A Comparison Between Digital Images Viewed on a Picture Archiving and Communication System Diagnostic Workstation and on a PC-Based Remote Viewing System by Emergency Physicians

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Picture Archiving and Communication Systems (PACS) make possible the viewing of radiographic images on computer workstations located where clinical care is delivered. By the nature of their work this feature is particularly useful for emergency physicians who view radiographic studies for information and use them to explain results to patients and their families. However, the high cost of PACS diagnostic workstations with fuller functionality places limits on the number of and therefore the accessibility to workstations in the emergency department. This study was undertaken to establish how well less expensive personal computer-based workstations would work to support these needs of emergency physicians. The study compared the outcome of observations by 5 emergency physicians on a series of radiographic studies containing subtle abnormalities displayed on both a PACS diagnostic workstation and on a PC-based workstation. The 73 digitized radiographic studies were randomly arranged on both types of workstation over four separate viewing sessions for each emergency physician. There was no statistical difference between a PACS diagnostic workstation and a PC-based workstation in this trial. The mean correct ratings were 59% on the PACS diagnostic workstations and 61% on the PC-based workstations. These findings also emphasize the need for prompt reporting by a radiologist.
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KEY WORDS: Digitized images, picture archiving, PC images, PACS, RVS, computers, radiology.

THE ROYAL ALEXANDRA Hospital for Children (RAHC) located at Westmead, Sydney, Australia is a 350 bed dedicated pediatric hospital providing specialist pediatric services for the people of Sydney and New South Wales and to many South East Asian and South Pacific rim countries. When opened on the 6 November 1995, it was the first filmless hospital in Australia and the first pediatric filmless hospital in the world. Being the first of its kind in Australia, the hospital has shed new light on the way radiographic studies (and other imaging modalities) are performed, archived, interpreted, and communicated between radiologists and clinicians.

Many trials in the last few years have shown the efficiency of a picture archiving and communication system (PACS) within a full scale hospital setting.¹⁻⁴ At RAHC, radiographic images are digi-

tally acquired and stored on optical disk archives. These images may be sent to reporting rooms within the radiology department to be interpreted by specialist radiologists and fellows. Images may also be distributed to a server and retrieved on workstations located on the wards where they are viewed by the clinician.

Owing to the nature of emergency care, immediate viewing of the images is desirable. The emergency department has access to both PACS diagnostic workstations and to PC-based workstations that enable one to view radiographic images. Each such PC workstation is known as a Remote Viewing System (RVS). Although there have been many trials proving the feasibility of PACS as an alternative (both economically and practically) to film-based radiology,⁵⁻¹¹ no trials to date have shown whether RVS viewed images are comparable to images viewed on a PACS diagnostic workstation.

Two PACS diagnostic workstations are currently located in the emergency department on the front desks of the observation ward and in ambulatory care. The same desks are also used by nursing staff and doctors. Because of the expense of PACS diagnostic workstations, only one workstation was available for each area of the emergency department. The workstation had to be placed in an area that is accessible to every physician. Privacy, unfortunately, had to be overlooked. Concerned parents of ill patients often gather around a crowded and noisy workstation to be informed about their child's radiographic studies.

Less expensive RVS workstations on the other

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hand could be located in the consultation rooms, and radiographic images can be displayed and explained to the concerned parents in a quieter and perhaps less stressful setting. Because of the relatively low cost of the RVS hardware, it is feasible that RVS software could be loaded onto the existing network of clinical workstations located in all of the consultation rooms of the emergency department, thereby enhancing the range of tools available to support the emergency physicians. RVS workstations would be a more economical option if the image quality were shown to be roughly equivalent to PACS diagnostic workstations.

The aim of this trial was to assess whether RVS workstations are equivalent to PACS diagnostic workstations for the evaluation of radiographic images in the emergency department by emergency physicians.

MATERIALS AND METHODS

The two viewing systems, PACS diagnostic workstations and RVS workstations, were set up in different areas of the emergency department. The PACS diagnostic workstations used in the trial was supplied by Medical Applications Pty Ltd of Australia (a joint venture of Phillips and Siemens) and is used for the viewing of radiographic images in the emergency department. The display consisted of a Simomed monochrome 21-inch monitor (Siemens, Germany) with a resolution of $1K \times 1K$ pixels and a luminescence of 175 lamberts. The system includes an MV200, SPARC5 with architecture, 64 MB RAM, 2 GB hard disk, where 1 GB is available for image storage. Network interface with the archiving and storage system was through Ethernet. The system software used was SunOstm (Unix).

The RVS system used was supplied by Cerner Pty Ltd (Siemens, Germany) and was implemented on a local basis in the emergency department. The display consisted of an NEC 17-inch monitor with a resolution of 1024×768 pixels and a luminescence of 50 lamberts with a Matrox MGA Millennium video controller. PC hardware consisted of a Compaq Prolinea 5166 Intel Pentium computer with 16 MB RAM, 2 GB hard disk. Network interface with an SPI/Diacom spooler was through FDDI and Ethernet. System software used was Windows (3.11 for workgroups; Microsoft Corporation, Redmond, WA) on Novel NetWare. The display mode was set to 8 bit, or 256 colors. The SPI/Diacom spooler used by the RVS included a 16 GB hard disk.

A series of radiographic studies were compiled for interpretation by 5 emergency physicians. The same 73 digital radiographic studies were randomly arranged on both a PACS diagnostic workstation and on a RVS workstation. They knew, of course, whether they were assessing an image on a PACS diagnostic workstation or on a RVS workstation.

Clinical histories were not given with the radiographic studies. The studies chosen for inclusion in the evaluation were selected from a series of patient radiographic studies performed

between 6 November 1995 and 15 December 1996 within the hospital but not necessarily in the emergency department. All abnormal radiographic studies selected for the study group included images with more often missed subtle abnormalities. The radiologists' reports were considered to be the gold standard for the trial. Before finalizing a radiographic report, the findings were validated by a senior radiologist. Radiologists included staff specialists and fellows. The emergency physicians consisted of 4 pediatric emergency staff specialists and 1 pediatric emergency registrar (Table 1).

The radiographic images were presented to each Emergency Physician in 4 rounds (Table 2). Each round was time limited to 30 minutes, giving a total viewing time of 2 hours. To decrease case recognition a 2 day time period was allowed between each round.

Each emergency physician who consented to participate was informed of the details of the trial before the first sitting and was given a result sheet for completion during each round.

Data were later coded as either correct or incorrect when compared with the gold standard. If a radiograph was normal and the emergency physician reported an abnormality, that case was graded as incorrect. Abnormal radiographic studies were marked as shown in Table 3.

The percentage of the PACS diagnostic workstation and RVS workstation interpretation that was in agreement with the gold standard was computed. For normal radiographic studies, the percentage represents the specificity of the test and, for abnormal radiographic studies, the sensitivity. The proportion of the results from the PACS diagnostic workstation and RVS workstation that was in agreement for normal and abnormal findings combined was also computed together with the sensitivity and specificity of the RVS results when compared to the PACS diagnostic workstation results, Kappa values and average correct classification rate.¹²

Table 1. Radiograph Selection

Normal	Number	Abnormal	Number
Chest Radiograph	14	Chest Radiograph	13
		Focal inflammatory changes	4
		Pleural effusion	3
		Pneumomediastinum	3
		Pneumothorax	
Long Bone Radiographs	10	Long Bone Radiographs	7
		Supracondylar fractures	4
		Spiral fractures	3
Skull Radiographs	5	Skull Radiographs	5
		Skull fractures	
Neonatal Chest Radiographs	2	Neonatal Chest Radiographs	6
		Hyaline membrane disease	
Abdominal Radiographs	5	Abdominal Radiographs	6
		Gallstones	3
		Renal Calculi	3
Total	36	Total	37

Table 2. Session Rotation

Round	Session	Number of Exams
1	PACS 1	35
2	RVS 2	38
3	RVS 1	35
4	PACS 2	38

RESULTS

Table 4 shows the percentage correct for both the normal and abnormal radiograph studies (ie, the specificity and sensitivity) when compared with the gold standard. The specificity and the sensitivity were very similar and were consistent both between systems and between the two sessions when the films were read.

When results from the RVS workstation were compared with the PACS diagnostic workstation as the gold standard, the proportion in agreement was similar for all physicians (Table 5). However, the sensitivity of the RVS was higher than the specificity indicating a closer agreement between the two systems for abnormal studies than for the normal studies for all physicians. The average correct classification rate between the two systems, which indicates the probability of a consistent answer, was high but the Kappa statistic was modest and suggested that the proportion of variance between

Table 3. Radiological Scoring

Focal inflammatory changes:	Exact position of the changes had to be noted or the question was marked as incorrect. If anything other than the inflammatory changes were noted then the question was marked as incorrect
Pleural effusion:	Pleural effusion and position had to be noted for a correct answer
Pneumomediastinum:	Pneumomediastinum had to be noted to obtain a correct answer
Pneumothorax:	A correct answer included noting the existence and position of the pneumothorax
Supracondylar fracture:	Exact anatomical location was needed for a correct answer
Spiral fracture:	As per Supracondylar fracture
Skull fracture:	Exact anatomical location was required for a correct answer
Hyaline membrane disease:	"Presence of" in neonatal radiograph was required
Gallstones and Renal Calculi:	Identification of calcified areas in the vicinity of either kidney, gall bladder or their associated ducts was required

Table 4. Percent Correct for PACS Diagnostic Workstation and RVS Workstation Compared with the Gold Standard (Radiologist Report)

Groups	PACS Workstation % Correct	RVS Workstation % Correct
Overall	58.9	60.5
Normal Exams	63.3	61.1
Abnormal Exams	54.6	60.0
Session 1	60.0	60.0
Session 2	57.9	61.2

the two systems was similar to the proportion of variance between films.

By using a 95% confidence interval to compare RVS and PACS it was found that in each of the above groups the confidence interval contained zero. Hence, there was no statistical difference between the RVS workstation and PACS diagnostic workstation in this trial.

DISCUSSION

The study confirmed that there is no statistically significant difference in the outcome of interpretations on a PACS diagnostic workstation and on a RVS workstation by emergency physicians. Although the aim of the trial was to assess whether a RVS is an equivalent radiographic viewing system to a PACS diagnostic workstation for the evaluation of emergency patient radiographic images, it is quite difficult to emulate the situations emergency clinicians are placed under in day-to-day practice. It would have been impractical and very time consuming to have a trial where a clinician was called to view a radiographic study as he or she was walking through the corridors of the emergency department.

Because of the impracticalities of an ideal trial, a time limit was placed on each round of the trial to increase the anxiety of the participant readers to a level which may be comparable to that experienced

Table 5. Comparison of RVS Workstation with PACS Diagnostic Workstation

Observer	Proportion in Agreement	Sensitivity	Specificity	ACCR	Kappa
I	0.75	0.83	0.59	0.86	0.41
II	0.71	0.93	0.60	0.83	0.44
III	0.68	0.72	0.62	0.80	0.33
IV	0.68	0.70	0.67	0.80	0.36
V	0.68	0.73	0.63	0.80	0.36
Total	0.70	0.76	0.62	0.82	0.39

Abbreviation: ACCR, Average Correct Classification Rate.

in situations encountered in the emergency department. All participant readers mentioned the fact that they were a little anxious before undergoing the trial, and this was noted especially before the first round of the trial. By the last round the participant readers remarked that their anxiety levels had decreased. It is often the case that anxiety levels influence performance. Considering this, it was of interest that there was no statistical difference between the responses of the first and the last rounds.

The issue of recall was brought up by the participants of the trial as rounds 3 and 4 were being conducted. All emergency physicians had mentioned that some radiographs could be recognized from previous rounds, but the actual abnormality could not be recalled. The method of conducting the trial allowed 2 days between rounds 1 and 2, and rounds 3 and 4. It also allowed for a 1 week break between rounds 2 and 3. Although possible, it is unlikely that recall introduced significant bias into the study.

Before the trial radiologists were consulted and made suggestions as to the categories of radiographic abnormalities that should be used in the trial. Although the categories of abnormalities used in this trial were limited, they were representative of the abnormalities that are more difficult to detect in the emergency situation and are often missed by junior staff.

Comparison of the assessment by image type was difficult in this trial in view of the limited number of available images. The relatively high error rate by emergency physician was not surprising considering the degree of difficulty of the films selected for inclusion in the study and the conditions under which each subject was tested. Only one subject scored consistently higher than the others with 105 correct responses out of a possible 146 in comparison with the remaining subjects with 334 out of a possible 584 answers correct ($P > .001$). This Emergency Physician received the same briefing that the other clinicians were given and was just as comfortable as the others with the use of both workstations.

Despite the level of training, previous studies looking at tuberculosis have shown considerable inter- and intra-observer variability even where radiograph studies are interpreted by radiologists and chest physicians.¹³ The results obtained related

to the degree of difficulty of the images. In our study, fractures are more readily detected than other abnormalities with calculi proving the hardest to detect (Table 5). This may in part be because of the training of the subjects who are more attuned to detecting acute injury but this could also suggest that bone images have greater clarity.

Earlier studies by Razavi et al¹⁰ and Steckel¹¹ have shown the comparability of digital radiological chest studies in varying formats and hard copy. The performance of lower resolution soft-copy images was equally as good and provided considerable financial and information technology (IT) benefits.¹¹ To date, however, no study has compared PACS workstation viewed images to those viewed on a RVS workstation. The benefits of implementing a PC-based viewing tool include cost savings and more access to work stations in a busy emergency department environment. Bringing the image to the clinical interface will not only contribute to improving work practice but will also overcome the issue of patient privacy created by having to locate expensive PACS diagnostic workstations in a central location.

Although this trial has proven what it set out to do, it should be noted that it was a small scale trial and was limited by a number of factors including the difficulty of replicating the pressure of a busy emergency room, the exam sample size, and the small number of emergency physicians participating in the study. The inability to blind the emergency physicians as to which system was being assessed in each sitting could have influenced their performance on either system.

Although the results of this study are limited in terms of their applicability to all types of imaging and other body systems not studied, they can be used as a basis for conducting a larger scale trial that would pay more rigorous attention to overcoming the above limitations. However, the results are sufficiently robust to support implementing a PC-based viewing system in the emergency department or outpatient environment to facilitate accessibility for the physician and increase patient privacy.

CONCLUSIONS

The results of this study have shown that our RVS workstation is an equivalent viewing system to our PACS diagnostic workstations for displaying

radiographic studies in an Emergency Department environment. The benefits of this in the diagnostic environment are considerable, particularly in terms of cost savings and the ability to support clinicians with a more extensive network of workstations at the point of clinical care delivery, either locally or remotely.

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