Integration, Acceptance Testing, and Clinical Operation of the Medical Information, Communication and Archive System, Phase II

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The Medical Information, Communication and Archive System (MICAS) is a multivendor incremental approach to picture archiving and communications system (PACS). It is a multimodality integrated image management system that is seamlessly integrated with the radiology information system (RIS). Phase II enhancements of MICAS include a permanent archive, automated workflow, study caches, Microsoft (Redmond, WA) Windows NT diagnostic workstations with all components adhering to Digital Information Communications in Medicine (DICOM) standards. MICAS is designed as an enterprise-wide PACS to provide images and reports throughout the Strong Health healthcare network. Phase II includes the addition of a Cemax-Icon (Fremont, CA) archive, PACS broker (Mitra, Waterloo, Canada), an interface (IDX PACSlink, Burlington, VT) to the RIS (IDXrad) plus the conversion of the UNIX-based redundant array of inexpensive disks (RAID) 5 temporary archives in phase I to NT-based RAID 0 DICOM modality-specific study caches (ImageLabs, Bedford, MA). The phase I acquisition engines and workflow management software was uninstalled and the Cemax archive manager (AM) assumed these functions. The existing ImageLabs UNIX-based viewing software was enhanced and converted to an NT-based DICOM viewer. Installation of phase II hardware and software and integration with existing components began in July 1998. Phase II of MICAS demonstrates that a multivendor open-system incremental approach to PACS is feasible, cost-effective, and has significant advantages over a single-vendor implementation.

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THE MEDICAL INFORMATION communication and archive system (MICAS) is a multivendor incremental approach to picture archiving and communications systems (PACS).¹⁻³ It is a multimodality integrated image management system that is seamlessly integrated with the radiology information system (RIS). Phase I was installed in February 1997. MICAS is designed as an enterprise-wide PACS to provide images and reports throughout the Strong Health healthcare network. MICAS

has demonstrated that a multivendor open system incremental approach to PACS is feasible, cost-effective, and has significant advantages over a single-vendor implementation.

The primary objectives of phase II of MICAS are to select and install a permanent archive⁴ automate workflow, convert the viewing software from the UNIX to Microsoft (Redmond, WA) Windows NT operating system, and demonstrate plug-and-play Digital Imaging and Communications in Medicine (DICOM).

PHASE II IMPLEMENTATION

Phase II implementation of MICAS was started in July 1998 with all components adhering to DICOM standards. Phase II includes the addition of a Cemax-Icon (Fremont, CA) archive, PACS Broker (Mitra, Waterloo, Canada), an interface (IDX PACSlink, Burlington, VT) to the RIS (IDXrad), plus the conversion of the UNIX-based redundant array of inexpensive disks (RAID) 5 temporary archives in phase I to NT-based RAID 0 DICOM modality specific study caches (ImageLabs).

The radiology network was updated. Due to an insufficient number of external internet protocol (IP) addresses on radiology's subnet, the IP addresses of all MICAS-related devices were converted to internal. An additional 100-Mbit vane was added to the existing Cabletron (Rochester, NH) SmartSwitch 6000 so that all components of MICAS, with the exception of the modalities, are fast-ethernet. All components of MICAS are directly connected to the Cabletron SmartSwitch resulting in a star network topology. Figure 1 is a flow diagram showing the components and data flow for phase II of MICAS.

The phase I acquisition engines and workflow management software were uninstalled and the Cemax Archive Manager (AM) has assumed these functions. Magnetic resonance (MR), computed tomography (CT), computed radiography (CR), nuclear medicine, and a film digitizer are the modalities interfaced with phase II MICAS. To improve workflow and to minimize data entry

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MICAS PHASE 2

Fig 1. Component and data flow diagram for phase II of MICAS. MICAS will be connected to the University enterprise-wide network during 1999 to provide studies throughout the Strong Health healthcare environment.

errors at the CT, MR, and CR modalities, the Mitra Relays, a modality worklist manager,⁵ was installed.

The archive includes Cemax-Icon Archive Manager Version 3.5 operating on a Sun (Mountain View, CA) Enterprise 450 with 1 GB of RAM, a Digital Equipment Corp (DEC, Nashua, NH) RAID 450 with 162 GB operating as RAID 5. Also included is an ATL (Milipitas, CA) DLT 7000 jukebox with two drives and 28 tapes (70 GB per tape lossless compressed), which can be expanded to four drives and 52 tapes for a total capacity of approximately 3.4 TB of data (lossless compression of 2) and a Mitra PACS Broker. The patient demographics and 7 to 10 days of images are stored on the RAID. The ImageLabs study caches provide approximately 30 days of modality specific storage in RAID 0 configuration. The CT and MR study caches are 54 GB each, the ultrasound study cache is 24 GB, and CR, nuclear medicine and digitized films share a 24 GB study cache.

The existing ImageLabs UNIX-based viewing software was enhanced and converted to an NT-based DICOM viewer. The enhancements included a new query and retrieve paradigm for improved workflow, reducing the user's eye movement and number of mouse clicks for a specific task and key images with annotation. DICOM compliant viewing software interacting with the AM and study caches from two other vendors are being tested and

will be incorporated where appropriate into the MICAS enterprise.

OPERATION OF PHASE II MICAS

Images are acquired from each of the respective modalities by the AM or the Mitra Relay and validated against the RIS demographics. They are then stored in the archive's RAID 5 and automatically routed by the AM to the specific modality's RAID 0 study cache. The prior patient's studies are automatically prefetched by the AM during the night and then routed to the appropriate study cache. When a patient is added to the schedule during the day, the RIS automatically notifies the AM via the PACS Broker and the add-on patient's prior studies are fetched and loaded onto the RAID 5 and appropriate study cache prior to a radiologist interpreting the current study.

The study caches are used to reduce the number of queries to the main archive and to provide approximately 30 days of fast retrieval. At present, the user queries the study cache from the ImageLabs viewer. It is planned that the study caches will automatically route studies directly to the ImageLabs workstation. If the study does not reside on the study cache, it can be retrieved from the Cemax jukebox. The viewer can query the Cemax demographic database and obtain a list of all the studies that have been archived for a patient. The user can then fetch the required studies from this list.

Within 24 hours of a study being acquired, the AM copies the study to the jukebox and automatically writes a backup bit file of the study to one of the four tapes reserved for this purpose. When one of these tapes is filled, it is removed from the jukebox and stored in a secure place away from the computer room. Thus, within 24 hours of acquiring a study, four copies of the study exist. Also, during the night a backup of the demographic data on the RAID is made.

Mitra Relays are being "beta"-tested, which provide the functionality of a modality worklist manager and acquisition engine. This device will improve operational efficiency by eliminating discrepancies between the demographic data provided by the RIS and data entered at the modality. The Relay is located at the modality workstation and incorporates local storage and DICOM routing capability, which provides a degree of redundancy and fault tolerance should the AM become overloaded or fail.

INSTALLATION AND ACCEPTANCE TESTING

Installation of phase II hardware and software and integration with existing components began the middle of July and was completed by the end of 1998. Initially, there were some problems with components from different vendors communicating with each other; however, the vendors worked together to resolve the problems. There was minimal interruption of normal workflow in the department considering that CT, MR, CR, and nuclear medicine were interfaced to the AM. Validation of vendor interfaces and acceptance testing is underway and is planned to be completed by the end of February 1999 with clinical operation to begin in March 1999.

The acceptance testing of MICAS includes testing of all components and the verification that no data are lost or corrupted during the transmission of data from one component to another. Detailed acceptance testing criteria were agreed upon prior to issuing purchase orders and forms the basis for the acceptance test. A partial list of the tests to be performed include:

- Comparison of the number of studies scheduled and performed by modality and room based on the RIS data to the number received by the archive, to those routed to the study caches and retrieved at the workstations. The number of series in each study and the number

of images in each series must also be validated.

- Study reconciliation.
- Patient orientation and measured values such as pixel values including Hounsfield number, distance in mm and angle verification.
- Transfer of demographic and study data from the RIS via the PACS Broker to that which is displayed on the studies at the workstation.
- Verification of the storage, retrieval and query/retrieve DICOM functionality.
- Verification of fetching, routing and compressions rules.
- Verification of study migration, backup and restore functions.
- Study and patient event changes that impact the functionality of the system.
- Verification of the fail safe and error notification features of the archive and other system components.

Lessons learned from the installation, integration and acceptance testing of phase I of MICAS were most helpful in implementing phase II. The second phase of MICAS was much easier to implement than phase I, even though more vendors and modalities were involved. The time and personnel required to upgrade the infrastructure and perform the necessary testing was significantly under estimated.

FUTURE ENHANCEMENTS OF MICAS— PHASE III AND BEYOND

During the second quarter of 1999, an ultrasound mini-PACS will be seamlessly integrated with MICAS. Also during 1999, the second phase of the archive will be installed,^{6,7} which includes a second Sun Enterprise 450 or equivalent, Cemax AM Version 4 and a second RAID in a separate computer room. The existing ATL jukebox will be expanded to four drives and 52 tapes and the networking and infrastructure will be upgraded and expanded to provide a significant degree of fault tolerance and redundancy for the MICAS. When the ATL jukebox is 80% to 90% full, probably in the year 2000, a second jukebox will be purchased, most likely DLT 12000 media with a capacity of 200 GB per tape lossless compressed or 20 TB for a 100-tape jukebox. It is planned that MICAS will be connected to the University enterprise-wide network during 1999.

SUMMARY

Phase II of MICAS with multiple vendors involved in all aspects of the system demonstrates that this approach to implementing PACS is both feasible and cost effective, however, requires a significant investment of personnel. To implement this approach to PACS it is most important to develop mutual trust and cooperation between the institution and the vendor as well as between all vendors involved in the project.

The advantages of this approach include (1) Validation of DICOM compliance of the system as each component is integrated with the system—the “plug and play” DICOM concept; (2) keeping up with the technological and clinical functionality curve without being dependent on the primary PACS vendor; (3) being able to select an open and

scalable hardware platform rather than having to accept the platform used by the software vendor provides obsolescence protection and flexibility in system development; (4) cost savings resulting from buying components as needed and being able to buy components in a competitive environment rather than being locked into a single vendor; and (5) leveraging the core competencies of each vendor—no single vendor can provide the “best of breed” solutions for all components of PACS.

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