Modality Interfacing: The Impact of a Relay Station

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We evaluated the effect of a deploying a relay station on demographic discrepancies, image segmentation for routing, quality control (QC), and technologist workflow in a distributed architecture type picture archiving and communication system (PACS) environment. A currently existing PACS environment for computed tomography (CT) was evaluated before and after the implementation of a relay station for demographic error-rate and correct study routing to the workstations. Assessment of the technologists' perceptions with respect to numerous workflow factors was performed with a questionnaire. Statistical analysis was performed using a chi-square test. The demographic error rate for CT examinations was nearly abolished with relay station deployment (14.0 % pre-Relay v 0.55 % post-Relay, $P < .001$, χ^2). The technologists' perception was favorable, with a substantial majority indicating that a positive impact is made on correcting demographic errors (90%), facilitating QC (67%), and ensuring proper routing (77%). A majority also felt the user interface was intuitive (93.3%) and preferred relay (90%) over film handling but that training should be provided both by didactic sessions and "hands on" time with a trainer. The times to perform tasks were favorable for the relay station (1 to 5 minutes) versus film production and handling (2 to 15 minutes). In conclusion, the relay station prospectively eliminates demographic errors, effectively segments images from the same study routing them to different workstations, and can be seamlessly integrated into the technologists' current workflow. This can be scalable and a lower cost solution as opposed to deploying dedicated PACS QC workstations.

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A FUNDAMENTAL TENET of current picture archiving and communication systems (PACS) implementation is that images should not be available without information. Therefore, each PACS should have a mechanism for linking the pertinent patient information (demographics, clinical history, allergies) with the image. That is, each image data set should be "labeled" or identified with a specific patient and linked to a patient folder or some other useful construct within the PACS.

Therefore, there are two components to a PACS archive. One component is the database that maintains patient metadata information and the other component is the file server that actually stores the image data sets. Many institutions already have a hospital information system (HIS) or radiology information system (RIS) in place in addition to the PACS information system. Ideally, these systems should be integrated for image management. When interfacing these systems, it is imperative that images should be labeled with accurate information and that synchronization occurs between information systems. In this sense, the PACS database and the HIS or RIS should mirror one another. Information transfer can occur by way of a RIS/PACS or HIS/RIS/PACS gateway that replaces the "paper trail" of requisitions that currently exists.

For most cross-sectional examinations such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US), the technologist manually enters patient demographic information into the acquisition device. The study and associated information are then "pushed" into the PACS via a gateway (preferably using the Digital Imaging and Communications in Medicine [DICOM] standard). The PACS then needs to handle or deal with both the image data set and associated information. If a HIS/RIS/PACS communication link is in place, then the PACS attempts to match the incoming study with what exists on its database. If a discrepancy occurs, the PACS can either reject the study (ie, not allow it into the system), place it on a special list (eg, "unspecified folder," "exceptions list," or "penalty box"), or create a new patient folder (ie, new study) with the erroneous data. This scenario is not uncommon because dual entry of patient information is fraught with problems, including a substantial potential for misspelling and other alphanumeric data errors (eg, transpositions). Therefore, at some point, operator intervention is required to rectify the situation. An operator must then have access to a PACS workstation to identify the problem and accomplish a solution "after the fact." This lesson has been learned from the military experience, where PACS workstations had to be retrospectively placed near each modality work area or next to each acquisition device. This becomes a costly endeavor. Another option is to

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designate a quality control (QC) area, but this removes an experienced human resource (technologist) from the acquisition area and from simultaneously scanning a patient. None of these described scenarios is well suited to maintaining workflow.

A robust mechanism for information transfer should also extend to the point of acquisition, but is not presently realized for several practical reasons. Modality worklist is a concept that entails two-way communication between the PACS database (or HIS/RIS) and the acquisition device. This is so that patients' demographic data and study-related information need not be re-entered by the technologist, but are routed into the acquisition device from an existing information system. This feature has been incorporated into the DICOM standard, but not yet widely implemented by vendors. While it is anticipated that modality worklist will be included in the functionality of new acquisition devices that come to market, what does one do with existing equipment? Retrofits may or may not be available to existing equipment and can be costly.

Another important consideration is that in a subspecialty radiology practice, such as an academic institution, a single patient's imaging studies may be interpreted by several different radiologists and/or at several different locations. Acquisition devices for CT and MRI do not permit facile segmentation of the image dataset. This is especially pertinent for CT body imaging, where helical and multislice scanning is used, generating voluminous data. The following scenarios are not uncommon. In a traumatized patient, time-effective imaging may include CT of multiple areas at one session, including head, cervical spine, chest, abdomen/pelvis, and injured extremities (eg, humerus, calcaneus). For neoplastic disorders such as Hodgkin's lymphoma, staging often includes CT imaging of the neck, chest, and abdomen/pelvis.

DICOM gateways facilitate communications across different vendors, but do not necessarily ensure data validation with respect to the RIS. When problems arise with study entry into the PACS, there is often "finger pointing" between the PACS vendor and the modality vendor. The user is put in the position to arbitrate and determine how a solution can be obtained, often consuming much time and effort. An all too common problem is the misunderstanding of "DICOM compliance." One needs to understand the importance and role of a DICOM conformance statement in this context.

DICOM compliance does not guarantee successful communication between devices, but does allow one to assess the feasibility of operating a device within a specific environment (or set of conditions). The purpose of the conformance statement is to allow a user to determine which optional components of the DICOM standard are supported by that particular implementation, and what extensions or specialization that implementation adds. By comparing the conformance statements from two implementations, a knowledgeable user should be able to determine whether or not interoperability is generally possible. However, while data validation and information integrity are important issues, they are currently outside the purview of DICOM but considered within a quality assurance (QA) or QC program of an institution.

Therefore, the problems that arise when transferring imaging studies to a PACS include lack of data integrity validation, inaccurate study routing, and poor DICOM conformance. Our purpose was to develop a robust solution, in conjunction with industry, which would be facile to use, seamlessly integrated into the technologists' workflow, scalable, relatively inexpensive, and could accomplish all pertinent tasks before sending the data set to the PACS. This "before the fact" solution is known as a relay station or modality QC station. Our hypothesis was to measure performance before and after the implementation of this relay station and to assess the technologists' perception of its impact.

MATERIALS AND METHODS

The study was performed in a large academic institution (720 beds) performing approximately 280,000 radiology examination per year. We focused the study on CT (five helical units; Siemens, Iselin, NJ) as part of phase 1 implementation of our new PACS (IMPAX, Agfa, Ridgefield, NJ). Technologists enter demographic and examination information (name, medical record number, exam identification number) at the console for every CT examination. The relay station was designed as a collaborative effort with a PACS integration company (Mitra, Waterloo, Canada). The goal was specifically to develop an interface to segment images acquired at a single session that need to be placed in different study folders and to reconcile and standardize the demographic data with our RIS. The process is meant to rectify exceptions at the point of care by the technologist. The information entered at the acquisition device is checked against the RIS database (IDXrad version 9.3; IDX, Burlington, VT), which is defined as containing the correct information. All demographic and exam information mismatches (exceptions) are reviewed and approved by the technologist and corrected by the relay program before images are

distributed for interpretation and archiving. We determined the exceptions rate over a 1-month period before relay stations were deployed and compared that to the exceptions rate after relay deployment.

All of the technologists participated in training that consisted of a 1-hour (or less) "hands on" session with a field engineer over a 1-week period before relay station deployment. A full-time software support employee monitored the relay stations and assisted in troubleshooting the system. Daily feedback from radiology technologists was used to refine the relay station software and determine stability of the functionality before collecting data.

We compared the exceptions rate for a period of 30 days before and after relay station deployment excluding the training and refinement period using a chi-square test. A questionnaire was administered to all CT technologists after the study period focusing on assessment of utility, ease of use, impact on workflow, and operator preference versus film-based handling and distribution.

RESULTS

A total of 2,887 CT examinations were generated during the pre-relay study period (31 days in August 1998) with 404 "exceptions" (14.0%). The relay station was deployed in September 1998. A

total of 4,033 CT examinations were generated during the post-relay study period (30 days in April 1999) with 22 "exceptions" (0.55%). This constituted a statistically significant reduction ($P < .001$, χ^2) in the percentages of exceptions that needed to be corrected by a PACS manager after the point-of-care (ie, "exceptions handling").

All CT examinations were segmented according to organ system using the relay station. The PACS manager supervised troubleshooting, surveyed radiologists, and performed daily QC on a subset of studies to determine proper segmentation. Prior to relay deployment, studies were not segmented. No problems with segmentation were identified during the study period after relay deployment.

The questionnaire was administered to 42 technologists working in the CT imaging section, with a 71% response rate ($n = 30$). The following results are based on the cumulative responses to the questionnaire (Table 1). The time to perform tasks was asked by incremental categories. The re-

Table 1. Technologist Questionnaire; Summary of Responses

WORK FLOW & TIME EFFICIENCY						
On average please estimate how much time does it take to complete each process PER STUDY						
	<1 min	1-2 min	2-5 min	5-10 min	10-15 min	>15 min
Film	0.0	0.0	36.6	40.0	16.6	6.0
Relay	13.3	46.6	26.6	13.3	0.0	0.0
				Yes		No
Is the user interface easy to use?				93.3		6.6
Is the relay streamlined into your workflow?				60.0		40.0
PREFERENCE						
FILM: print film, collate film & bring folders to reading area						10.0
RELAY: complete study on relay & push studies real-time to the workstations						90.0
TRAINING						
How much training did you receive?		<1 hour (80.0)		>1 hour (13.3)		None (6.6)
Was this sufficient? YES:		37.5		50.0		0.0
Was this sufficient? NO:		62.5		50.0		100
How would you structure the training program:						
a. computer-based tutorial		0.0				
b. classroom lecture "didactic" session		0.0				
c. "hands on" with a trainer		36.6				
d. combination		56.7 (most indicated didactic & hands on as preferred)				
e. something else		3.3 (text book)				
f. no change to current training program		3.3				
QUALITY CONTROL						
Do you feel that the relay station makes a significant positive impact on:						
				Yes		No
a. correcting patient information errors				90.0		10.0
b. facilitating your role in quality control (QC)				66.6		33.3
c. ensuring that the appropriate images are routed to the correct workstation				76.6		23.3

NOTE. Numbers are percentage of respondents who chose that answer (N = 30).

sponses for film-based handling predominated in the 2- to 15-minutes range and the responses for relay predominated in the 1- to 5-minutes range. A majority felt the user interface was intuitive (93.3%), streamlined into their workflow (60.0%), and preferred relay (90%) to film handling. Most technologists indicated that they received less than 1 hour of training (80.0%), which was felt to be insufficient (62.5%). When asked how the training program should be structured, didactic sessions and "hands on" training with a trainer was favored. A substantial majority indicated that a positive impact is made on correcting demographic errors (90%), facilitating QC (67%), and ensuring proper routing (77%).

DISCUSSION

Under an academic-industrial collaboration we designed and built a software program, called a relay station, to address two common problems that currently exist for cross-sectional imaging modality interfacing. This was used to reconcile alphanumeric demographic errors with respect to the radiology information repository and to perform reliable segmentation of contiguously acquired image data sets. These functions are performed prospectively with respect to entry of the image data set into the PACS, eliminating retrospective (or "after the fact") maintenance of the PACS database, thus facilitating radiologists' and technologists' workflow in a subspecialty-oriented practice environment. Our study showed those performance improvements of an existing distributed architecture PACS for CT (and extensible to MRI) studies could be obtained by implementing a relay station and were preferred over film handling by the technologists.

PACS are increasingly deployed in radiology practices. PACS allow enterprise-wide distribution for interpretation and viewing of imaging datasets. To justify the large capital investment necessary for its deployment, PACS need to reduce costs associated with film handling, improve the efficiency of radiologists and nonradiologists, and improve care. PACS are huge systems with many communications, performance, and maintenance issues for both equipment and information integrity. Information system interfaces and gateways may be considered analogous to Band-Aids until fully integrated systems or distributed interface architectures become the status quo. To achieve these goals, PACS

not only need to perform the obvious tasks of acquiring digital information from the acquisition modality (CT, MRI, etc) and accurately display them on computer systems (workstations), but it also needs to re-engineer and improve the multiple tasks performed by humans in the analog environment. Such intelligent PACS need to accomplish tasks such as delivering studies to the appropriate reading stations (routing), filing films accurately (archiving), and retrieving them in a timely fashion (prefetching).

In the analog paradigm, if the patient demographics entered by a technologist at the acquisition modality are incorrect, images may still be interpreted, and films may still be archived in the correct patient folder. The films may be reprinted with corrected demographic information, or correct labels may be placed on the film if the error is detected. In the digital world, unless such demographic errors are detected, images may be electronically filed inaccurately and may never be retrievable (if the PACS allows this). This has enormous implications for the quality of care. Another example of how PACS need to function is the handling of spiral (helical) and multislice (multidetector) CT examinations, where multiple organ systems are routinely imaged nearly simultaneously. In the analog world, films may be sorted according to organ system (particularly in academic institutions) and delivered to the appropriate alternator. With a PACS, the entire image set would need to be similarly divided (or segmented) and automatically delivered to the appropriate workstation and later available as a specific comparison study. This functionality has obvious implications for radiology practice efficiency.

Although some of the functionality required for an *intelligent* PACS environment is commercially available from various vendors, perhaps the most important function, namely, the validation of patient demographic information, has remained largely a manual after-the-fact process even in the most sophisticated PACS installations. Segmentation of examinations performed with spiral CT has also remained an elusive goal for PACS so far. While the above-mentioned functions may be automated to some degree, humans are still best at dealing with disparate types of data and technologists should still be expected to take responsibility for the image dataset integrity and treat it as their product. To achieve the greatest workflow enhance-

ment for radiologists, a study must be quality-controlled by an experienced operator and brought into the PACS in a contemporaneous fashion.

The relay station (or modality QC station) we have described fits within the concept of an intelligent PACS environment and fulfills two important quality assurance functions: (1) reconciling demographic discrepancies with the existing HIS or RIS prior to entry into the PACS, and (2) segmentation of the image dataset to route studies to the appropriate reading list or workstation. Modality worklist addresses problem no. 1 quite well and is being requested by many users, but the issue of QC and segmentation is not addressed by DICOM nor should it be, because these are institution-specific. For these functions, the relay adds flexibility and can be scalable to a specific installation. There is not a large capital expenditure, as is customary for a full-fledged workstation. Workstations can cost in the range of \$40,000 to \$60,000, versus relay,

which has a list price of approximately \$20,000 (Impax technologies). Another key goal is to provide rapid and consistent transaction times by performing these functions in real time as opposed to batch mode (eg, at the end of a shift), so that contemporaneous image interpretation can ensue. An important component for seamless PACS integration is the technologist interfaces with the system, especially the use and location of QC workstations. QC workstations need to be colocated with all modalities so that the technologist can verify that patient data have made it into the PACS and that the appropriate study is matched with that patient. Technologists and support staff are important to maintaining workflow and their encounter with the PACS will likely be through special interfaces designed to facilitate the specific job. Our technologists found the relay station easy to use and believe that it did not add significantly to their workload.