Technology Requirements for Image Management and Communication (IMAC) System in Medicine

Seong K. Mun, Ph.D.
Georgetown University Medical Center

Introduction

On a given day, the Department of Radiology of Georgetown University Hospital with 500 beds, handles 300-400 patient visits (in-patients and out patients), and generates approximately 1000 sheet of new film images. Images of previous studies, which are usually kept at several film libraries, are retrieved for physicians for comparison. Hundreds of film jackets containing thousands of sheet of films are manually handled daily. Sometimes the films cannot be located because they are checked out by others, misplaced, misfiled or stolen. Difficulties in the management of radiology films throughout a hospital are a constant source of frustration. Delays in getting images and associated diagnostic reports to the appropriate health care providers degrade the quality of radiology service. A number of problems exist in the operations of radiology service because the image media is film. The conventional approach of adding more people, space, and money to solve these problems has not produced satisfactory results. It is doubtful that the average radiology department can afford to continue to function in a predominantly manual mode for many more years.

Over the past two decades new imaging technologies such as MRI, CT, SPECT, and ultrasound have given the radiologist a powerful set of new diagnostic tools, but on the other hand the quality of radiology service has not experienced similar revolutionary improvements over the same period. In fact, the use of many imaging modalities has imposed additional difficulties in the management of films and data because: (a) they are often produced in physically distant locations, (b) images are presented in a variety of film formats, (c) radiology service has become highly subspecialized causing a greater need to review multimodality images, and (d) within large and complex medical care facilities there is an increasing number of competing demands for radiological images.

From a clinical perspective, there are several potential problems in the film-based environment which result in poor service. First, a delay may occur in scheduling an examination. Once an examination has been completed, several factors may delay or adversely affect the quality of the report. These include both delays in accessing either current films or older images and missing previous studies. Since a single sheet of film cannot be in two places at once, the availability of films currently in use is also problematic. This is potentially more important when multimodality comparisons are required. Finally, the current workload on a radiologist may affect report generation time.

Delays in getting radiologic procedures and reports completed can result in delays in patient care, and, if the referring physicians become too frustrated by such delays, the radiologist's professional role may be affected. Improvements in radiology service can have a positive impact in patient care which in turn makes the radiology service that much more effective.

During a baseline study at Georgetown University Hospital in 1987 we found that 9% of films were unavailable when requested. The reasons for this are that they may be in another department or signed out for multimodality correlation, used for educational and research activities, in transit, misfiled on shelves, misfiled in the wrong jacket, given away, or stolen. Some of these problems are virtually impossible to resolve (e.g., misfiling in the wrong jacket, given away) in a film-based service.
Unavailable films cause a loss of productivity among radiologists, the clerical staff, the technical staff, and referring physicians and their staffs. Unavailable films also cause misuse of expendable supplies such as film and chemicals, and misuse of the equipment resources used in film duplication.

When a diagnosis requires a multimodality correlation study, reporting is often delayed due to difficulties in collecting related images from various imaging systems. This creates a delay between the completion of a procedure and reading.

One solution to the problem of missing files is to duplicate film files, thereby increasing space requirements. Also, the report process is frequently hindered by the unavailability of films, so the match-up of reports and films is incomplete, forcing the duplication of files in many departments.

The management of the vast amounts of medical images and information generated by today's clinical services is a growing problem. Solutions to the problem will increasingly require the use of advanced technologies which include data storage, image display, communications, and human engineering. A new concept that is gaining momentum to address this image management problem in radiology is the Picture Archiving and Communication System (PACS) or Imaging Management and Communication (IMAC) System.

Image Management and Communication System

Over the past two years Georgetown University and the University of Washington have been implementing image management networks based on AT&T's CommView®. While the implementation is still under way, partial implementation has provided valuable experiences. The status of digital approaches to radiology image management is highlighted here.

Georgetown configuration: The Georgetown configuration consists of five groups: acquisition devices, the central database, display devices, a teleradiology link, and a research environment. Fiber optic cable at 40 Mbps is the primary communication medium for this network. Three acquisition modules link 2 CT, 1 MR, 3 Ultrasound, 2 film digitizers, and computed radiography (CR) AGFA to the database, which uses mirrored magnetic storage and an 89 platter optical jukebox archive. Approximately 3000 frames of images are acquired digitally every day. Display is via three 4-screen (with parallel transfer disks), one 2-screen, and four 1-screen enhanced graphic display workstations, located in Neuroradiology, Abdominal Imaging, Ultrasound, General Radiology, Pediatric Intensive Care Unit, Neonatal Intensive Care Unit, a Surgical Intensive Unit, and Nuclear Medicine. The most workstations support 1000 line x 1200 line displays handling 2000 x 2500 x 12 bits of data set. The network is interfaced to a hospital information system.

The research environment includes SUN, PIXAR, PIXEL, DECSTATION, and links to other departments and physicians' homes.

Technology Requirements

Technology requirements for IMAC has a different origin from those of other diagnostic imaging devices. IMAC technology is not an income generator and it is difficult to pinpoint a disease that IMAC can diagnose or treat, therefore it is not a billable activity. Funds to support IMAC must come from existing financial resources that are already under enormous stress. IMAC installation is seen more as a infrastructure performing support functions. For diagnostic systems many new specialty products can be developed and marketed, because these costs can be easily justified. However, IMAC is very price sensitive and for the IMAC project, one must use commercially available technology that is supported by a larger commercial market. IMAC is not a single device, it is a collection of devices on a network that must perform a variety of tasks. In a way it is similar to any other data management technology except that IMAC deals with greater data volume, highly responsive workstations displaying large matrix with
greater dynamic range. The users are some of the highest paid professional that demand speed and speed. It is, therefore, difficult to pinpoint a single technology that will make the concept of IMAC totally acceptable. One other cost related issue is the cost of the basic entry level building block. As any other networks, the utility of the network improves as the network provides more comprehensive coverage. This means greater investment before any benefits can be realized. This manuscript attempts to address a range of technologies that will have significant role in IMAC.

**Digital Imaging System:** Many new imaging systems such as MR and CT are already in digital format, but the bulk (70%) of radiology work still involves conventional x-ray imaging. There must be an acceptable method of acquiring digital radiography. So far, computed radiography (CR) based reusable phosphor plate is the best alternative for digital radiography. It has some limitations in the spatial resolution especially for a small pneumothorax. A system with higher resolution without compromising contrast resolution is needed for digital radiography. Currently a single CR image requires 50 Mbits (2000 x 2500 x 10 or 12 bits). In some cases it may be necessary to go beyond current matrix size for a 14 in x 17 in field of view. Additional work in direct digital capture is needed and it has been proposed that sampling pitch of 100 micron with 12 bits of contrast scale should cover 98% of the performance of the film.

Interfacing existing digital imaging modalities is still a significant problem, more so on one product line over the other, because, these devices were never designed with communication capability in mind. A standard interface called ACR/NEMA is being developed, but they are not readily available as yet. Again the small size of the market keeps the cost of specialty interface units very high. Currently it could cost $100,000 to interface a CT scanner to a network.

**Storage:** A hospital such as Georgetown generated 5 Terabytes of images per year and image must be kept for at least 5 years. A large archive with high information density is needed for at least 20 Terabytes of storage. High access speed to an archive may not be necessary in radiology because, the most of image transactions are scheduled, therefore image retrieval from the archive can be made according to schedule. Recently optical tapes and digital tapes show a great deal of promise as the price for bytes come down. Depending on the network design, there can be a number of storages devices on a network; archive, active storage, interface units, imaging systems, and workstations. Management of these storage devices requires complex data base management software.

While the virtue of centralized archive is well understood, in some cases distributed or individualized archive may of more beneficial. A number of studies are underway to compare various method of archive management.

**Data Compression:** Large amount of scientific data has demonstrated that radiologists cannot distinguish the difference in diagnostic image quality when the images have been compressed to 15:1. However, there is still some clinical resistance to accept irreversible compression.

Implementation of compression methods throughout the network is however a very complex engineering task. Certain images, such as MR and CT should not be compressed for we have to preserved the numeral values of each PIXEL. Other images may be compressed in a fully reversible method. These various scenarios pose a greater challenge to the network designers.

**Database Software:** The database structure allows for smooth retrieval of single cases by name or identification number, but no relational search features are available as yet mainly because, it is difficult and time consuming to enter the extra data fields into the data base at the time of image acquisition. The data base of a IMAC network must be integrated with either a radiology information system or a hospital information system.

**Network and Communication:** The network performance depends on many factors; speed of Central Procession Unit (CPU), Digital Communication Service Unit, Disk I/O speed, communication
protocol and signalling rate. IMAC network will utilize all types of communication technology depending on applications. In most cases in the United States, medicine is practiced within the commuting distance, not requiring a long distance communication. In special cases, such as the military health care system, long distant communication and global communication of diagnostic images are required. The medical field alone is not big enough to support a special communications technology. If smaller images (MR, CT and Nuclear Medicine) are involved, 19.2 modem may be adequate, but for Chest images at least a T-1 rate is desirable. The communication speed requirements will be determined by the work load. Within a hospital, a high speed network (100 Mbps) can serve as a communications backbone. Once high speed ISDN or FDDI capabilities are readily available at an affordable cost, such long distance communication may be used more in medicine and it could have significant impact in medicine, but is it difficult to speculate what impact might it might have on patient care and the practice of medicine.

**Workstations:** In our earlier work, our primary focus in workstations was to improve image display and communication speed. Once we achieve that, many other problems surfaced. Workstation requirements will be discussed by Dr. Kim later in this session. A couple of operational issues are discussed here. Workstations must be a single point of contact for physician and it must provide services that paper or film cannot. This means the network service for the workstations must be comprehensive in terms of types of accessible data. The single point of contact (SPOC) workstations should provide access to images, reports, lab results and all patient care information.

Workstations must do more than just display images. They must assist the physicians to work more accurately, consistently and efficiently. Integration of computer aided diagnosis (CADx) into a workstation will enhance the utility of this expensive technology. There is a degree of variability among the radiologists and their performance can vary from one day to another. If the use of CADx can reduce such variability, it could be a powerful inducement to move toward digital environment.

**Impact of IMAC to the Design of Imaging Systems:** Digital imaging systems of today are self contained in its capabilities which include, archives, workstations, and some communication capabilities, and hard copy devices. As these devices become networked together some of these duplicated functions can be supported by a shared capability, eventually reducing the cost of each device. Imaging devices can eventually become an efficient data collection and image reconstruction device. This has already happened in nuclear medicine, where a common computer system can support different gamma camera.

**Discussion**

Image management technology is indeed a systems engineering and a new way to conduct patient care activities in the hospital. Hospital as a whole will gain a great deal of benefit, but the transition to total IMAC environment will not be easy. Whenever a new information system is implemented, there is a redistribution of efforts. Some may have to do more than others. This creates a great deal of resistance for change. Others may take the attitude of "This is not my problem."

The IMAC system should set a higher goal than trying to compete with films and paper. It must provide clear advantage over the existing film system at a comparable price. No single technology can make or break IMAC concept. It has to be viewed from a total systems engineering and operational engineering perspective. One should avoid using too many specialized products to reduce the cost.

Many of the current devices that are useful for IMAC still do not have proper communication capability. They need to be upgraded to support operational and management efficiency. Certain smaller applications of IMAC technologies have proved to be cost effective and clinically desirable. The use of teleradiology is becoming very popular and provision of digital portable images to intensive care units within a hospital is also well received. These two applications can be considered as a first step toward a comprehensive IMAC network in the future. More time, effort and ingenuity is required before an affordable total filmless radiology department becomes a reality.

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