Control Method for Preloading With Priority Information in an Integrated Radiology Information System/Picture Archiving and Communication System

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More than 10 years has passed since the concept of picture archiving and communication systems (PACS) was first proposed. A great deal of effort has been expended to make PACS suitable for routine use in clinical settings, but only a few systems are currently used in this manner. A major reason is the lack of the assurance of throughput equivalent to that of a conventional system based on order sheets and analog films. In this report, two techniques to increase throughput have been introduced and studied. The first is the preloading of data elements from the various information systems and the PACS. The second is the use of the priority information to rank order the examinations placed on the list for interpretation. We have applied these techniques to an actual system and have measured the distribution of time for processing examinations. These two techniques appear to make PACS useful in routine practice, because most of the urgent cases were interpreted within the target time of 40 minutes.

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KEY WORDS: hospital information system (HIS), radiology information system (RIS), picture archiving and communication system (PACS), system integration, routine practice, throughput, radiology, computers.

IN RECENT YEARS there have been a number of attempts to develop clinically useful picture archiving and communications system (PACS). However, work remains to be done before such systems are able to replace conventional operating methods in a radiology department.¹⁻⁴ One of the major reasons is that the radiology information system (RIS)/PACS environment may not be able to offer throughput equivalent to that of conventional systems based on order sheets and analog films. The purpose of this report is to discuss a method to use a PACS in a practical manner in a real environment focusing on throughput of the system.

In routine practice, prompt examination and interpretation (called "immediate reading" or "wet reading") is particularly important. This is usually for those urgent outpatients who are to return to the outpatient clinic immediately after the examination for consultation with the referring physician. Radiologists are expected to complete their interpretation and formulate a report as soon as possible after the end of the examination. This not only reduces

the time the patient must remain in the hospital, but also avoids a return visit, thus minimizing inconvenience to the patient and increasing the productivity of the hospital. Therefore, shortening the time between performance of an imaging procedure and getting the results of the referring physician is important.

Preparations for the reading are made by radiology staff by gathering the necessary information, including medical record files, examination requisitions, and film folders for previous films and unread films. To expedite the interpretation of the immediate reading cases, radiology staff also manage the priority of reading by changing the order of the waiting folder queue.

In an electronic environment using PACS, prompt gathering of the necessary information for interpretation and managing the interpretation of high-priority cases cannot easily be achieved because of the following reasons: First, access to the images is slow because of the relatively low image transfer speed of the system and the slow retrieval from the optical disk archive. Second, it is still difficult to obtain and display the medical records and ordering information from different systems such as the hospital information system (HIS) concurrently. Third, the lack of priority control sometimes causes delays in the interpretation of urgent cases. This situation becomes even more complicated in a hybrid environment, in which medical records are handled manually. In this case, correct phasing of the integration of the electronic and the manual information is of particular importance to provide concurrent presentation of the information to the radiologist.

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Fig 1. Configuration of HIS/RIS/PACS system in Toshiba General Hospital (as of October 1994). RT, router; RIT, radiology information terminal; SMT, system manager terminal; STN, station for network interface; SM, system manager; TFS, file server; TWS, viewing station; TWY, network interface.

Several reports have discussed the results of a PACS implementation for routine clinical use. Madigan Army Medical Center reported the evaluation results of their PACS, but the experience with RIS and HIS has not been reported yet⁵. Large-scale implementation of HIS/RIS/PACS is planned and ongoing at Osaka University Hospital⁶; however, routine clinical use of the PACS for primary interpretation has not yet begun. Furthermore, there are few reports of HIS/RIS/PACS implementations with primary diagnosis and a performance evaluation based on the routine clinical operation.

The goal of this article is to provide a way for a PACS to shorten the time between the end of the examination and the delivery of the results to the referring physician.

Two techniques have been introduced and combined to this end: the preloading of the data elements from the various information systems and PACS and the use of the priority information to rank order examinations on the list for interpretation. In addition, preparing and delivering the manually managed information at the viewing station when it is needed is facilitated. We have applied these techniques to an actual system and have measured the distribution of time for processing examinations.

METHODS

The hospital where the integrated RIS/PACS was installed, Toshiba General Hospital in Tokyo, is a 310-bed hospital with 850 outpatient visits per day. Even though it was founded by Toshiba Corporation, it is not limited to company employees but is open to local residents on a referral basis. It has 20 clinics and

Table 1. Specifications of the Integrated RIS/PACS System at Toshiba General Hospital

	Film
Connected Modalities	CR × 3 CT MR NM Digitizer Total
Assumed Max. No. of Images/day	420 990 780 100 108 —
Assumed Max. No. of data amount/day	5.2 GB
Database capacity	525 GB:(Optical disk library (175 GB each) × 3)
Image viewer	Viewing Station (VS) × :2-6 CRT (1k × 1k)/VS
Local storage	:Original resolution including CR(2k × 2k)
Displayed data:	
CT, MR, NM	:Original resolution
CR	:Quadrant of the original or minified to 1k × 1k
Location of VS	:Diagnostic imaging department conference room, wards and out-patient clinics of neurosurgery and urology
Network type	
Acquisition (modalities to DB)	Packet switching (FDDI: 100 Mbps)
Loading (DB to VS)	Circuit switching (LX-7400: 400 Mbps) or packet switching
RIS integration	Yes
Electronic reporting	Yes
HIS integration	Yes: Order, patient demographic data, examination results
Interpretation	Immediately after the examination (wet reading)

Abbreviations: RIS, radiology information system; PACS, picture archiving and communication system; CR, computed radiography; CT, computed tomography; MR, magnetic resonance; NM, nuclear medicine; CRT, cathode ray tube; DB, database; FDDI, fiber distribution data interface; HIS, hospital information system.

Fig 2. The necessary information flow for interpretation.

an affiliated health maintenance facility. The hospital was renovated in May 1993, including the installation of an HIS for the entire hospital and a RIS/PACS in the Diagnostic Imaging Department. There are four radiologists in the Diagnostic Imaging Department. With the renovation of the hospital as a turning point, the Diagnostic Imaging Department began interpreting almost all images produced by the department directly from workstation displays. The integrated RIS/PACS system was installed with the expectation that it would support daily reading of studies by offering an immediate and chronologically comparative reading function.⁷⁻⁹

Until 1995, filmless operation by the integrated RIS/PACS was limited to within the Diagnostic Imaging Department, and therefore film files and paper reports were still produced for delivery to referring physicians in the wards and outpatient clinics. Expansion of the RIS/PACS to the conference room for the clinics was completed in May 1994, and further expansion to the wards and outpatient clinics of the Departments of Neurosurgery and Urology was completed in early 1996. The configuration and specifications of the system are shown in Fig 1 and Table 1, respectively.

Requirements for Supporting Daily Practical Reading

The role of the Diagnostic Imaging Department is to return the interpretation result on the ordering request to the referring physician. Figure 2 shows the necessary information flow for interpretation. A sample of the number of examination orders from the HIS is shown in Fig 3 as a function of time of day.

Table 2. Actual Number of Included Radiological Examinations

	10/24	10/25	10/26	10/27	10/28	10/29	Total
General X-ray							
Urgent outpatient	39	44	26	29	26	20	184
Nonurgent outpatient	18	15	14	24	16	11	98
Inpatient	20	18	16	15	13	8	90
Contrast medium	3	7	4	8	4	1	27
CT	15	15	17	16	13	8	84
MR	6	5	5	7	8	5	36
Others	0	1	1	1	2	0	5
Total	101	105	83	100	82	53	524

NOTE. Data were collected from Monday, October 24, 1994 through Saturday, October 29, 1994.

Abbreviations: CT, computed tomography; MR, magnetic resonance.

There are three types of orders: urgent outpatients, inpatients, and nonurgent outpatients. An urgent case is one for which the ordering physician requests an immediate consultation. An immediate interpretation or "wet reading" is rendered for urgent outpatients. Orders for inpatients have the second highest priority, whereas readings for nonurgent outpatients are expected to be completed within 1 day. The peak for urgent outpatients occurs late in the morning. In this hospital, 40% of examinations are for urgent outpatients, requested mainly by orthopedics and internal medicine.

All of these activities are now being performed using a conventional film system. When we support these activities using the RIS/PACS, the time required for interpretation must be comparable to, or preferably less than, that required by the conventional system.

Integrated RIS/PACS Architecture

As shown in Fig 4, the "integrated RIS/PACS system" consists of RIS/PACS, and various modalities integrated in such a way that they are connected to each other to share the ordering information, examination priority information, preloading information, and so on. These data are necessary to prioritize and control the preloading of images, image transfers, and the listing of the examination orders for both the radiologists and clerks.

The RIS distributes the ordering information and patient demographic information sent from HIS to the modalities or the

Fig 3. Distribution of orders as function of arrival time (summed every 30 minutes), October 24, 1994 (Monday); total = 101; no. of inpatients = 24; no. of outpatients (nonurgent) = 34; no. of outpatients (urgent) = 43.

Fig 4. Integrated RIS/PACS system architecture.

RIS terminals in each examination room. Because radiology technicians can refer to the ordering work list displayed on either the modality console or the RIS terminal, throughput of the examination can be increased. In addition, for those modalities that can receive the patient demographic information from RIS, duplicate input of the data can be eliminated. Furthermore, actual examination data returned from the modality to RIS is to be used for billing for procedures.

After the examination images are registered on the PACS database, they are sent to the PACS viewing station via the PACS file server. Based on the ordering information, scheduling information, and patient registration information from the RIS, the system manager program of the PACS prioritizes the images to be sent to viewing stations and displays the work list for the studies on the viewing station and on the dedicated system manager terminal. Because the list is sorted in priority order, radiologists can easily select the urgent examinations. This list can also be checked by the clerks on their dedicated terminal, so that they can prepare the manually handled information such as medical records in time for the interpretation of the urgent cases.

Preloading and control with priority information are used to cause the necessary information to arrive at the viewing station on time, as shown in Fig 2.

Image Preloading in Phase With Examination Interpretation

Immediately after the examination is completed, images and their associated patient information are sent to a file server and passed on to the viewing station. In this integrated RIS/PACS

Fig 5. Conceptual outline of migration and dynamic preloading.

system, a queuing algorithm causes examinations with higher priority to be earlier on the list of cases to be reported. The control software in the system manager program selects the earliest urgent examination in the queue and selects the destination (Fig 5), namely, the viewing station with the smallest number of remaining examinations.

Prior Comparison Studies

Because of the slow access to the images stored on the optical disk, it is necessary for the file server to retrieve prior comparison studies from the optical disk library to its own magnetic disk in advance. Then the preloading of the prior comparison studies to the viewing station is performed.

Scheduling information is used first for advance retrieval. However, this is not completely satisfactory because scheduling information is not always available for urgent patients. Thus, the information on patient arrivals at the reception desk of the Diagnostic Imaging Department is also used, so that the advance retrieval can be performed within the interval between the registration and the completion of the examination, usually approximately 10 minutes. The same algorithm for preloading unread images is applied to the retrieved previous images to be loaded in phase at the destination viewing station. The number of previous examinations retrieved in advance is currently limited because of the performance of our file server. Therefore, additional comparison studies are obtained on an on-demand basis when needed.

Table 3. Mean Time Stamp Intervals

	Reception to End of Examination	End of Examination to End of Interpretation	End of Interpretation to End of Filming	Processing Time: Reception to End of Filming
General X-ray (n = 328)				
Urgent outpatient: n = 169	8:02	16:04	2:50	26:56
Nonurgent outpatient: n = 92	6:50	41:05	10:31	58:26
Inpatient: n = 67	9:15	44:03	4:49	58:07
Others (n = 119)				
Urgent outpatient: n = 25	35:19	22:12	15:26	72:58
Sum of inpatient and nonurgent outpatient: n = 94	37:01	84:06	12:27	133:44

NOTE: Others includes contrast, computed tomography, magnetic resonance, nuclear medicine. This measurement is based on the actual data on October 24-29, 1994; N = 447. Data are given as min:sec.

Fig 6. Distribution of time from the reception of the patient to the end of filming within the Radiology Department for general X-ray examination, October 24 through 29, 1994; total = 333; no. of nonurgent outpatient = 92; no. of urgent outpatient = 174; no. of inpatient = 67.

Priority Control for Case Interpretation

The preloaded examinations are either listed on the viewing station or the independent system manager terminal located beside the viewing station. The list on the system manager terminal is sorted by priority and the order of arrival. The radiologist can perform interpretations with the appropriate priority by simply following the order of the list.

Concurrent Presentation of the Information With Manual Systems

In many current RIS/PACS implementations reports, medical records and ordering information, including the concerns of the referring physician, are likely to be in nondigital form and managed by manual routines. In this situation merging the electronic information and the manually delivered information is required. The clerk in charge of preparing the film folders and medical records is responsible for delivering them to the proper viewing station and for placing them in the proper order. The radiologist selects the images on the viewing station and the corresponding medical record files that have been manually delivered and placed in order by the clerk.

PERFORMANCE EVALUATION

We evaluated the performance on immediate reading cases by measuring the processing time for urgent examinations in the

Diagnostic Imaging Department based on the actual operation of the Toshiba General Hospital integrated RIS/PACS.

Measurement Methods

We installed time stamping software in the RIS controller and the PACS controller. This software records the time of the execution of certain control commands or manual key input by users. The following operations were time stamped:

1. Reception of the patient at the reception desk of the Diagnostic Imaging Department, input by a receptionist (RIS)
2. The end of the examination in the examination room, input by the radiology technicians (RIS)
3. The end of image transfer to the viewing station, logged by the system (PACS)
4. The completion of image interpretation, input by the radiologist (PACS)
5. The end of filming (film file generation for distribution to wards and outpatient clinics) (RIS)

The above data were merged, and the time between the time-stamped events was recorded. The processing speed was calculated and analyzed by type of examination.

The patients used for this evaluation were seen from October 24, 1994 through October 29, 1994. The characteristics are shown in Table 2. Patients undergoing two or more examinations in a single day (in which the examination time is longer

Fig 7. Distribution of time from the reception of the patient to the end of filming within the Radiology Department for other examinations, October 24 through 29, 1994; total = 119; no. of inpatient and nonurgent outpatient = 94; no. of urgent outpatient = 25.

Fig 8. Time stamp intervals for urgent general X-ray examinations for outpatients.

than the actual time) and portable examinations (in which the time stamp for data input does not reflect the actual examination time) were excluded.

RESULTS

The processing times for urgent and nonurgent patients for general X-ray and other examinations are shown in Table 3. The following results were obtained:

- 1. General X-ray examinations and other examinations for urgent outpatients were processed within 30 minutes and within 1 hour on average after reception, respectively.
- 2. A majority of general X-ray examinations for urgent outpatients were processed within 40 minutes after reception, whereas other examinations took longer (Fig 6).
- 3. For other types of examinations, there was a difference between urgent and nonurgent examinations (Fig 7).
- 4. For general X-ray examinations for urgent outpatient, it took 20 minutes to the end of the

interpretation, even when images were preloaded within approximately 5 minutes after the end of the examination. The reason is that there is a waiting time after electronic images are transferred until the manually distributed images can be put in the correct order. Consequently, processing was completed within the specified time at any time during that day (Figs 8, 9).

- 5. The waiting time for images at each viewing station was slightly increased at peak time, but all examinations were completed within regular working day (Fig 10).

In summary, the processing time for urgent outpatient examinations in the Diagnostic Imaging Department was reduced compared with that of nonurgent examinations. The goal of processing cases from patient reception to a completed report in 40 minutes, which was the primary design objective of the system, was achieved without interfering with routine operations.

Fig 9. Time stamp interval of general X-ray examinations for inpatient and nonurgent outpatients.

Fig 10. Number of queued examinations in every 30-minute interval, October 24, 1994 (Monday); total = 101.

DISCUSSION

The success of our method is established by this evaluation of the processing time for immediate reading cases and because the system has been actually operated in this manner since May 1993. Our methods and results should be useful in other parts of the hospital. The method is also applicable to other type of hospitals to support immediate reading in a practical setting, regardless of the percentage of the urgent cases.

There are approximately 10,000 hospitals in Japan with more than 20 beds and 500 hospitals with more than 500 beds. The system of interpretation employed at these hospitals can be classified as follows:

1. Interpretation and reporting of all examinations is performed in the Diagnostic Imaging Department.

2. Interpretation and reporting of a limited set of diagnostic modalities (eg, computed tomography and magnetic resonance) is performed in the Diagnostic Imaging Department.
3. Interpretation is performed in wards and outpatient clinics.

Most hospitals in the United States are classified as being of the first type, whereas most hospitals in Japan are of the second type. The mechanisms discussed in this article are applicable for both the first and second types of departments. For the hospitals of the third type, even if the system is managed directly by the HIS, it is necessary to prepare the necessary information, including the manually delivered information, at the HIS viewing station and to prioritize the order of the presentation. Therefore, we can apply the technique proposed in this paper to the third type of system also.

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