DICOM Modality Worklist: An Essential Component in a PACS Environment

M. Elon Gale and Daniel R. Gale

The development and acceptance of the digital communication in medicine (DICOM) standard has become a basic requirement for the implementation of electronic imaging in radiology. DICOM is now evolving to provide a standard for electronic communication between radiology and other parts of the hospital enterprise. In a completely integrated filmless radiology department, there are 3 core computer systems, the picture archiving and communication system (PACS), the hospital or radiology information system (HIS, RIS), and the acquisition modality. Ideally, each would have bidirectional communication with the other 2 systems. At a minimum, a PACS must be able to receive and acknowledge receipt of image and demographic data from the modalities. Similarly, the modalities must be able to send images and demographic data to the PACS. Now that basic DICOM communication protocols for query or retrieval, storage, and print classes have become established through both conformance statements and intervendor testing, there has been an increase in interest in enhancing the functionality of communication between the 3 computers. Historically, demographic data passed to the PACS have been generated manually at the modality despite the existence of the same data on the HIS or RIS. In more current sophisticated implementations, acquisition modalities are able to receive patient and study-related data from the HIS or RIS. DICOM Modality Worklist is the missing electronic link that transfers this critical information between the acquisition modalities and the HIS or RIS. This report describes the concepts, issues, and impact of DICOM Modality Worklist implementation in a PACS environment.

KEY WORDS: DICOM, PACS, worklist.

DATA INTEGRITY is essential for successful implementation of an electronic medical record and for a picture archiving and communication system (PACS) installation. The absence of reliable data can increase the time required by a technologist performing quality control at a workstation or system administrator doing data repair at a system console. More importantly, unreliable data can impact directly patient care when images are labeled incorrectly and stored incorrectly on the PACS, rendering them incomplete, mismatched, unmatched, or simply missing.

Historically, acquisition modalities such as computed tomography (CT) scanners, magnetic resonance imaging (MRI) scanners, or ultrasound (US) machines have not supported communication links between the hospital information systems (HIS) or radiology information systems (RIS). When first introduced, even primarily digital modalities such as computed radiography (CR) relied on manual entry of demographic data into the modality control system. Early on, development of third party computer "brokers" provided a means of indirect communication between the modalities and the HIS or RIS when the information system was capable of providing the data from older protocols available on the HIS or RIS. In a film-based environment, typographical errors, formatting errors, or incomplete data entry might go unrecognized or uncorrected because these errors do not significantly affect work flow. In a PACS environment even minor errors in data entry can cause severe disruption of the work flow by rendering the images inaccessible. For example, a space entered at the keyboard instead of a hyphen, or an extra space between the first and last names, might render an accession number (the unique numerical identifier assigned to the examination by the HIS or RIS) unrecognizable to PACS. These minor deviations from precise data entry would not be confusing to a radiologist reading the flash card label on a standard radiograph or the data page from a digital acquisition device such as CT or MRI. The errors usually require manual intervention to repair so that work flow is not disrupted, and the electronic medical record remains accurate and intact.

Recent releases of radiology equipment are much more likely to have connectivity to HIS or RIS as an optional feature. The query for and retrieval of patient and study information are mediated by a process known as digital communication in medicine (DICOM) Modality Worklist. Acquisition modalities enabled with this option then function as a short-term digital information repository for the

From the Radiology Service (114), VA Boston Health Care System, Boston, MA.

Address reprint requests to M. Elon Gale, MD, Radiology Service (114), VA Boston Health Care System, 150 South Huntington Ave, Boston, MA 02130.

0897-1889/00/1303-0002$10.00/0

doi:10.1053/jdim.2000.8054

HIS or RIS along with the other more basic attributes of image acquisition and distribution. The communication of patient demographic and study-related data between the HIS or RIS and the acquisition modality is governed by DICOM standards. (*http://www.nema.org/nema/medical/dicom/*) in a similar manner to other DICOM image functions such as DICOM storage or print class standards.

The successful implementation of DICOM Modality Worklist requires 3 components: an acquisition device capable of implementing DICOM Modality Worklist, a DICOM Modality Worklist service provider, and a reliable network between them and the HIS or RIS.[1-3] Many newly manufactured acquisition devices have DICOM Modality Worklist available as an option, and some vendors have retrofitted existing equipment to provide this functionality. In other cases, third party worklist devices can be added to older acquisition devices, although these may not be as integrated with the modality as a native implementation. On the acquisition modality, a thoughtful, user-friendly design of the DICOM Modality Worklist interface also is crucial for a successful implementation. There are a few major commercial suppliers of independent DICOM Modality Worklist service interfaces. The Veterans Administration has utilized a DICOM Modality Worklist service provider directly integrated with its HIS.[4]

This report reviews from the perspective of a radiology user the implications of lack of data integrity without DICOM Modality Worklist, the basic networking requirements necessary for implementation, the common DICOM Modality Worklist interactions with DICOM Modality Worklist service providers, the requirements for an easy to use interface, and the benefits derived from DICOM Modality Worklist implementation.

SCOPE OF THE PROBLEM

The magnitude of the problem of unreliable demographic and examination data is to a large measure dependant on the rigor with which manual data entry at the modalities is adhered to by the technologists and the size of the installation. To assure study accountability or obtain additional study-related information, PACS may be designed to use or cross check HIS or RIS data with that received from an acquisition modality.[5] The key component for this cross checking is an accession number that provides the unique link between the physician order for a study on the HIS or RIS, the actual study performed on the acquisition modality, and the images associated with the physician's order and completed study on the PACS. Mismatches between the patient demographics (patient identification) or study data (accession number) provided to the PACS by the HIS or RIS, the gold standard, and those associated with the images provided by the modality typically cause the case to go into a holding area for manual correction on the PACS.

At our institution we have been utilizing PACS for nearly 3 years for computed radiography (CR) and for 2 years for all other modalities except mammography and angiography, which are still film based. Our system contains 3 remote sites connected via T1 telecommunication links, CT and MR scanners, gamma cameras, ultrasound machines, and multiple CR units. An analysis of mismatched cases for the first 10 months of 1998 for our PACS is shown in Fig 1. During this period, only CR utilized modality worklist, and as a result there were relatively few mismatches with this modality compared with the others. The presence of the low level of mismatches for CR during this period was caused by PACS network communication problems or downtime of the HIS that provided source data to the modality worklist. Beginning in mid 1998 and continuing through June 1999 DICOM Modality Worklist software was introduced on US, MRI, and CT (Fig 2).

DATA CORRECTION

Preventing or correcting mismatched cases usually is done at 1 of 2 stages in the workflow. Some modalities, such as CR provide a quality control workstation that functions as intermediary between PACS and the acquisition device. The intermediary may be configured to require the technologist to review each individual image or study before manually sending the case to PACS. If the mismatch has been recognized and identified, it is then possible for the technologist to correct it before submission. However, the quality control workstations are configured commonly to act as immediate and automatic conduits for temporary image storage along with DICOM format conversion or may not be used at all. In these configurations, it is not possible to correct mismatches at the modality-provided intermediary device because the technolo-

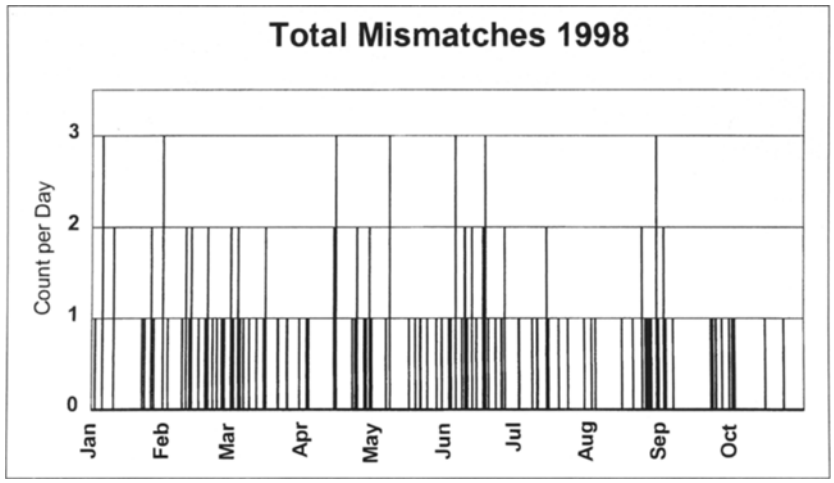

Fig 1. An aggregated bar graph of the total number of daily mismatches during the 10-month period shows a relatively even temporal distribution. The large number of mismatches require a significant amount of administrative time for correction.

gist does not have access to the images before image transfer. Other imaging devices such as CT, US, or MRI typically do not provide quality control workstations independent of the acquisition devices. When incorrect demographic or study-related data are entered into these devices, it is difficult, if not impossible, to prevent the erroneous data from reaching the PACS once scanning has commenced.

Correcting most mismatches often is done on the PACS rather than the acquisition modality or associated workstation. This occurs because the examinations typically are not stored long term on the modalities because of limited storage capacity and because the errors usually are not identified until the study reaches and is processed by the PACS. Reassembling and reassigning mismatched cases often requires multiple steps, depending on the root cause of the mismatch. Demographic typographical errors tend to be the easiest to repair because the errors are readily identifiable at the administrative console. Errors in which the images are assigned by the technologist to the wrong patient tend to require much more time, because these images must be viewed on the PACS and compared with others to ascertain the correct patient identity. Cases in which the HIS or RIS system is down and accession numbers do not exist at the time of the examination require an intermediate level of effort to repair because both the PACS

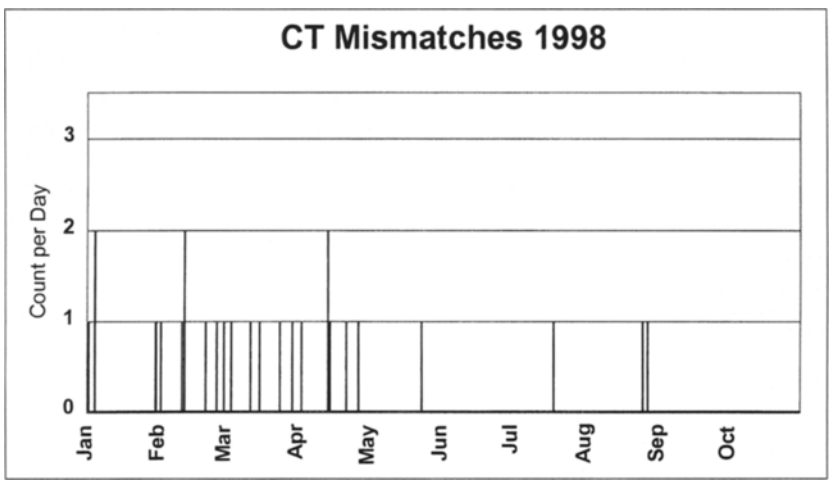

Fig 2. There are far fewer CT mismatches as shown on this daily mismatch bar graph after worklist was instituted compared with the number recorded during the first half of the time period without modality worklist.

and HIS or RIS databases must be accessed. Although these are the most common causes of mismatched studies in our experience, others exist.

OUR INSTITUTION'S EXPERIENCE

Most typical studies on our system required an average of 10 to 15 minutes to repair. At our site, a total of 126 mismatches were identified in CT, US, MRI, and CR during the 10-month interval during which we did approximately 48,800 studies (0.26%). This corresponds to approximately 20 to 30 hours of time spent in mismatch repair effort.

In addition to the effort required by the supervising technologist, mismatches affected the interpreting radiologist. When studies were mismatched, prefetch algorithms (that determine which images were retrieved from the archive), autorouting (which determines which workstations are sent the study), and screen display rules (which orders the images on the screen based on examination type) were all not operational.[6] This occurred because these PACS processes were dependent on information such as CPT code, ordering physician, or patient location, obtained from the HIS. If studies were not repaired immediately by the technologist, then the radiologist's workflow often was disrupted by the requirement for manual preparation (historical image retrieval, study retrieval from the server to the workstation, and screen assignment) of the case at the time of reading.

The acceptance and use of the DICOM Modality Worklist by the radiology technologists has been universal and overwhelming. Typically, when the technologists were first trained in the use of DICOM Modality Worklist, they perceived the system as an added step in their registration process without real benefit, because they were experienced typists for data entry. However, once they became facile with the worklist methodology, and recognized both the ease with which the systems were operated and the impact on decreasing mismatch repair time, they became strong supporters of the technology.

NETWORKING

Most modality vendors provide only a single network interface for the an acquisition device. This potentially can be problematic because PACS installations reside commonly on a network that is separate from that on which the DICOM Modality Worklist server and HIS or RIS system reside. Both the HIS or RIS and PACS system administrators generally prefer to maintain strict controls on data traffic between the 2. Therefore, the acquisition modality either must be placed on the PACS network and DICOM query requests routed through the interface between the 2 systems, or be placed on the HIS or RIS network and image information be routed in the opposite direction across the bridge between the 2. In general, the former configuration is used to minimize network traffic on the HIS or RIS.

Ideally, and for ease of installation, either the DICOM Modality Worklist server or all the modalities should have dual network interfaces, 1 for HIS or RIS DICOM Modality Worklist queries, and 1 for communication to the PACS. It is much simpler to have dual network capability on the DICOM Modality Worklist server than on each of the individual modalities. However, at least 1 CR vendor inherently provides this capability, because the DICOM query computer is different from the modality capture and transfer computer. Without dual network interfaces additional routers, along with their inherent configuration and reliability problems, are required.

MODALITY WORKLIST—DICOM MODALITY WORKLIST SERVICE PROVIDER INTERACTION TYPES

The DICOM Modality Worklist server must provide information to the modalities in DICOM format, but may itself receive information from the HIS or RIS in either DICOM or Health Level 7 (HL7) format (*http://www.hl7.org*). HL7 has been an HIS and RIS industry standard since 1987, and has been certified by American National Standards Institute (ANSI) as an accredited standards developer. Most major DICOM Modality Worklist server suppliers support information HIS or RIS links with either DICOM or HL7 format.[7]

In a typical configuration, the modality queries the DICOM Modality Worklist server in 1 of 2 ways. The query occurs either when the operator interactively requests the update or when the operator indicates on the modality interface that a new patient is about to be examined and thereby triggers the modality to automatically request the update. In few implementations, the acquisition modality automatically queries the DICOM Modality Worklist server but at a scheduled time interval. Each method has its advantages and disadvantages and

uses that are tempered by the requirements of the routine operation of each modality. With DICOM Modality Worklist, data are sent only from the worklist server when requested by the worklist modality client, and, therefore, network utilization is most efficient.

FILTER AND SEARCH CRITERIA

The information provided to the modality by the DICOM Modality Worklist server must be filtered appropriately. The worklist server should be configured to provide only CT requests to CT scanners, MRI requests to MR scanners and so on. In some cases the worklist server and modality client may limit the data to a specific piece of modality equipment rather than to the broader category of imaging type. The larger the overall workload of the PACS and the radiology department, the more filtration is essential. Modality worklist screens all have a limited amount of display area without using scrolling or paging. To be most efficient, the display should only encompass those examinations that potentially might be selected on the modality, and at the time when the study is being done. Search criteria using a DICOM Modality Worklist query therefore should be limited by the filtering criteria.

The worklist should be searchable by several different parameters, depending on the circumstances. These parameters include accession number, patient name, patient identification number, request date, and procedure name. In some cases, a search evaluates the data that already have been transferred to the modality by a previous broad search (eg, all cases registered for a specific day). In other cases, querying the DICOM Modality Worklist searches for and returns from the central worklist server database a specific case.

The most essential search requirement is the capability to find a specific accession number, because this number uniquely identifies all aspects of the examination and thereby maps to all the patient demographics. An accession number–specific search minimizes the interactive process for the technologist because the unique patient and study data automatically populates the acquisition device data fields. This process avoids a second selection step on the modality and another possibility for error.

Unfortunately, in early implementations some modality vendors did not provide appropriate retrieval and storage of accession numbers and assumed that patient name or identification number would be sufficient. Without accession number handling, a search may be made for the patient, but the results may provide confusing information for the technologist because a patient may have more than 1 pending examination in a given imaging type on the HIS or RIS. For example, when a trauma patient with multiple CT scan requests is searched for by patient, the worklist server responds with multiple options, rather than with an unique examination. And if the modality display does not provide the procedure name or other sufficiently distinguishing information in the retrieved data, the technologist may select the incorrect association at random from the available examinations for the patient.

In a very broad query, a list of all possible pending entries is retrieved and then stored on the modality. The technologist selects the correct case from the locally stored list. Typically, this list does not contain the entire universe of ordered items but is limited to the appropriate imaging type, CT, MRI, or CR so that extraneous cases do not obscure the possible selection candidates for that modality. An advantage of this type of query occurs when the HIS or RIS system is unavailable for scheduled or unscheduled down time. Under these circumstances, when no additional demographic data can be retrieved, recent data remain available in a modality-based local database cache.

In an intermediate type of query, wildcards can be used to restrict the retrieved data to a patient name or identification (ID) number that matches in some portion the full name or number. For example, the name *Smith* might be searched by entering *Smi* or *Smi**, or the patient ID *123456789* might be queried using *1234* or *1234** or **567**. This may be quite helpful when there are a limited number of possible cases, and supplying partial information is sufficient to uniquely match the search criteria. Although this intermediate query is useful and sometimes available, it may violate the formal DICOM standard for unique patient matching. Therefore, in many instances, the wildcard search is conducted on the modality itself using the already retrieved local database.

It also is important to be able to search by request date. In some instances, patients may arrive at a time either much earlier or later than their scheduled appointment when registration may not have

been performed yet or may have been deleted from the HIS or RIS. The ability to search for all requests or scheduled examinations by date is a useful tool in the practical setting of patients arriving unexpectedly without an accession number having been generated.

SORT AND DISPLAY CRITERIA

The DICOM Modality Worklist display should contain the same 5 essential data elements that comprise the ideal search parameters: patient name, patient identification number, examination accession number, procedure name, and request date. Another useful way to sort cases is by complete or incomplete status. The worklist display should be able to be sorted in ascending or descending numerical or alphabetical order for each of the data elements. Additional data elements such as allergies and common procedure terminology (CPT) codes may be useful additions to the worklist but should not be provided at the expense of limiting visibility of the essential 5 data points. Most current vendor implementations provide 3 to 5 of the 5 data fields on their displays. Sorting on the acquisition modalities is available to a variable degree depending on the specific implementation.

USER INTERFACES

Interface design for DICOM Modality Worklist is as crucial to successful implementation as successful networking and messaging between computer systems. A poorly designed interface can

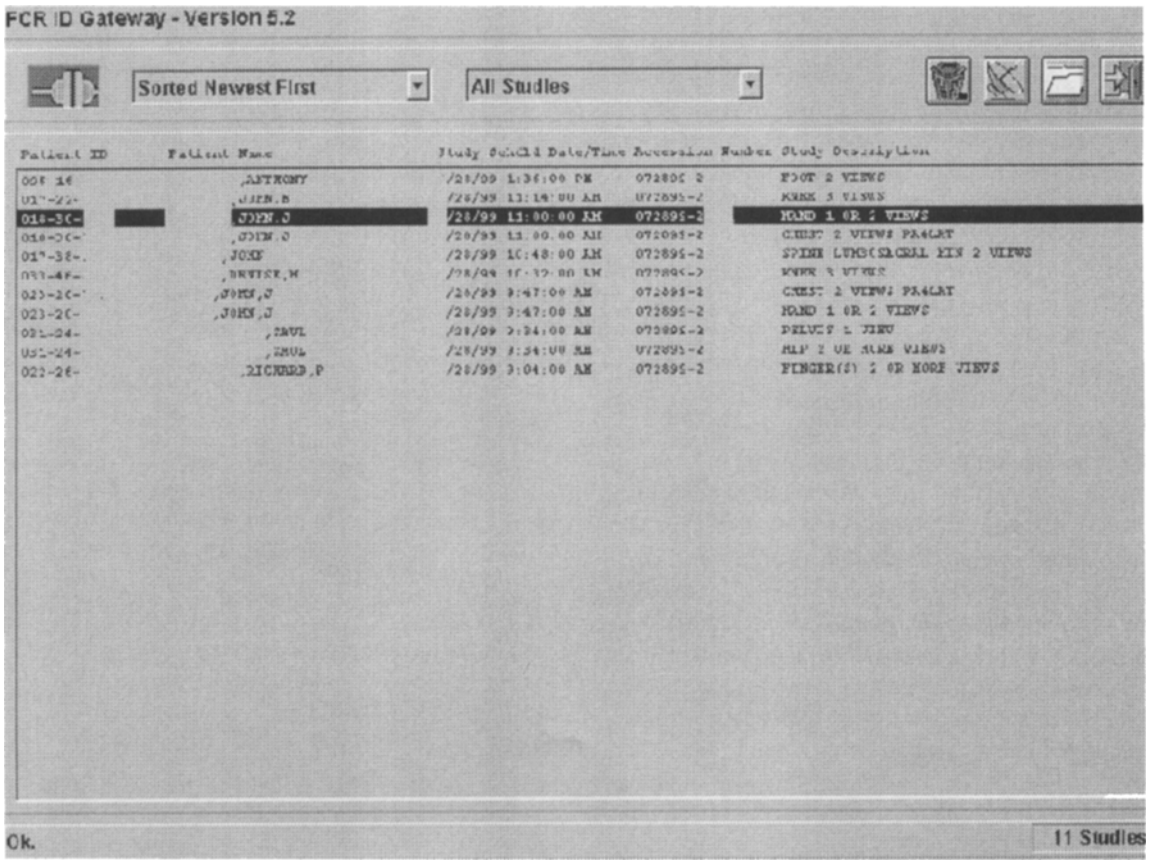

Fig 3. This image of version of 5.2 of the Fuji CR ID Gateway interface (altered from the original display and to remove specific patient identification information) shows multiple patient names. Names are automatically cleared from the bottom after a user-defined time period is reached. The interface displays 5 essential worklist elements: patient name, accession number, date, patient identification number, and procedure name. Data entry is either by keyboard or barcode. It can be sorted by name, date, or accession number, in ascending or descending order and filtered by complete or incomplete status. When a match is obtained by HIS or RIS query, the system not only populates the demographic fields, but it also selects the correct body part on the modality interface. An older version of the Fuji software, version 5.1, did not provide the procedure name and therefore did not prevent selection errors. (Photo used with permission of Fuji Medical Systems USA, Inc.)

cause a technologist to introduce nearly as many errors as a system without DICOM Modality Worklist. An optimal implementation should provide technologists with essential patient demographic and examination data in a simple, configurable, and easy-to-use format.

The interface display must be large enough to allow the technologist to view a reasonable proportion of the potential cases from which to select using a font that is easily legible (Fig 3). Although early implementations of modality worklist often required a separate computer or device to act as a gateway between the modality itself and the PACS because of the existing design limitations of the acquisition equipment, manufacturers have begun to build in the interface directly into the modality console in more recent equipment models. For the technologist, this simplifies the process of interacting with the equipment. However, depending on the device, the display screen may have size limitations that offset the advantage of being built in. For example, the screen displays on US machines typically are somewhat smaller than those on CT or MR scanners. Although limiting the amount of information available without scrolling, small screens enhance the portability of systems that use them (Fig 4).

There are several methods for physical interaction with the interface: keyboard, touch screen, mouse, and barcode. In most DICOM Modality Worklist implementations, keyboard selection may be used as an alternative or back up for the other methods. Although most common, keyboard input typically requires the technologist to press up and down arrow keys multiple times to highlight the correct patient entry, and is, as a result, relatively slow and inefficient. Consequently, use of a mouse tends to be significantly quicker than keyboard entry. However, the quickness of the mouse entry tends to allow the technologist to select cases too rapidly. Occasionally, the technologist may select an adjacent entry from the worklist causing a mismatch of the identity of the patient and the image. Inadequate space for the mouse to be manipulated, a common occurrence in some work areas, predisposes to this error. Touch screen entry, although slightly more reliable than a mouse, tends to require a larger amount of screen area to display

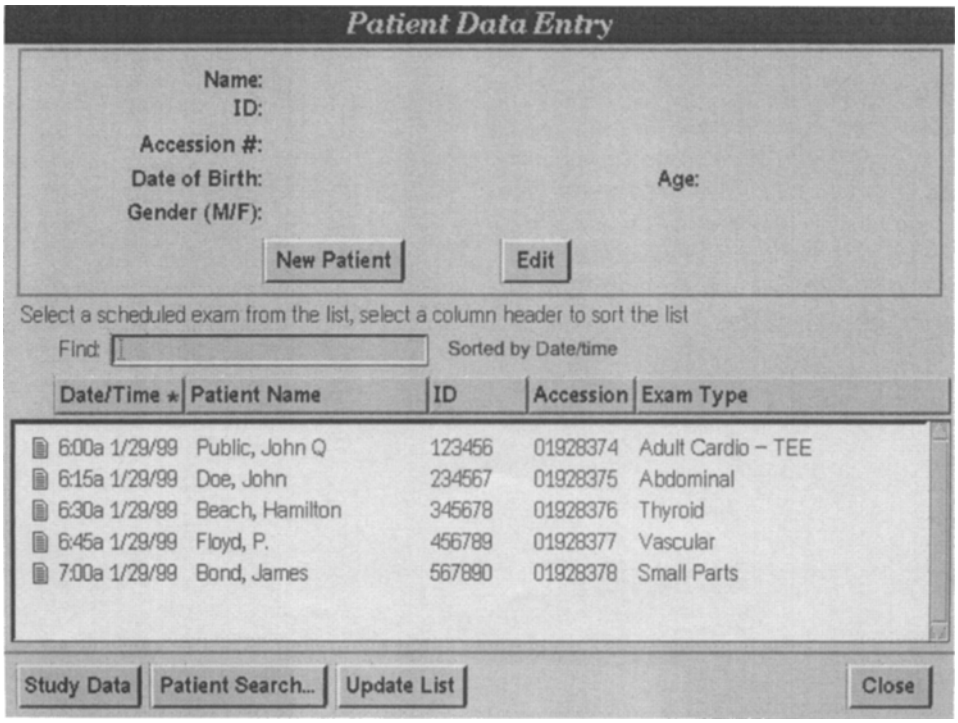

Fig 4. This image from an ATL Ultrasound machine (HDI 3500 and HDI 5000) shows all 5 key selection elements, patient name, accession number, date, patient ID number, and procedure name. The entries can be selected using a trackball and keyboard. (Photo used with permission of ATL Ultrasound.)

each touch button, and, therefore, tends to minimize the total number of requests visible at any one time.

Some systems provide, in addition to keyboard, touch screen, or mouse entry, the ability to scan barcodes. This is the most reliable method for data entry into an acquisition device. Barcodes typically are generated by the HIS or RIS and contain encoded information for the accession number, or the patient's ID number. These provide the ideal input medium because they require less technologist time and tend to be far more accurate than any of the other means. In our department, only CR uses a barcode system. Although it accounts for approximately 50% of examination procedures, CR is only responsible for 8% of the mismatches in our experience.

CONCLUSION

Although DICOM Modality Worklist has been a late entry into the implementation focus for filmless radiology, it is a key component that should be implemented to maintain as high a level of data integrity as possible and to speed technical operations at the data collection points. A broad range of implementation strategies exist, and should be tailored to the particular circumstances of the PACS implementation, HIS or RIS capabilities, and modality interfaces. Modality vendors should be encouraged strongly to provide DICOM Modality Worklist capabilities on all new equipment designs, and to retrofit legacy equipment with similar functions. Accession number support and handling is the key element determining the usefulness and robustness of the DICOM Modality Worklist implementation. Both radiologist and technologist productivity is improved with DICOM Modality Worklist in place.

ACKNOWLEDGMENT

The authors acknowledge both the support and education provided by Peter Kuzmak of the Veterans Administration.

REFERENCES

1. Behlen F: A DICOM document-oriented approach to PACS infrastructure. J Digit Imaging 11:35-38, 1998 (suppl 1)

2. Carrino JA, Unkel PJ, Miller ID, et al: Large-Scale PACS implementation. J Digit Imaging 11:3-7, 1998 (suppl 1)

3. Levine BA, Cleary KR, Norton GS, et al: Experience implementing a DICOM 3.0 multivendor teleradiology network. Telemedicine J 4:167-175, 1998

4. Kuzmak PM, Dayhoff RE: The Department of Veterans Affairs integration of imaging into the healthcare enterprise using the VistA hospital information system and digital imaging and communications in medicine. J Digit Imaging 11:53-64, 1998

5. Lou SL, Hoogstrate DR, Huang HK: An automated PACS image acquisition and recovery scheme for image integrity based on the DICOM standard. Computerized Medical Imaging and Graphics 21:209-218, 1997

6. Gale D, Gale ME, Schwartz RKS, et al: An automated picture archiving and communication system workstation interface: A timesaving enhancement. AJR 174:33-36, 2000

7. Oosterwijk H: DICOM versus HL7 for modality interfacing. J Digit Imaging 11:39-41, 1998 (suppl 1)