SESSION 4A: Electronic Systems Applications: Enterprise

The Use of Digital Imaging and Communications in Medicine (DICOM) in the Integration of Imaging into the Electronic Patient Record at the Department of Veterans Affairs

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The US Department of Veterans Affairs (VA) is using the Digital Imaging and Communications in Medicine (DICOM) standard to integrate image data objects from multiple systems for use across the health care enterprise. DICOM uses a structured representation of image data and a communication mechanism that allows the VA to easily acquire images from multiple sources and store them directly into the online patient record. The VA can obtain both radiology and nonradiology images using DICOM, and can display them on low-cost clinician's color workstations throughout the medical center. High-resolution gray-scale diagnostic-quality multimonitor workstations with specialized viewing software can be used for reading radiology images. The VA's DICOM capabilities can interface six different commercial picture archiving and communication systems (PACS) and more than 20 different image acquisition modalities. The VA is advancing its use of DICOM beyond radiology. New color imaging applications for gastrointestinal endoscopy and ophthalmology using DICOM are under development. These are the first DICOM offerings for the vendors, who are planning to support the recently passed DICOM Visible Light and Structured Reporting service classes. Implementing these in VistA is a challenge because of the different workflow and software support for these disciplines within the VA hospital information system (HIS) environment.

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THE VETERANS AFFAIRS (VA) health care enterprise consists of a nationwide network of 172 VA Medical Centers (VAMCs) and numerous outpatient clinics serving a patient population of 25 million veterans. The VistA hospital information system (HIS) is used at all of these sites. VistA is a comprehensive HIS that supports all the clinical services. For example, the radiology information subsystem (RIS) is one of more than 50 different clinical specialty modules that make up VistA. Imaging is an integral part of this HIS. All of these applications share a distributed Microsoft (Redmond, WA) Windows-based client-server network architecture, a central database technology, and a common software development environment.

The VistA HIS and RIS provide extensive sup-

port for imaging and contain a full image management infrastructure.¹ Image acquisition, exportation, display, networking, long-term archiving capabilities, and integration with the clinical database are all supported. VistA handles a variety of image color and gray-scale image objects for different medical specialties. Clinicians use low-cost workstations to access the entire online computerized patient medical record, including all images and electrocardiograms. Radiologists can use a diagnostic-quality reading capability that is totally integrated with the RIS, resulting in a seamless operation and a streamlined workflow.

The VA has almost a decade of experience acquiring non-Digital Imaging and Communications in Medicine (DICOM)² images in nonradiology disciplines and considerable experience with DICOM for radiology. About a half million non-DICOM images have been acquired for the 20 or so disciplines, while about 9 million radiological DICOM images have been obtained. Handling DICOM images outside of radiology is quite new.

In the VA, DICOM is used to handle all transfer of text and image data between these systems. The acquisition device obtains patient and study identification information from the RIS or the HIS and associates it as image-specific information with the image data object. The picture archiving and communication system (PACS) associates the image data with study and patient data obtained from the RIS or the HIS. The VA's HIS associates the image data with the patient's other online medical record data.

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VISTA IMAGING ARCHITECTURE

Integration of Imaging With the Computer-Based Patient Record Subsystem

An important factor in the success of Vista Imaging is its integration with online clinical information from many specialties. The VA-developed computer-based patient record subsystem (CPRS) software is a bidirectional Windows-based electronic patient record application that runs on the clinician's workstation. All of the patient's orders, medications, reports, laboratory values, etc are easily accessible via CPRS. Cumulative laboratory results are available in either tabular or graphical formats in CPRS, and orders and progress notes may be reviewed and updated as well.

The image display application works in conjunction with the CPRS subsystem, allowing the entire patient medical record to be displayed at the workstation. Pointers within the database link the image data to the patient and study data, making it possible at a clinician's workstation to view the textual report in one window and the associated images in another. While using CPRS, electrocardiograms and thumbnail images associated with reports automatically appear. The clinician has only to mouse click on the thumbnail to see the full size images (Fig 1).

Fig 2. VistaA multimedia object database schema.

Database Schema

A common object-oriented approach is used for interfacing all multimedia data to the online patient record. Image management information is stored in the Vista HIS database, in the same manner as all of the rest of the patient text data.

Information about each image is stored in a multimedia object table. Each image entry in the table points to an image file stored on a server outside of the HIS database. The image entry also contains information about the object type and the patient. Figure 2 shows three image objects in the multimedia object table. Each image object points to its corresponding image file.

A set of related multimedia objects are collectively joined together into a multimedia group. The

Fig 1. Integrated clinical workstation.

multimedia group is then associated with the specific patient study data record, for example, a radiology report, a medicine procedure, or an ophthalmology note. This association allows the user to navigate from the patient to the images and then to the corresponding study, or from the patient to the study and then to the corresponding images. In Fig 2, the three image objects are joined together to form a multimedia group in the multimedia object table. The multimedia group is associated with a medicine procedure in the medicine procedure table. Other studies in the radiology report table and the progress notes table are associated to other multimedia groups in the multimedia object table.

VistA can handle many other types of objects besides DICOM.

VISTA DICOM DATA FLOW

A VistA DICOM gateway enables the VistA HIS to communicate using the DICOM protocols. The gateway application runs on an NT workstation and has access to the VistA HIS system database. The gateway performs all the DICOM services and can send and receive text data and image data.³⁻⁵

Flow of Image Data Objects Between Modalities and HIS

In order for a DICOM image to be properly matched to its corresponding study, it must contain the correct HIS/RIS patient and study identification information. The VA requires the patient name, patient identifier (social security number), and study accession number to be present in each DICOM image header, in order for the image to be properly associated with the correct patient and study. Image-producing modalities need to have this data before performing the study so that it can be placed into the image headers.

The DICOM modality worklist service allows an image producing modality to query a service provider to obtain this information. The VistA DICOM text gateway provides the DICOM modality worklist service, and maintains a list of all imaging orders that are active on the HIS. The modality can query the VistA modality worklist provider to obtain the information on the active requests.

The VistA modality worklist provider can also use the patient database directly as a source of information for the modality worklist service. This capability allows the VistA modality worklist pro-

vider to supply information about old studies when old films are being scanned. The ability to access the patient database is one of the important benefits of the integration of the VistA modality worklist provider with the HIS that is not available to stand-alone commercial units.

The VistA DICOM image gateway can acquire DICOM images from any source and send DICOM images to any destination. It can also interrogate an external DICOM image storage system and obtain images from it.

Images that are acquired by the VistA DICOM image gateway are matched to the corresponding patient and study on the HIS/RIS. Management information about the image files is stored in the main hospital database. The images are then stored on centrally located NT file servers, where they can be accessed by VistA image display applications running on Windows workstations located throughout the facility.

Flow of Image Data Objects Between Commercial PACS and HIS

Commercial PACS need to have HIS/RIS event data in order to operate efficiently. The VistA DICOM text gateway supplies the following set of text information messages to the commercial PACS: patient demographic change; ADT (admission, discharge, and transfer); order entry (when a patient arrives for an examination); examination changes (cancels); examination verification (completion of image acquisition); and report transfer (preliminary and final).

All images on a commercial PACS are "pulled" to the VistA system by the DICOM image gateway. The images are then added to the online patient record so that they can be displayed on clinical workstations throughout the facility. The capability to display image data as an integral part of the online patient record is essential in enabling a hospital to operate filmlessly.

DICOM FOR NONRADIOLOGY MODALITIES

We are just beginning to interface DICOM imaging modalities outside of the Radiology Department. We acquired about a half million non-DICOM frame-grabbed color images for the nonradiology services over the last decade and have developed the techniques of integrating images into the online patient record. This is more complicated than it may appear. In VistA, the way the study data

is stored is different for each specialty. Workflow is different too, particularly in terms of order placement and examination. Some specialties routinely report their findings using progress notes, while others use structured data, and others (primarily radiology) use unstructured report text. Interfacing DICOM image acquisition to the whole HIS is a bit more challenging than just doing the radiology portion alone.

Design Changes Needed to Support DICOM for Nonradiology Modalities

We encountered several areas where design changes were necessary to support DICOM for nonradiology modalities.

Workflow issues. One major issue involved differences in data content in the HIS or specialty subsystems as compared with the radiology subsystem. Outside of radiology, our HIS does not provide workflow event transactions for most of the imaging procedures. Within radiology, because of the volume and complexity of the process, there is well-developed workflow software that generates notification transactions for each step in the processing of a study. In radiology, these transactions track the state of each active study and are used to maintain the modality worklist database. In the nonradiology specialties, however, there are few event transactions, because the small volume of studies and the less complex process has not justified that degree of workflow software development of the HIS. There are many nonradiology procedures where separate orders are not routinely placed. In order to deal with this, we first changed the workflow to create a unique identifier for the study and then modified the VistA modality worklist provider to obtain this information from the main hospital database. (This technique is similar to looking up an old study in the radiology database, mentioned above.)

Usage of object-oriented techniques. In the comprehensive VistA HIS, different clinical subsystems support different diagnostic disciplines. In order to support DICOM beyond radiology, we applied object-oriented techniques to our modality worklist and our image processing capabilities to map the diagnostic discipline to the corresponding clinical subsystem. We added an "imaging service" attribute to the image acquisition device database schema to identify the diagnostic discipline using the instrument. The value of the "imaging service"

attribute is used to select the corresponding method for modality worklist lookup, and is used in image processing to determine the "accession number" lookup method, as well as how to associate the image(s) with the corresponding diagnostic discipline patient report (Fig 2).

Change in image display order. Some studies require two (or more) procedures, for example, a gastrointestinal examination that includes fluoroscopy and endoscopy. All images are interpreted by the same specialist and findings are contained in a single report or progress note. The images from both of these procedure steps are obtained intermixed together. We found it to be highly desirable, however, that all the fluoroscopic images be displayed separately from all the color endoscopic images. We accomplished this by creating a separate group in the VistA multimedia object table (Fig 2) for each set of images, and associating each group with the same patient report. This adds a level to the traditional DICOM "patient/study/series/image" hierarchy, forming a five-level hierarchy: "patient/study/study component/series/image," and is consistent with the real-world model in the latest release of the DICOM standard.⁶

Operational changes for DICOM image acquisition for nonradiology modalities. To obtain non-DICOM images with VA image capture software, the user goes into the VA image capture application on the workstation, selects the patient and the study (or creates the study), and acquires the images. Image acquisition may automatically create a record of the procedure on the HIS, if its not already there. The workstation interacts directly with the HIS. Comments about each image can be entered during the image acquisition process. Each image and its comments are immediately stored as part of the study in the patient record.

Using a DICOM interface is more complicated since there are at least three systems involved in the image acquisition process. A DICOM gateway (1) must supply patient and study identification to the image acquisition device; (2) the images have to be acquired by the acquisition device; and (3) then they must be sent to the storage provider. This workflow scenario requires that an order identifying the study be entered into the HIS before the procedure is done. Only then can patient and study information be transferred to the instrument by the modality worklist service. When a separate order is not routinely placed for a nonradiology procedure,

a user must either interact with the HIS to create a record of the procedure or interact with the image acquisition modality to enter the data manually.

Experience with vendors. The use of DICOM outside of radiology is still in its infancy, and many products are still in the early stage of development. Our first nonradiology DICOM instrument was a fluoroscope used in the gastrointestinal laboratory. We consider this to be a "nonradiology" device because the report and data are handled by a gastrointestinal information subsystem, not the RIS. The fluoroscope device required manual entry of patient and study information, and initially could only support fourteen characters of the patient name, eight characters of the patient identifier (social security numbers are nine digits long), and had no accession number! At the VA's insistence, the vendor subsequently accommodated more data in the DICOM image header and the unit became operational.

We are working with several nonradiology vendors who are using commercial DICOM toolkits. The degree of success of the implementation is very dependent on the maturity of the DICOM capability provided by the toolkit vendor. Also, vendors have varying involvement with the DICOM standards community, and this may be reflected in their products.

CONCLUSIONS

Integration of imaging within the electronic patient record is an important success factor at the VA. Our end-users want more than the traditional PACS consisting of stand-alone gray-scale imaging

systems. Clinicians want integrated order entry, result reporting, and image display applications on their workstations, so that they have complete online access to the patient's medical record. DICOM has been an essential ingredient in the success of the VA's image integration endeavors. Because of good HIS integration, the VA now has a successful imaging operation where about 90% of the images are provided by DICOM.

The modality worklist functionality is critical to identify the proper patient and study in order to be able to insert images into the longitudinal multimedia patient record. Because of this, the VA and other government agencies are now requiring this capability of all modality vendors.

The first use of DICOM outside of radiology is progressing slowly with varied success. It is clear that the key to success in the DICOM arena is for the nonradiology modality vendors to use well-developed commercially supported toolkits. Some vendors are further ahead than others. In order for DICOM to succeed outside of radiology, low-cost, high-quality toolkits need to be commonly available from many different sources. The nonradiology equipment vendors cannot charge an exorbitant fee for DICOM capabilities, since their products are far less expensive than the typical radiology instruments. The imaging toolkit vendors who are developing DICOM capabilities should become active members of the DICOM community. The opportunities for the use of DICOM outside of radiology are great, and it is possible that in the future we may see more instruments using DICOM outside of radiology than within.

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