Impact of a Diagnostic Workstation on Workflow in the Emergency Department at a Level I Trauma Center

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Purpose: When a computed tomography (CT) scan on a patient from the emergency department is completed at University of Medicine and Dentistry of New Jersey (UMDNJ)-University Hospital, a non-picture archiving and communication system (PACS) environment, formal diagnostic review cannot begin until the images are printed and transported to the on-call radiology resident. The time to reach a final diagnosis has been significantly reduced by the introduction of a single workstation in the on-call reading room. **Materials and Methods:** Five radiology residents were studied. Each read 10 CT studies on film and 10 on a workstation. After a training period to familiarize the residents with the workstation, measurements were taken of the time required to read the examination and the time required for printing and transporting or networking the images. **Results:** The average time required to transmit the images was reduced from approximately 40 minutes to 16 minutes. Interpretation times between the workstation and film were comparable. **Conclusion:** The addition of a single workstation significantly reduces the time required to reach a final diagnosis by obviating the need to print and transport the images to the on-call radiology resident. Such time savings can have a significant impact on the care of trauma patients.

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IT IS WELL KNOWN that picture archiving and communication systems (PACS) can improve radiology report turnaround time.¹ It has also been established that this is due, in part, to a decrease in the delay between image acquisition and the time the images are available for radiologist review. However, the high cost of purchasing, installing, and maintaining a PACS has been a major barrier for many institutions.² The purpose of our study is to demonstrate that the installation of a single low-cost workstation in a key location in a non-PACS environment can have a dramatic impact on workflow, and thereby patient care.

METHODS AND MATERIALS

Patients and Readers

Five radiology residents prospectively reviewed 100 computed tomography (CT) scans from the emergency department. One was a second-year resident; the remaining were in their first year. All readings took place while on-call during the evenings, nights, and weekends. Each resident reviewed 10 CT scans on film and 10 using a PC workstation. Each resident underwent an initial training session which involved reading five CT scans on the workstation in order to avoid learning

Table 1. Workstation Configuration

Hardware	Dell Precision 210 Workstation, 650-MHz Pentium III, 256-MB RAM, 30-GB HD, 24" Trinitron monitor running at 1,600 × 1,200 resolution
Software	PiView 4.0
Total cost	≈\$9,000

curve effects. For each examination, four times were recorded: (1) time the last image was acquired, (2) time images were received by the on-call radiology resident, (3) time image review began, and (4) time the resident reached a final diagnosis which he communicated to the emergency department. The latter two times were recorded to determine if there was any significant difference in diagnostic review time. The type of each scan (eg, head, abdominopelvic, or cervical spine) was also recorded.

Workstation and CT Scanner

The workstation is comprised of a high-end PC (Table 1) and an off-the-shelf software product called PiView (Mediface, Seoul, Korea, www.mediface.com). PiView provides standard image viewing and manipulation capabilities and communicates with our General Electric (Milwaukee, WI) HiQ CT scanner via the Digital Imaging and Communications in Medicine (DICOM) standard. The workstation was installed without any special assistance from either Mediface or GE.

Image Transmission

For the studies read on film, image transmission was considered to begin when image filming was started by the CT technologist. While this time was estimated as the time the last image was acquired, it actually occurred sooner, as filming of the first image of a study starts concurrently with image acquisition. The time the images were received was measured as the time the technologist brought the stack of films to the on-call radiology resident, who sits in a room about 30 feet away from the CT scanner and film printer.

For the studies read on the workstation, image transmission times were computed in two ways. The first is the actual time it took from the time the last image was acquired, until the last

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Fig 1. Histogram of time for transmission of filmed images, N=50.

image was received on the workstation. Secondly, a measure of image transmission was recorded wherein image transfer was considered to begin when the technologist clicked on the "Send" button. It should be noted that all trauma head and abdominopelvic CTs were initially previewed at the CT console to ensure that the patient was in no imminent danger. Also, all CT studies were subsequently reviewed with an attending radiologist.

RESULTS

Transmission Times

For the filmed studies, the average time until the images were delivered to the on-call radiology resident was 40 minutes. The distribution of the data is shown in Fig 1. Ten of the 50 filmed studies took longer than an hour to be delivered.

For the images transmitted through the network, the average time for image delivery was 16 minutes. This measurement was taken from the time the last image was acquired until the last image arrived at the workstation. As such, this measurement was heavily dependent upon when the technologist pressed the "Send" button. The distribution of these data is shown in Fig 2. Forty-four of the 50 networked studies arrived within a half hour, and only two arrived later than an hour. Networked studies require around 2 minutes at

most to transfer, as our ethernet network transmits a typical 500 -KB CT image in 1 second, and most studies contain 30 to 60 images.

Reading Times

Reading times of the five radiology residents are demonstrated for both abdominopelvic and head CTs (which comprised 93 of the 100 examinations) with side-by-side comparisons of film reading to workstation reading in Figs 3 and 4. In most cases, the difference within any one reader was only 1 or 2 minutes.

DISCUSSION

Delivery of films was delayed for various reasons. The filming process takes at least 20 minutes from the time it is begun until the last film comes out of the laser imager. The CT technologist invariably must tend to other tasks in the interim, and shuttle back and forth between the filming process and his/her other duties. Furthermore, when our trauma center gets busy, the technologist sometimes lets filmed studies accumulate at the CT scanner while trying to keep pace with the rapid patient throughput. This further delays image delivery to the radiologist because the technologist can only bring studies over in batches.

Fig 2. Histogram of time for transmission of networked images, N=50.

Fig 3. Average reading times of abdominopelvic CTs on both film and workstation for all 5 radiology residents.

Transmission times for networked images were more of a function of when the technologist remembered to press the "Send" button than of the actual data transfer rate. During the study period, the CT technologists digitally transmitted images to the workstation only for the purposes of the study and not as part of their normal routine. As such, they would often forget to initiate the transfer of images. If workstation reading were to be fully implemented, the CT console would be configured to autoroute the images to the workstation, thereby obviating the need for any technologist interven-

Fig 4. Average reading times of head CTs on both film and workstation for all 5 radiology residents.

tion, and making this second measurement a fairer representation of the true transmission time. In this limited study, no significant network delays were noted, and the actual data transfer times of all studies were under 2 minutes.

The small differences in reading times were not statistically significant and were clearly far smaller than the time savings achieved by network transmission of images versus film. That is, even a 5-minute difference in reading time is negligible compared to the hour or two saved by networking the images to a workstation. Interruptions during image interpretation were a confounding factor. Since these readings took place during on-call hours, the residents were frequently interrupted while reading the CTs to look at other "quicker" studies like chest radiographs. Anecdotally, one resident reported that he was interrupted less when he was looking at films. He perceived that when he was looking at filmed studies, the housestaff could see that he was busy, but when he looked at studies on the workstation, some of the housestaff thought that he was only "playing." Another factor that may account for the longer reading times of abdominopelvic CTs on the workstation was the ability to view all of the images in multiple window settings, instead of the few provided on film.

In sum, the data demonstrate that placement of this single workstation in the on-call reading room has reduced the average 40 minute transmission time of CTs by more than half, at a cost of under \$10,000. Furthermore, autorouting to the workstation would shrink the time to a mere 1 to 2 minutes. Thus even before an institution is ready for a full-scale PACS, a single well-placed workstation can dramatically decrease diagnosis times and thereby improve patient care.

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