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Picture archiving and communication system: prospective study

圖片存檔和通訊系統：預期研究

Objectives. To evaluate the use of a picture archiving and communication system and user satisfaction in order to further improve its quality.
Design. Prospective study.
Setting. Medical college hospital, Japan.
Materials and methods. An automated computerised method was used to collect the data from March 1999 to February 2000.
Main outcome measures. Each workstation automatically recorded data on the rank of the user, purpose of use, use of postprocessing tools, and user satisfaction.
Results. The number of resident users in the radiology reading room increased and those outside the reading room decreased, but the number of staff users changed little. The purpose of use and the use of postprocessing functions in the reading room were not significantly different from those outside it (P=0.179 and P=0.269, respectively). The average numbers of images accessed per workstation monthly in the reading room, the general practice ward, and the gastroenterology ward were 1081, 970, and 741, respectively. Only 12 images in the orthopaedic surgery out-patient clinic and 70 images in the orthopaedic surgery ward, however, were accessed per month. The percentages of satisfied users decreased both inside and outside the reading room. The degree of satisfaction of users in the reading room was significantly different from that outside it (P=0.004). The most common reason for dissatisfaction was the length of time necessary to retrieve images.
Conclusions. It is necessary to shorten response times of picture archiving and communication system workstations. Repeated data collection and evaluation, however, are also important.

目的：評估圖片存檔和通訊系統的使用以及用戶的滿意程度，以便進一步改善其品質。
設計：預期研究。
安排：醫學院醫院，日本。
取材及方法：使用自動化電腦方法，收集1999年3月至2000年2月期間的資料。
主要結果測量：每個工作站自動記錄用戶等級、使用用途、後處理工具的使用以及用戶滿意程度的資料。
結果：在放射醫學閱讀室內使用的人數增加，在閱讀室外使用的人數減少，而職員使用的人數變化不大。使用用途和後處理功能的使用方面，閱讀室內的使用者與閱讀室外的使用者無顯著差別 (P=0.179 及 P=0.269)。每個工作站每月圖片讀取平均數分別為：閱讀室 1081 ，普通病房 970 ，腸胃病病房 741 。然而，矯形外科門診部每月僅讀取了12張圖片，矯形外科病房每月讀取了70張圖片。滿意用戶的百分比在閱讀室內外都有所下降。在滿意程度方面，閱讀室內的用戶和閱讀室外的用戶有顯著的差別(P=0.004)。最常見的不滿是讀取圖片所需的時間太長。
結論：必需縮短圖片存檔和通訊系統工作站的回應時間。但重複的資料收集和評估亦很重要。

Key words:
Diagnostic imaging;
Information storage and retrieval;
Radiology;
Radiology information systems

關鍵詞：
圖像診斷；
信息存取；
放射醫學；
放射醫學信息系統

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Introduction

The National Defense Medical College Hospital is a large Japanese provincial hospital with a large-scale picture archiving and communication system (PACS). The PACS includes computed radiography (CR), magnetic resonance imaging (MRI), computed tomography (CT), ultrasound (US), digital fluoroscopy, nuclear

medicine (NM), and a film-digitiser acquisition modality. We have developed a large-scale PACS that can digitally store the images produced by a variety of the modalities that have been incrementally introduced over the past 7 years. All images produced in our hospital are stored on the PACS server, substantially improving the quality of our database and clinical service. Radiologists are able to view all images on workstations in the radiology reading room at any time. Use of this system has improved the availability of image resources for diagnosis and reduced the film jacket-related workload.

In March 1999, the radiology department acquired seven more PACS workstations to access and compare images. Three workstations (1K HI-C655 stations, Fuji Photo Film Co., Ltd., Tokyo, Japan) were located in the reading room, and one workstation each was located in the divisions of NM, CT, US, and angiography. Seven other workstations had already been located in the radiology and orthopaedic surgery out-patient clinics, the emergency room, the general practice, gastroenterology, and orthopaedic surgery wards, and in the MRI room. Each workstation had one display.

We initially hypothesised that satisfaction with image quality and image processing capabilities among radiologists and physicians would be high, and that they would experience substantial improvements in the quality of service. However, there were no reliable data based on direct observations and objective measurements. These data are necessary to improve workflow and user satisfaction, not only for radiologists but for referring physicians.[1,2] We conducted a computerised survey that was installed onto the PACS workstations where all data could be collected automatically.

We describe the results of this prospective study designed to evaluate PACS use and user satisfaction in selected sites to obtain useful suggestions for improvement from both radiologists and referring physicians.

Materials and methods

We have developed a large-scale hybrid PACS that can store images produced by a variety of digital modalities. All images are printed by laser printers on film, stored in film jackets, and used for patient care, education, and research (hybrid of printed films and digital files). We can also use digital images stored on a central PACS server (Fuji Photo Film Co., Ltd., Tokyo, Japan).

This PACS design has been gradually refined since 1992. Computed radiography was designated the primary format for capturing images; however, non-CR modalities were included as secondary formats (hybrid of primary and secondary images). This procedure enabled all images to be stored on a central PACS server. All modalities had been transferred to CR, with the exception of one conventional X-ray fluoroscope, before January 1999. Images obtained with the conventional X-ray fluoroscope could not be stored on the PACS server. Ongoing digitisation of all fluoroscope images began in January 1999, and all images produced in our hospital have been stored on the PACS server since this time.

This newly developed PACS Expanding-Data Management System (Fuji Photo Film Co., Ltd., Tokyo, Japan) integrates and manages all CR and non-CR images. All digital images are stored on the non-digital imaging and communications in medicine (non-DICOM) server; however, images from the newly equipped MRI and CT are stored on both DICOM and non-DICOM servers. In other words, this system is a DICOM and non-DICOM hybrid.

In March 1999, we installed seven new PACS workstations (HI-C655, Fuji Photo Film Co., Ltd., Tokyo, Japan) in addition to the previous ones. The resolution of the display station monitors was 1600 x 1200 x 8 bits. Three workstations were located in the radiology reading room, and one workstation each was located in the orthopaedic surgery out-patient clinic, and the general practice, gastroenterology and orthopaedic surgery wards. Before the study commenced, several meetings were held to educate users about how to use the workstations. We collected data on PACS usage and satisfaction from all consecutive users between 1 March 1999 and 29 February 2000. Each workstation automatically recorded information on the rank of the user, purpose of use, use of postprocessing tools, and user satisfaction. The results of user satisfaction were divided into three categories: dissatisfied, almost satisfied, and satisfied. Display time was measured three times by two different observers.

Statistical analysis was performed using the independent-sample two-tailed Mann-Whitney *U* test to detect associations among the subsets. A P value of <0.05 was considered significant.

Results

Between May 1999 and October 1999, the number of users in the reading room increased rapidly, being 93, 137, and 232 for the first, second, and third 2-month periods, respectively. The number of users outside the reading room, however, changed little, being 71, 75, and 47 for the first, second, and third 2-month periods, respectively. In the reading room, the number of resident users increased rapidly between September 1999 and October 1999 (3, 16, and 113 for the first, second, and third 2-month periods, respectively), although the number of staff users (professors, assistant professors, and fellows) changed little. In contrast with the rapid increase in the number of resident users in the reading room, the number of resident users outside the reading room decreased rapidly between September 1999 and October 1999 (38, 42, and 3 for the first, second, and third 2-month periods, respectively). The number of staff users, however, changed little. Purpose of use of PACS in the reading room and outside the reading room is shown in Fig 1. Most

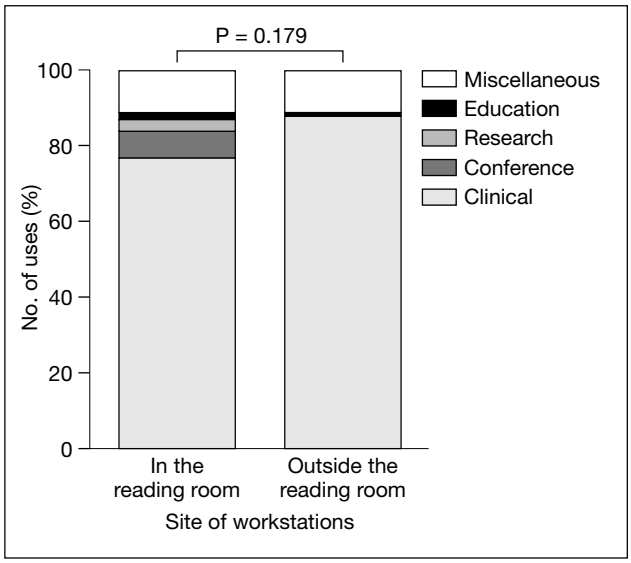

Fig 1. Purpose of use (May–October 1999)

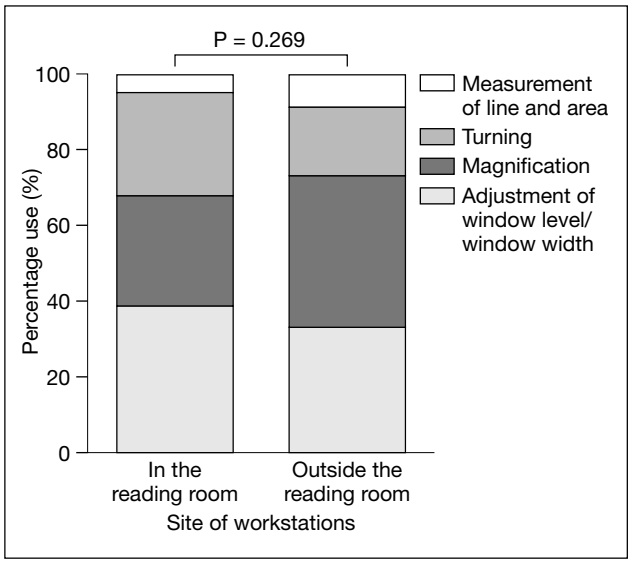

Fig 2. Total number of uses of postprocessing functions (May–October 1999)

people used the PACS workstations for clinical viewing. In 77% of cases in the reading room and 88% outside the reading room, use was for clinical viewing. The purpose of use was not significantly different between the two groups (P=0.179). We also compared the total number of uses of the four most commonly used postprocessing tools: measurements of line and area, turning, magnification, and handling of window level and window width (Fig 2). The postprocessing tools were used 1877 times in the reading room and 1092 times outside the reading room from May 1999 to October 1999. The frequency of use of each tool was not significantly different between the two subsets (P=0.269).

The numbers of prefetchings per terminal between March 1999 and February 2000 are shown in Fig 3. A slight decrease in the number of prefetchings was noted in the radiology reading room; however, the numbers of prefetchings per workstation outside the reading room remained

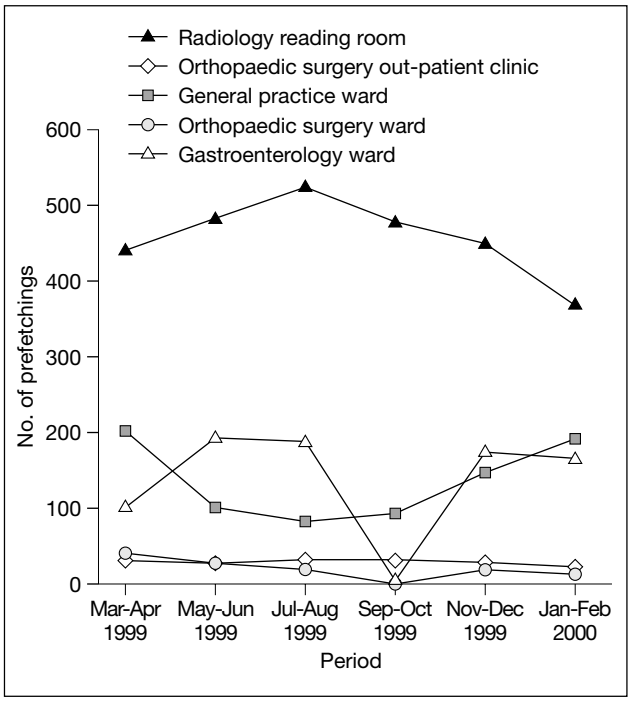

Fig 3. Number of prefetchings per workstation

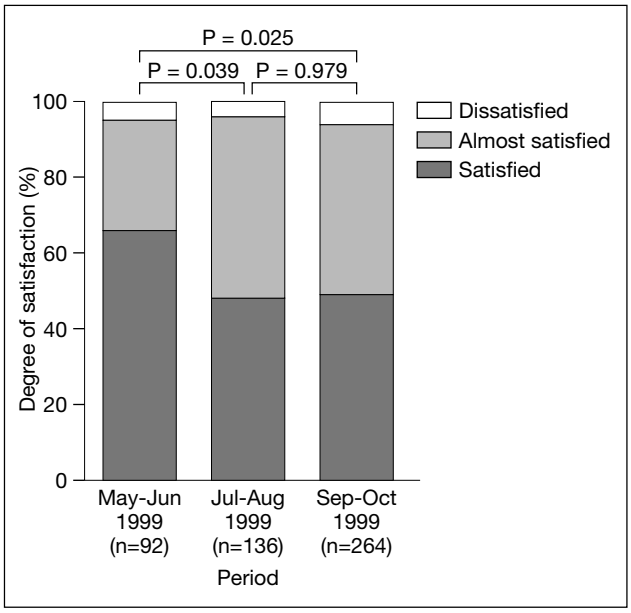

Fig 4. User satisfaction in the radiology reading room

almost constant throughout the year. The number of images accessed per workstation per month was highest of all in the reading room (1081 images per month), followed by the general practice ward (970 images per month) and gastroenterology ward (741 images per month). The PACS images, however, were seldom accessed in the out-patient clinic or orthopaedic surgery ward (12 and 70 images per month, respectively).

We assessed user satisfaction in the radiology reading room and outside the reading room. In the reading room, the percentage of 'satisfied' users was 66% between May and June 1999, but decreased to 49% between September and October 1999 (Fig 4). The degree of satisfaction between

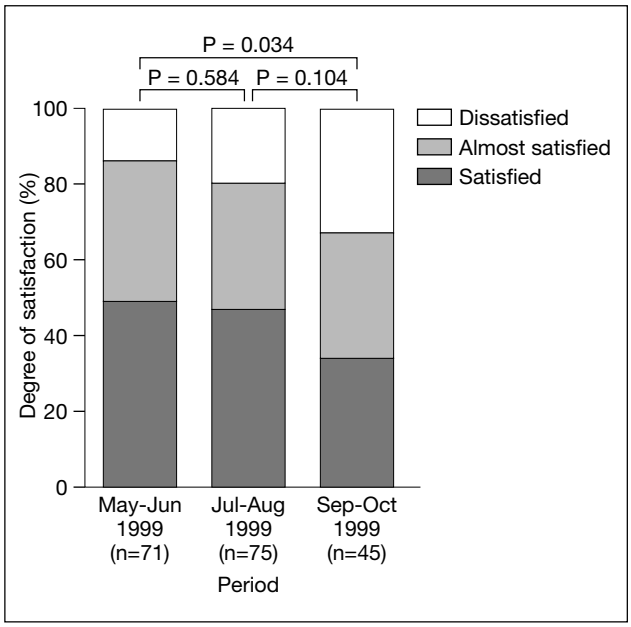

Fig 5. User satisfaction outside the radiology reading room

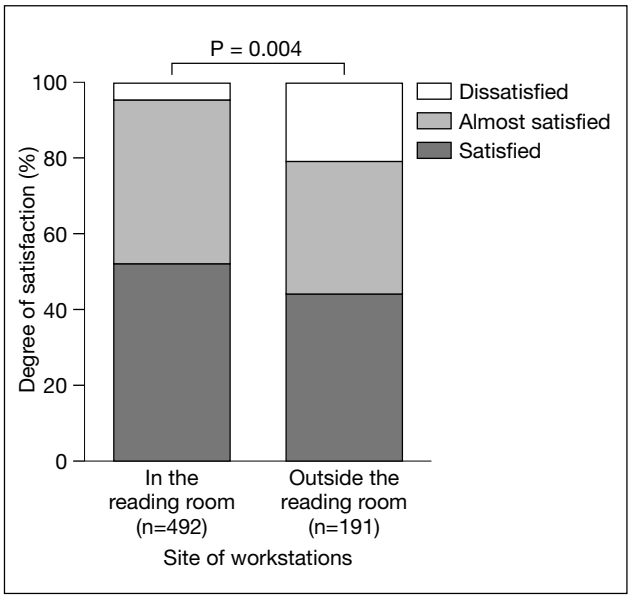

Fig 6. User satisfaction in the radiology reading room and outside (May–October 1999)

September 1999 and October 1999 was significantly different from that between May 1999 and June 1999 (P=0.025). User satisfaction outside the reading room is shown in Fig 5. The percentage of 'dissatisfied' users increased and those 'satisfied' decreased. The degree of satisfaction between September and October 1999 was significantly different from that between May and June 1999 (P=0.034) (Fig 5). We also compared the degree of satisfaction in the reading room with that outside the reading room between May and October 1999 (Fig 6). The percentage of 'satisfied' users was 52% in the reading room, but the percentage outside the reading room was 44%. The percentage of 'dissatisfied' users was 5% in the reading room as compared with 21% outside the reading room. The degree of satisfaction was significantly different between the two groups (P=0.004). The most common reason for dissatisfaction was the length of time necessary to retrieve images. This was despite the fact that viewing images, including any previous or current results, was possible at any of the workstations in as little as 10 to 30 seconds, with an average time of 25 seconds from the time the user began retrieving. Detailed evaluation of dissatisfaction or satisfaction was not performed, so as not to add undue complexity to the study.

Discussion

Many studies have been performed on the acceptability of PACS to both clinicians and radiologists, the efficiency of PACS, and its cost-effectiveness.[3-5] This survey differs from previous reports in that each workstation automatically collected the data by direct observations and objective measurements of consecutive users.[2,6] Measures based on computerised systems allow automated collection of huge amounts of data at any time. This method seems to be more useful for obtaining reliable data than the ordinary questionnaire.

The number of users at our hospital fluctuated during the study period. One of the reasons is that personnel changes of resident doctors occurred from September to October 1999, so that the number of resident users suddenly changed both in the reading room and outside it, while there was no change in the number of fellows. The number of resident users in the reading room increased suddenly between September and October 1999 because newly assigned residents favoured the PACS over the film jacket system. The sudden decrease in the number of resident users outside the reading room was because most resident doctors originated from other hospitals and had no experience in using the PACS workstations. Training in their use was needed for those lacking familiarity. The number of staff users did not change substantially because no personnel change occurred during the period. The number of potential users in each category was similar. The results of this study suggest that a cross-sectional survey such as an ordinary questionnaire is not adequate for the precise evaluation of PACS usage, but rather that data should be collected for several months, or at intervals of several months. In the evaluation of the purpose of use and the use of postprocessing functions, the findings for the reading room and outside it were similar (Figs 1 and 2). These results suggest that a similar type of workstation could be made available in the reading room for radiologists and in other places for other clinicians. Minor individual modifications, however, are necessary in order to make the PACS more convenient, useful, and satisfying for all users.

As shown in Fig 3, the number of prefetchings per workstation in each place did not change substantially during the study period. A temporary decrease in the number of prefetchings in the gastroenterology ward was due to ward closure between September and October 1999. The frequency of use, however, differed between locations. Thus, some workstations are often used, others seldom, as noted

in the orthopaedic surgery out-patient clinic and ward. The low numbers of images viewed by orthopaedic clinicians in all areas suggests incomplete acceptance or implementation of the system. By acquiring these data, we can plan for future placement of workstations, anticipate problem extractions, and make individual modifications. Based on these data, further investigations of use in the out-patient clinic and orthopaedic surgery ward have commenced.

The tendency of user satisfaction to decline noted both in the radiology reading room and outside the reading room is alarming. One of the main reasons was the time delay in retrieving images. In fact, retrieval time is faster than a human operator can perform the same task but depends ultimately on response times of the PACS workstations. It appears that users wait for images while the PACS is searching, and that this is a perceptual problem.[7] Once users learn to use the workstations and become accustomed to retrieving images, simply waiting becomes more frustrating for them. This may explain the gradual decline in satisfaction in association with consistent use throughout the year. These results also suggest that cross-sectional assessment of user satisfaction is not adequate. Assessment of user satisfaction should be repeated several months later or be performed continuously for 6 months or more. The differences in user satisfaction between radiologists and referring physicians may be due to the perceptual difference described. Nevertheless, a faster link to the PACS server is being planned.

Conclusion

This study suggests that it is necessary to shorten response times of PACS workstations; however, repeated data collection and evaluation are also important in planning further improvements in quality of the PACS.

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