncology) were examined to delineate user patterns with focus on use of historical image data, the age of the retrieved studies and associates user transactions of the DICOM archive.

MATERIAL AND METHODS

Description of CIMS

CIMS supports filmless operation for the clinical neurologic services (Neurosurgery, Neurology, Neuropathology, Radiation Oncology) at the authors' institution. Its basic architecture is diagrammed in Fig 1. The key components are the CIMS clinician viewer (CIMS Viewer) and a DICOM archive/distribution system. As currently configured, CIMS operates on the institutional intranet (10 Mb switched or shared to the desktop), is supported by a 300-GB redundant array of inexpensive disks (RAID) five cache called the Active Patient Image Repository (APIR), which holds about 8 weeks of patient studies. The archive system consists of a commercial database (Oracle, Redwood Shores, CA), a SUN E450 Server (SUN Microsystems, Mountainview, CA), the Archive Manager software (Emageon, Birmingham, AL), and a Storage Tek 9710 DLT system (Storage Tek, Bloomfield, CO) with 2-TB capacity. From the CIMS Viewer, the user queries the archive database for the desired patient/study. A Common Object Request Broker Architecture (CORBA) service transmits the request as a DICOM query to the Archive Manager. If the queried study is in the APIR (an "active study"), it is returned to the user within a few seconds. If the study is not in the APIR, CIMS notifies the

Fig 1. CIMS' architecture enables the user to access the entire archive from a viewing station. If a study is not available in the cache (APIR), it is automatically moved from the archive. This study focuses on analysis of the CORBA Server and DICOM Archive Manager logs.

user and automatically moves the study into the APIR for viewing with a latency of 3 to 5 minutes. In this manner, the user has access to all archived images. At present, the archive has accumulated about 3 years of studies

Data Collection

The CORBA and Archive logs were reviewed to analyze the use pattern of one member of the Neurosurgical Oncology team (B.L.G.) from April 1 to June 30, 2000. The CORBA logs provided a detailed listing of the studies that were queried and viewed including user name and location (internet protocol [IP] address), date, time, and series viewed. The archive logs indicated the date and time a study was moved from the archive. This review focuses age of study at time of viewing and whether the study was moved from the archive at time of viewing.

Definitions

A clinical session was defined as an episode of viewing within which a clinician called up one or more patient studies for review. "Session" is a more accurate representation of clinician patient care activity than a "study query." The patient population reported here has a clinic cycle of approximately 1 week; therefore, a current study is one reviewed within 1 week (7 days) of acquisition. Likewise for this patient population, a historical study was defined as one that was recalled for viewing more than 1 week (8 or more days) after its acquisition.

RESULTS

For the service analyzed over the specified interval, there were 400 queries for 233 studies within a total of 297 individual clinical sessions (Fig 2). Magnetic resonance imaging (MRI) com-

prised 49% of the studies, computed tomography (CT) 47%, and computed radiography (CR, plane radiographs) 4%.

Patterns of Current and Historical Study Retrieval

Approximately 50% of the queries ($n = 202$) were for current studies and 50% ($n = 198$) were for historical studies. Analysis of concurrent use of current and historical images within individual sessions showed that for 37% of the sessions, only a current study was requested, for 31% of the sessions a current and at least one historical study was requested, and for 32% of the sessions only a historical study was requested. So for this service, under the current CIMS configuration, 63% of CIMS sessions involved retrieval of an historical study (older than 7 days).

Age of Requested Historical Studies

A total of 198 requests were made for historical studies (older than 7 days). Examination of the age of these studies revealed that 70% were less than 8 weeks old, and therefore resided in the APIR (cache). Thirty percent (30%) were older than 8 weeks, and therefore required a user transaction with the archive for study retrieval. Further analysis showed that approximately 25% were older than 3 months and 10% were older than 6 months. Figure 3 graphs the age distribution of studies queried for review.

Utilization patterns: current and historical images

Total of 233 studies called in 297 sessions

Fig 2. User queries and how they comprised CIMS sessions. The critical point is that 63% of CIMS' sessions involved retrieval of an historical study for patient care.

Age of study at time of query for patient care (n = 400 queries)

Fig 3. The DICOM Archive Manager logs demonstrate brisk activity for retrieval of historical images. This graph shows that about 25% of studies were over 3 months old. Under the current CIMS caching configuration, all of these studies would be accessed by a user transaction against the archive.

DISCUSSION AND CONCLUSION

Conclusions about CIMS use patterns need to take the following into consideration. CIMS does not yet process digitized film nor provide access to outside studies so film is still used. CIMS uses a simple strategy of caching 300 GB of data for rapid access. A smaller cache would result in more user-based archive transactions, whereas a larger cache would yield fewer archive hits. These data represent the utilization patterns of one neurosurgical oncologist. Each specialty has its own pattern. The intent of this study was to examine an image-intensive service to analyze the user-based transactions of the archive itself.

The ideal system would provide instantaneous access to data for any user regardless of time or location. A number of factors make this difficult. Contemporary solutions for rapid image delivery include various caching strategies combined with prefetching (off-line retrieval) studies from the archive based on rules that attempt to anticipate user needs. While network bandwidth is a consideration behind these load distribution efforts, another important consideration is that traditional DICOM archives were built for storage not transactional activity.

Our analysis of one clinical service demonstrates a complicated pattern of historical image use. Sixty-three percent (63%) of the time, the user calls for a historical study and for half of these,

there is no associated current study. The authors' caching strategy was such that 70% of these studies were available in cache, but 30% required user-based retrieval from the archive. A closer look at this 30% is required to understand whether the number could have been reduced by a prefetch strategy. A simple strategy would be to have all ward and clinic patient studies moved into the cache. However, this institutions' hospital information system (HIS)-based patient registries such as admission/discharge/transfer (ADT), master patient record (MPR), etc are not yet mature enough to interface with an enterprise CIMS to enable such prefetch notification. In addition, ad hoc consults are common such that the system cannot predict the need for all studies. It is known from the Neurosurgical records that up to 10% of the patient encounters are of this type. This would suggest that the best rule-based prefetching system interface with a robust patient registry could reduce user-based archive transactions to 10% of the total image use. This number would probably be similar for most of the acute care specialties such as Orthopedics, Trauma, Cardiology, ENT, Plastics, etc, although utilization review would be required to gain a more exact figure.

This is an important specification for the archive component of an image management solution. Traditional radiology PACS are designed to store, not transact, with most historical studies managed by

prefetching. Radiologists will undoubtedly use archive transactions more frequently as electronic libraries grow. In contrast, enterprise clinician needs for historical studies are more difficult to anticipate due to the complexities of the clinical environment. This report suggests that even the best prefetch strategies, which could include routing to specialty-specific web servers, would require that users pull from

the archive up to 10% of the time. Prefetch and caching strategies may be cost-effective up to a point, but the cost of anticipating and caching the unpredictable 10% may be prohibitive. The authors suggest that while rule-based routing and prefetching are valuable strategies, attention should be paid to assessing the capability of the enterprise archive to handle user-based real-time queries.