Effect of Filmless Imaging on Utilization of Radiologic Services with a Two-stage, Hospital-wide Implementation of a Picture Archiving and Communication System: Initial Experience of a Fee-for-service Model

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A medium-sized general hospital using a fee-for-service model implemented a hospital-wide picture archiving and communication system (PACS) in two stages. This study evaluated the reporting time with filmless operation and the effect of filmless imaging on referring physicians' use of the radiologic service before and after completion of the second stage of PACS implementation. The relationship between the total number of hospital patients and the number of radiologic department patients was also evaluated. All sample images were retrieved from the PACS. All corresponding reports except for one for a computerized tomography study were available. The median reporting time for different studies performed during working hours was less than 2 hours. There was a significantly positive and linear relationship ($p < 0.01$) between the total number of hospital patients and the number of radiologic department patients after hospital-wide implementation of PACS. We conclude that the fee-for-service model had no negative impact on referring physicians' use of radiologic services in a filmless hospital.

Key Words: picture archiving and communication system, PACS, filmless radiology
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The picture archiving and communication system (PACS) is an emerging solution for the challenges a hospital encounters in the management of imaging data in the era of computer and network technology and is proving to be an important part of an integrated information system in a modern hospital. The goal of becoming a so-called filmless hospital can be achieved by successfully installing and integrating a hospital-wide PACS with other information systems, such as a hospital information system (HIS) and radiology information system (RIS).

There are several advantages to a filmless hospital. In PACS, imaging data are generated, transferred, and stored digitally. This allows the image information to be transferred rapidly within the network and archived by computer using reliable memory media within a small space. Theoretically, PACS can manage imaging data more efficiently than conventional management systems, and it can allow physicians the convenience of timely access to their patients' images and

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imaging reports without the need for much effort. More thorough studies of the images can also be performed. For example, phone consultations with radiologists are possible when both sides can view the same images at different workstations. According to a survey from the UK, more historical images were reviewed when the PACS was in use [1]. The time required to obtain an imaging diagnosis is also significantly decreased in the emergency department and intensive care unit [2, 3]. Even more interesting is the report that, in certain cases, lesion detection can be facilitated by soft-copy review with variable window width and center level settings to accentuate the contrast between normal and abnormal tissue [4]. Therefore, in terms of improved operational efficiency and diagnostic ability, patients should be better served with PACS than conventional film-based management systems. From the economics point of view, with filmless radiology, film-related costs such as the film itself, processing chemicals, personnel and space can be reduced drastically. From an environmental point of view, the release into the environment of toxins from film processing can also be diminished.

Not only the technical issues, but also user acceptability are critical success factors for PACS implementation [5]. Filmless operation makes all referring physicians and radiologists change their behavior in viewing medical images. The health care provider and the managers of imaging departments need to discover whether this change has any impact on the utilization of radiologic service in order to provide high-quality patient care with proper resources.

The effect of PACS and filmless imaging on utilization of radiologic services in a hospital using a capitation reimbursement mechanism has been discussed [6]. In this article, we analyze the effect of two-stage hospital-wide PACS implementation at an institution that uses a fee-for-service model. The report time is also a measure of the efficiency of the radiologic service; this was also evaluated.

Materials and Methods

The Municipal Hsiao-Kang Hospital is a local teaching general hospital with 428 beds. It has two intensive care units (ICUs), one pediatric complete nursing unit, nine general wards, eight operating rooms, one emergency room (ER), and more than 15 offices in the outpatient department (OPD). The main imaging department, the Department of Radiology, has three computed radiography units (CR; Fuji Medical Systems, Tokyo, Japan), one mammography unit (Toshiba Medical Systems, Tochigi-Ken, Japan), one computerized tomography unit (CT; Toshiba Medical Systems), one digital fluoroscopy unit (Toshiba Medical Systems), and one digital subtraction angiography unit (Toshiba Medical Systems). All imaging modalities in this department, except mammography, are compatible with digital imaging and communications in medicine (DICOM) standards. The Department of Radiology is staffed with two radiologists, seven radiographic technologists, and one nursing and three administrative assistants.

PACS implementation

Two-stage hospital-wide implementation of PACS was started in November 1998. The CR images were first sent to PACS in December 1998. All DICOM-compatible imaging modalities had been linked and nine workstations distributed throughout the hospital by the end of the first stage of implementation in January 1999. In addition to the Department of Radiology, the ER, ICU, surgical and medical wards, and OPD (chest medicine, surgery, urology, orthopedics) were provided with workstations. The plain radiographs of patients from these clinical units were interpreted by a radiologist and reviewed by clinicians using soft-copy displays on monitors. The second stage of implementation lasted from June to July 1999. During this stage, all radiologic images except mammograms were sent to PACS. PACS service was extended to all the wards and OPDs except psychiatry, dermatology, and dentistry. In total, 40 diagnostic and review workstations were installed. The RIS and HIS were further integrated with PACS at this stage.

PACS infrastructure

All images from the various modalities are first sent to the main server (Hewlett-Packard, Cupertino, CA, USA), duplicated in a backup server (Acer, Taipei, Taiwan), and then sent to a forwarding server (Hewlett-Packard, Cupertino, CA, USA). Redundant design is used for main and forwarding servers. Components are linked by fiber optics or fast-ethernet networks with a bandwidth of 100 Mbit/second.

In our system, images are compressed by PACS software (UNIsight, EBM, Co., Ltd, Taipei, Taiwan).

Lossless compression with a ratio of about 3:1 is used for near-term images in the redundant array of inexpensive disc (RAID) in the main and backup servers. Lossless images are stored for about 6 months in the main and backup servers for primary imaging diagnosis. They are stored in magneto-optical discs of 2.6 gigabytes (GB) before they are converted into lossy format in the main server. Except for CT, images stored in the forwarding server and long-term images in the main server undergo lossy compression with a ratio of about 18:1. The capacities of RAID for main, backup, and forwarding servers are about 200, 100, and 400 GB, respectively. In the diagnostic workstations in the Department of Radiology, images from the main server are displayed on 2K x 2K or 1K x 1K monochrome monitors (Data Ray, Westminster, CO, USA); 1K x 1K monochrome monitors are also used in the ER and OPD (chest medicine, urology), where they display images from the main or forwarding server. The remaining clinical review workstations are equipped with 19- or 21-inch PC (personal computer)-based color monitors (ViewSonic, Walnut, CA, USA), which display images from the main or forwarding server.

Analysis

Reporting times were evaluated retrospectively after implementation of the hospital-wide PACS was complete. Stratified random sampling for radiography, CT, and special examinations used a random-number table from the technical records written by radiographic technicians. The study included 457 of 48,961 radiographs, 134 of 2813 CT examinations, and 136 of 2854 special examinations collected between October 1999 and September 2000. The images and their corresponding reports, prepared and typed by radiologists, were retrieved retrospectively. Reporting time was defined as the interval between the time the image was generated and the time the written report was made available on the PACS and HIS. The examining times for radiography and CT studies were categorized into four different time periods: Time A, normal working hours (8 AM to 4 PM Monday to Friday and 8 AM to 11 AM Saturday); Time B, 4 PM to 0 AM Monday to Friday; Time C, 0 AM to 8 AM Monday to Saturday; and Time D, other off-duty hours (4 PM to 0 AM the day before any holiday and 11 AM to 0 AM Saturday and all Sundays and holidays).

In order to objectively access the influence of PACS on the utilization of radiologic services by clinicians, the relationship between the total number of hospital patients and the number of radiologic department patient visits before and after hospital-wide PACS implementation was also evaluated. The total number of hospital patients included the number of patients visiting the OPD and ER and the number of patients admitted to wards multiplied by the length of stay in days.

Statistical analysis

Pearson correlation was used to test the associations between the total hospital patient number and radiological department patient number before and after hospital-wide PACS implementation. A p value of less than 0.05 was considered statistically significant.

Results

The archiving efficiency of our PACS was good, in that all the sampled images, including plain radiographs, special examinations, and CT studies, could be retrieved from the forwarding server. All imaging reports, except one for a CT study, could be reviewed. The reporting times found for the four time periods are summarized in Table 1. The reporting times for special examinations during Times B, C, and D were not calculated because very few such examinations were performed during these time periods. Median reporting times for radiography, CT, and special examinations performed during working hours (Time A) were less than 2 hours and the respective mean times were between 2 and 3 hours. Reporting times for studies performed during off-duty hours (Times B, C, and D) were significantly longer than for those performed during Time A.

The total numbers of hospital patients and the numbers of radiologic department patients are listed in Table 2. There was a significant linear relationship ($r = 0.82$, $p < 0.01$) between these two patient numbers after completion of hospital-wide PACS implementation.

Discussion

Our study validates the good reliability and efficiency of imaging data management with PACS in a medium-

Table 1. Reporting times (in minutes) during various time periods

Time period	Radiography		CT		Special examinations	
	Mean	Median	Mean	Median	Mean	Median
A	170 ± 251	98	124 ± 135	105	134 ± 89	105
B	743 ± 525	844	834 ± 409	761	N/A	N/A
C	491 ± 662	414	306 ± 154	308	N/A	N/A
D	1769 ± 1089	1345	1756 ± 648	1760	N/A	N/A

CT = computerized tomography; mean = mean ± standard deviation; Time A = 8 AM to 4 PM Monday to Friday, 8 AM to 11AM Saturday; Time B = 4 PM to 0 AM Monday to Friday; N/A = not available; Time C = 0 AM to 8 AM Monday to Saturday; Time D = other off-duty hours (4PM to 0 AM the day before any holiday and 11 AM to 0 AM Saturday and all Sundays and holidays).

Table 2. The total number of hospital patients and the number of radiologic department patients before and after hospital-wide implementation of a picture archiving and communication system (PACS)

	Date	Hospital patients	Department patients	Statistics
1st-stage PACS				
	January '99	21,824	3489	$r = 0.50$
	February '99	20,955	2973	$p > 0.05$*
	March '99	27,314	4491	
	April '99	27,711	3776	
	May '99	26,306	3580	
	June '99	26,765	3129	
	July '99	29,624	3586	
	August '99	30,868	3779	
2nd-stage PACS				
	October '99	32,030	3687	$r = 0.82$
	November '99	33,227	3979	$p < 0.01$*
	December '99	36,205	4183	
	January '00	33,952	4317	
	February '00	29,681	3437	
	March '00	36,054	4272	
	April '00	33,611	5022	
	May '00	37,677	5198	
	June '00	35,380	4620	
	July '00	37,336	4736	
	August '00	39,508	5132	
	September '00	39,062	5068	

r = Pearson correlation coefficient. *t-test for a correlation coefficient.

sized general hospital. In this study, one CT report could not be found in our reporting database for some unknown reason. An RIS fully integrated with PACS and HIS should also be installed, and a better quality-control mechanism involving dedicated personnel or an effective automated system should be used because if radiologists do not accurately interpret imaging studies in a timely fashion, a malpractice case may follow [7].

The mean and median reporting times for all studies were acceptable for working hours, but considerable variation did occur, possibly due to an occasional shortage of radiologists, for example, when there was an extraordinary number of additional emergency examinations or imaging-guided interventions. According to research by Mehta et al [8], a PACS can decrease the average time needed for a preliminary report to be available on the HIS. Also, radiologist

productivity and report turnaround time are improved with soft-copy interpretation using a PACS workstation [9]. Our mean reporting times for after-hours time periods are significantly longer than those during working hours due to the lack of 24-hour in-house service by a board-certified radiologist. However, in the environment of PACS and digital imaging, after-hours support by a qualified radiologist can be achieved with teleradiology and web browser technology, which is now offered by most PACS vendors [10, 11].

The transition from a partially implemented to a hospital-wide PACS had no negative impact on the use of the radiologic service by clinicians in our institution, even though it did change the way most physicians viewed images. The two-stage installation of the information system made it possible for some physicians to become familiar with the system. Detailed discussion and consensus were also offered and achieved before enterprise-wide implementation. The utilization of radiologic services by clinicians can be affected by many factors, including insurance payment systems and satisfaction with the imaging services. In a large-scale study conducted by Reiner et al, the transition to filmless operation was associated with an increase in the use of radiologic services [6]. A capitation reimbursement mechanism instead of a fee-for-service model was used in most of their medical centers. They did not receive additional pay based on the increase in the volume of imaging examinations. Therefore, they assume that referring physicians may increase their use of imaging services because they consider them to be of high quality and easy to access. In a fee-for-service model, in order to balance the financial status, some regulations are needed to prevent a dramatic increase in the use of high-technology studies. Hence, clinician use of radiologic services may be limited and utilization of radiologic examinations may not be unduly increased. In conclusion, most imaging studies performed during working hours can be reported in a timely fashion with soft-copy interpretation by certified radiologists. Although a PACS makes a significant change in the way medical images are viewed by both radiologist and referring physician, no obviously negative impact was found on their use of radiologic services in a hospital using a fee-for-service model.

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