Clinician Usage Patterns of a Desktop Radiology Information Display Application

Bradley J. Erickson, William J. Ryan, Dale G. Gehring, and Calvin Beebe

We developed a system for delivering radiologic images and reports to desktop computers used for the electronic medical record (EMR). This system was used by both primary care physicians and specialists primarily in the out-patient setting. The system records all physician interactions with the application to a database. This usage information was then studied in order to understand the value and requirements of an application that could display radiology information (reports and images) on EMR workstations. In this report we describe some of the differences and similarities in usage patterns for the two physician groups. A very high percentage of physicians indicated that having image display capabilities on the workstations was very valuable.

KEY WORDS: PACS; Computerized patient record; electronic medical record

PICTURE ARCHIVAL and communication systems (PACS) are becoming common in radiology departments for several reasons. One valuable feature of PACS is the ability to distribute images more quickly and efficiently than film; but the ability to view film in nearly any location (eg, walking down the hallway or in the operating room) has been difficult to duplicate with electronic systems. In 1994, the Mayo Department of Radiology identified three areas of its practice to serve as pilot project areas for 3 different vendors' PACS. This was to serve as a learning experience about the issues of implementing PACS in our department, and our institution. The three projects were a valuable learning experience which ultimately lead to the selection of one system which is being expanded at the Rochester campus.

While that system served many of the identified needs well, it became apparent that using vendor workstations as the means for distributing images to all clinicians would be quite expensive, and probably not feasible. Specific issues which arose included how to provide images in each examination room so that private consultation with patients could occur. Paper printouts were tested, and while this was popular with some physicians and patients, it proved slow, printers were difficult to maintain, and there was some concern about confidentiality (how to dispose of the prints). Placing dedicated image display workstations in every examination or hospital room was not feasible. Some of the impediments to implementing this strategy included: the cost of the workstations; providing the additional space required by a separate workstation; it meant another application that physicians had to log onto and identify the patient which reduced their efficiency; increased training requirements; and it was another computer to be maintained. It quickly became clear that dedicated image display (vendor) workstations would not be the final solution to ubiquitous image access.

Mayo has also been developing an integrated electronic medical record which has been deployed in several areas of the institution. This set of applications consisted of a mixture of existing commercial applications, applications developed jointly between Mayo and industry partners, and solely Mayo-developed applications. To support this effort, substantial infrastructure investments have been made, including the deployment of Windows NT (Microsoft Corp, Redmond, WA) workstations throughout the institution. Prior to doing the three PACS pilot projects, Mayo and IBM had jointly developed a PACS for cross-sectional imaging. As a part of that project, we developed an application (READS) that could display images[1] on PC-based workstations. Clinicians (we will use this term to refer to non-radiologist physicians) had used the READS system, and in formal usability testing, it was determined that the application was suitable for clinician use. After identifying the aspects that were difficult or inappropriate for clinicians, we designed an application which would display images on the Electronic Medical Record (EMR) workstations.

METHODS

The EMR application we developed (called QREADS) was implemented as a pilot project for image display on EMR workstations for clinicians in two general categories of out-

From the Department of Radiology, Mayo Foundation, Rochester, MN.

Address reprint requests to Bradley J Erickson, Radiology, Mayo Fdn, Rochester MN 55905.

0897-1889/98/1103-1042$8.00/0

patient settings: primary care including internal medicine, pediatrics, and family practice, and specialty clinics including neurology, neurosurgery and endocrinology. The application was written in C++ using Microsoft Visual C++ Version 4 (Microsoft Corp, Redmond, WA). The application is automatically distributed to workstations using an automated software distribution application. The technology of the QREADS system has been previously described[2] and hence, is only briefly described here. Figure 1 demonstrates how QREADS relates to our PACS and Radiology Information System (RIS). When an examination has been reported, images are transferred from the PACS to the clinical images gateway (CIG) using DICOM. This transfer is automatic in some cases, and in others, is initiated by the RIS. The CIG compresses the images using wavelet compression[3] and stores them onto a file server. The ratio selected depends on the modality, but ranges from 10:1 for MRI and CT to 100:1 for computed radiography. The filename used for storing the images is determined by the RIS. Successful execution of this operation is signaled by the CIG to RIS, so that the RIS knows that the image file(s) are now valid. All network transfers use the standard institutional network. This is predominantly 10Mbit/sec ethernet with a 100Mbit/sec FDDI backbone.

The fileserver used for this project has a capacity of 100 gigabytes. Because compression is used, approximately 10 months of data can be stored on this server, based on our current examination volume of approximately 4,000 CT, 2,500 MRI and 3,500 CR examinations per month. This estimate does not include space for prior examinations that might be used for comparison (pre-fetching) because few previous examinations were available on the commercial PACS, and to limit the amount of development required for the pilot. We are now designing connections to the Admission/Dismissal Transfer module to allow intelligent retrieval of old examinations to this server from PACS, and to remove examinations when patients are dismissed. This will help to assure that all relevant examinations are available for clinicians, not just the current radiology examinations.

The user interface of QREADS is shown in Fig 2. Once a patient has been selected, the list of available examinations is provided in a listbox on the left. This exam list is obtained directly from the RIS. In addition to indicating the date and type of examination, the availability of images is also indicated. The user may then click on any examination, and the report text is immediately retrieved from RIS, and displayed on the right. If the user double-clicks on the exam, or clicks the 'Open Exam' button, the images for that examination will be retrieved from the clinical images server, decompressed, and displayed. The user may adjust brightness and contrast, and for CT, standard settings for soft tissue, bone, lung, and brain are provided. The user may drag-and-drop navigation images to the larger display areas, or use next/previous buttons. Double clicking one of the images will zoom that image to full screen. Tools for image measurement, and copying the image to the clipboard are also provided.

In order to obtain objective information about image delivery to clinician workstations, we designed the QREADS application with the ability to store every bit of clinician interaction in a database. The database has subsequently been studied to determine when and how images and reports are viewed and manipulated on the EMR workstations. Each time the user logs in, the user name, machine identifier, and a session identifier are stored. Each mouse button press/GUI selection is stored in the

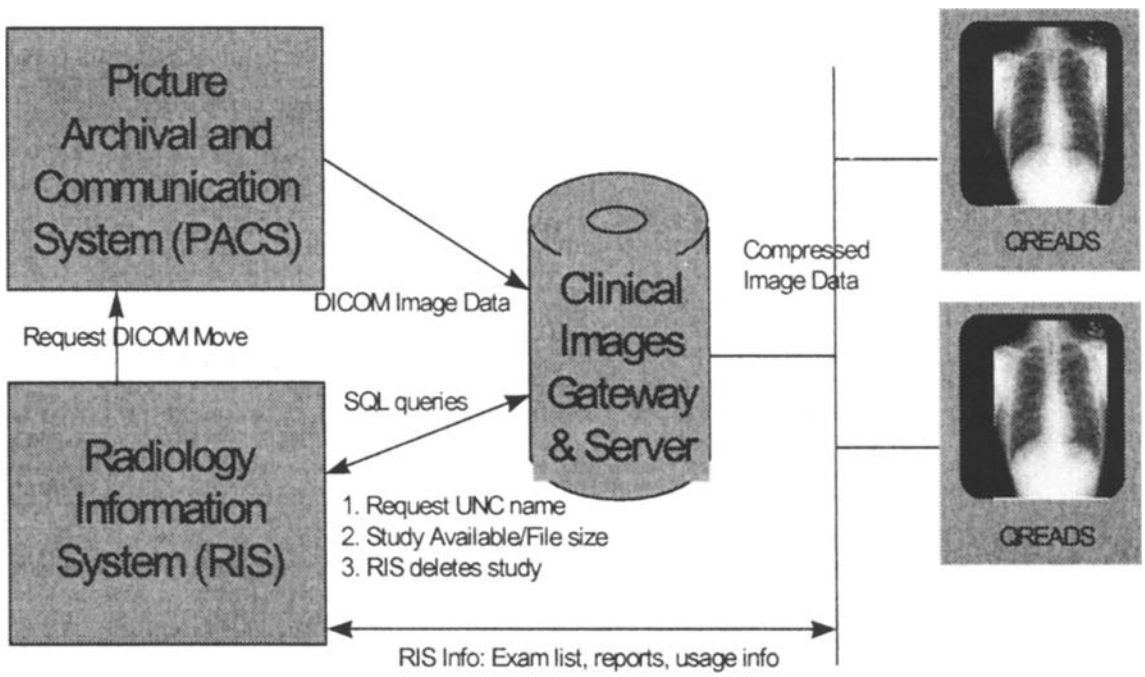

Fig 1. Schematic diagram of information flow for QREADS. When an examination has been reported, images are transferred from the PACS to the clinical images gateway (CIG) using DICOM. The CIG compresses the images and stores them on a file server, and notifies the RIS of their availability, and filename. When QREADS begins, it logs into RIS, and requests the examination list for each patient. When an examination is selected, the report is transmitted. If images are available, the filename is also transmitted. The network connection was 10 Mbit ethernet.

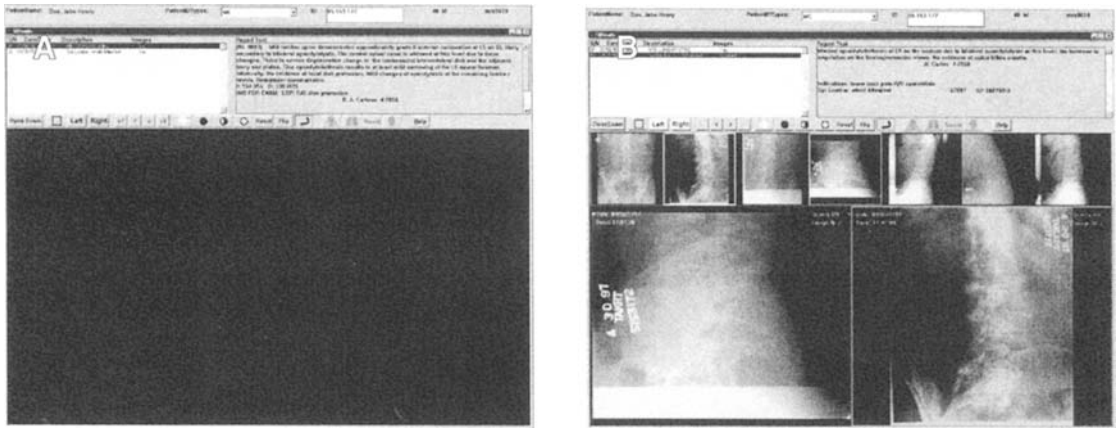

Fig 2. The QREADS application (A) shows the application when an examination for a patient has been selected. The report is shown in the upper right. (B) is when the images for an examination have been opened. Other display modes allow zooming the image and a magnifying glass.

database indicating the session ID, nature of event, and a time stamp. Usage parameters may then later be retrieved using Structured Query Language queries.

The duration of this pilot project was 6 months. During the first two months, significant training occurred, and so usage data was not considered useful or reliable. Usage data reported here was collected during the final four months of the pilot period and the following two months (the system was approved and became a production application which continues to be used and expanded). Thus, the data are for a period of six months. All physicians in the participating departments had access to the system, but because film continued to be delivered in the usual fashion, system usage was entirely voluntary. The departments participating were broadly grouped in primary care physicians (N = 90) or specialists (N = 115). All physicians in the participating departments were sent a questionnaire at the end of the pilot.

RESULTS

This study shows that the ability to review images, even if they are of reduced quality, is an important capability for EMR workstations. The average user (primary care or specialist) reviewed 3.2 examinations on 2.1 patients per day; there was no statistically significant difference between primary care and specialist. If clinicians viewed reports on QREADS, the reviewed the images as well on about 65%. Of all the cases that were available, between 10% (radiographs) and 25% (MRIs) were reviewed electronically, even though routine film delivery was continued during this pilot. We did find a statistically significant difference in the usage patterns of primary care physicians and specialists (Fig 3) for some types of operations. For the most part, image manipulation tools were used sparingly (about 5% of cases in which images were reviewed). Unfortunately, there were not enough historical examinations available to draw useful conclusions about historical examinations usage patterns.

We also performed a post-pilot survey of the physician users. Of the 205 possible respondents, 57 returned the survey within 2 weeks. Physician estimates of usage obtained from the questionnaire agreed reasonably well with the measured values. Most primary care physicians reported using the system 3 times per week, and log data indicated a mean rate of 159 users per week for 90 physicians, but there was a wide variation. (Note also that the logged data set included all days, and so holidays or vacations produce artificially low average usage rates). Specialists thought they used the system more frequently—typically 5 times per week (logged data showed a mean rate of 280 users per week of 115 specialists on the roster). We found that some users accessed the system as many as 25 times in one week.

The log data also revealed a marked difference in the percentage of primary care physicians who looked only at reports (63%), compared with specialists (23%) ($P < 0.021$). A few primary care physicians usually looked at the images, but many rarely did. Much less variation existed for the specialists. Images of the head were more likely to be viewed than other body parts, such as the spine. Among physicians who viewed images, specialists and primary care physicians tended to manipulate image viewing parameters at similar rates.

The survey performed at the end of the pilot period provided valuable information about how and why QREADS was used. While there were

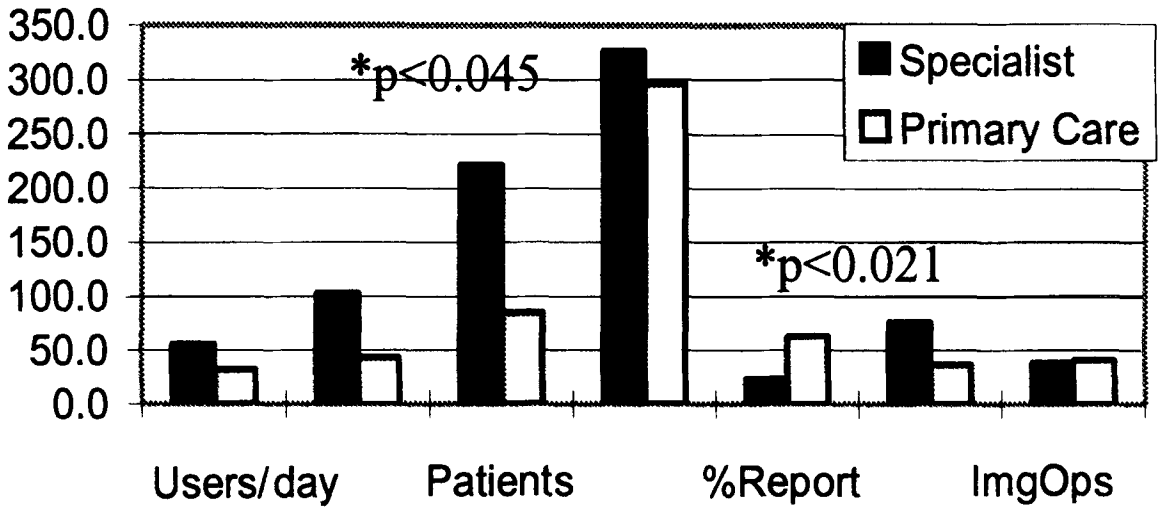

Fig 3. Logged data usage for the six month period comparing specialist and primary care usage patterns. There was a statistically significant difference between specialists and primary care physicians in the number of patients they reviewed using QREADS, and in the fraction of examinations on which they reviewed images.

some statistically significant differences in the usage patterns between the two groups, an important point was clearly made in the survey responses: even though some users only occasionally reviewed images, having such a facility available was considered *essential* by 94% of the 57 respondents. The most common reason was to show patients' important imaging findings in the privacy of the examination room. In several cases, it was noted that these images were only available in electronic form at the time the patient presented for consultation suggesting efficiency might be improved, but this was not measured as a part of this study.

At the beginning of this project, we were concerned about the acceptability of compressed images on color CRTs. Fifty-five of 57 (96%) physicians felt that image quality was acceptable.

DISCUSSION

While PACS is becoming an increasingly pervasive technology in radiology departments, we must be aware of how it affects the clinicians who are taking care of the patients. Patients are becoming quite sophisticated about imaging and computer technologies. While PACS might allow us to provide state-of-the-art radiologic imaging and interpretation, conveying those services in a poorly conceived fashion will degrade radiology's image.

The main driver for PACS is economic (either film savings or practice efficiency) but improvements in the practice of medicine are also a commonly cited motivation. Within the department, savings may be accrued by eliminated the handling and storage of films.[4,5] Large savings outside the department may also be possible if mechanisms for film distribution and tracking can be replaced with an electronic system such as we describe here. Electronic imaging also permits much more flexibility in how a practice is operated. This could result in improved efficiency, or perhaps improved care. Improved patient care and increased efficiency due to immediate delivery of images has been documented for the Intensive Care Unit setting,[6] but likely applies to the outpatient setting as well. Because many of the benefits of electronic radiology depend on electronic image delivery to clinicians, it is important that we understand how they use images, and how to meet those needs.

This is one of the first reports of clinician workstation usage patterns for outpatients or using EMR workstations. Siegel[7] et al reported on their experience with vendor PACS workstation usage in their hospital, but that report was limited because it only provided information on the fraction of workstations with active sessions tested every 15 minutes. This report provides information on outpatient clinician usage which is substantially richer: not only is it known if somebody used the system, but also how they used it. This provides a much more useful set of data to use for understanding how PACS workstations is used in the care-provider arena, and how workstations should be designed in order to better meet those needs. We found the system to be heavily used despite continuing film

delivery. Specialists looked at images more frequently than primary care physicians.

The survey revealed a few differences between the groups in terms of the reasons for usage (patient education, resident education, self-confirmation of findings), but there was substantial variation within the groups, which makes the groups less separable. Both groups nearly unanimously (96%) agreed that having access to images in patient examination rooms was very important to clinical practice.

An important question which was not addressed in this study is whether electronic imaging increases the efficiency or productivity of clinicians, or if there is a change or improvement in patient management. It is possible that the role of electronic image display does not entirely replace the role played by film. It is also possible that clinicians will be less efficient if only electronic images are available. Many adopters of electronic imaging have forged ahead with electronic imaging, and forced the clinicians to adapt to the new environment. Anecdotal assessments of the effects on their efficiency has varied but designing a study to measure the effects is difficult—many factors affect how efficient or productive a physician is, and identifying the extent to which electronic imaging has produced a change is very difficult.

A separate question is whether any improved efficiency that might occur improves patient outcome. In the acute hospital situation, the impact is probably more apparent, and indeed, has been measured.[6] It is not so clear what impact there might be in the outpatient setting. It is possible that the major impact is to reduce the amount of empirical therapy because the results of imaging tests are more immediately available.

We describe a system for efficiently delivering images to clinicians in an outpatient setting. The highly compressed image data allows many months of data to be immediately accessible and significantly reduces network bandwidth demands. The system allows us to efficiently collect data on usage patterns by clinicians. Based on this utility, some differences in usage patterns distinguishing specialists and primary care doctors have been established. But while primary care physicians use images less often, having an image review capability anywhere they see patients is essential in optimal health care delivery.

The design we have implemented uses high-level compression and standard networks to provide reasonable image transmission speeds. We did not chose "web technology" for the implementation for a few reasons. In the first place, we recognized that the greatest driver for this application was to improve the efficiency of the care provider. This could be best accomplished by using a special application which was optimized to meet this need. Web technology is certainly capable of displaying radiographic images on standard workstations, but because it was not designed for this task, the hypertext transmission protocol (HTTP) will always have more overhead. It was also less clear how a web browser could be securely integrated into our EMR, which provides the patient navigation mechanism. While these challenges are solvable, the constraints of implementing a pilot project within a limited time frame excluded this option.

CONCLUSIONS

An application which can display radiologic images and reports was both very popular and considered essential to an outpatient practice for both primary care physicians and specialists. While there was some differences in how frequently images were viewed between the two groups, even occasional use by primary care physicians was considered to be adequate justification for including it in the suite of EMR applications.

REFERENCES

1. Erickson BJ, Ryan WJ, Gehring DG: READS: A Radiology-Oriented Electronic Analysis and Display Station. J Digit Imaging 10:67-69, 1997

2. Erickson BJ, Ryan WJ, Gehring DG, Beebe C: Image Display for Clinicians on Medical Record Workstations. J Digit Imaging 10:38-40, 1997

3. Manduca A: Medical image compression with wavelet/subband coding. IEEE Eng in Medicine and Biology 14:639-46, 1995

4. Langlotz CP, Seshadri S: Technology assessment methods for radiology systems. Radiologic Clinics of North America 34:667-79, 1996

5. Pratt HM, Langlotz CP, Feingold ER, et al: Incremental cost of department-wide implementation of a picture archiving and communication system and computed radiography. Radiology 206:245-252, 1998

6. Redfern RO, Kundel HL, Seshadri SB, et al: PACS workstation usage and patient outcome surrogates. Proc SPIE 3035:424-430, 1997

7. Siegel EL, Protopapas Z, Reiner BI, et al: Patterns of utilization of computer workstations in a filmless environment and implications for current and future picture archiving and communication systems. J Digit Imaging 10:41-43, 1997 (suppl)