SESSION VI: Image Display Workstations and Applications

A Picture Archiving and Communications System Featuring Multiple Monitors Using Windows98

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We present an effective approach to manage, review, and distribute Digital Imaging and Communications in Medicine (DICOM) images with multiple monitors using Windows98 (Microsoft Corp, Redmond, WA) that can be implemented in an office-based setting. Computed tomography (CT), magnetic resonance imaging (MRI), and angiographic DICOM images were collected, compressed, and stored using Medweb (Medweb, Inc, San Francisco, CA) software. The Medweb server used the Linux/UNIX operating system on a Pentium 333-MHz processor with 128 MB of RAM. Short-term storage capacity was about 2 weeks with routine usage of an 11-GB hard drive. Images were presented for reading on a dual-monitor Windows98 Pentium display station with 160 MB of RAM using a Medweb/Netscape (Netscape Communications Corp, Mountain View, CA) viewer. There was no significant discrepancy in diagnosis between electronic and conventional film images. Mean reading time for 32 cases was 118 seconds. The Medweb JAVA plug-in viewer loaded the first image within 30 seconds of selecting the case for review. Full uncompressed 16-bit images allowed different window settings to better assess for pathology. Multiple monitors allowed viewing various hanging protocols. Cine viewing was also possible. Key diagnostic images were electronically transmitted to referring physicians. On-call radiologists were able to access images through the Internet. By combining Medweb, DICOM, and web-browser software using desktop personal computers (PCs), an easily accessible picture archiving and communications system (PACS) is available to radiologists and referring physicians. Multiple monitors are easily configured and managed using Windows98. This system can sustain changes and can be extended to provide variable functions using inexpensive PCs.

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THE PURPOSE OF OUR STUDY was to manage, review, and interpret Digital Imaging and Communications in Medicine (DICOM)

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images using a dual-monitor Windows98 (Microsoft Corp, Redmond, WA) web-based platform. The questions we wanted to address were: Can a standard web-based personal computer (PC) program be used for interpretation and consultation when film is unavailable? Will Windows98 be adequate for a dual monitor review station? Can we reduce film costs and still maintain excellent patient care with prompt reporting of the findings to clinicians using a web-based platform?

METHODS AND MATERIALS

Computed tomography (CT), magnetic resonance imaging (MRI), and angiographic DICOM images were collected, compressed, and stored using Medweb (Medweb, Inc, San Francisco, CA) software. The Medweb server used the Linux/UNIX operating system on a Pentium 333-MHz processor with 128 MB of RAM. Short-term storage capacity was about 2 weeks with an 11-GB hard drive. Images were presented for reading on a dual-monitor Windows98 Pentium display station with 160 MB of RAM using a Medweb JAVA plug-in and a Netscape (Netscape Communications Corp, Mountain View, CA) viewer. An additional 4-MB Peripheral Component Interconnect (PCI) graphics adapter (cost \$30) was installed to drive a second standard 17-in 1K monitor.

Three radiology staff evaluated 32 digital studies over a 2-week period. Studies included three MRI studies (two MR cholangiograms, and one female pelvis), one angiogram, 18 head CT studies, two musculoskeletal CT scans, and eight body CT cases. Studies were automatically transferred to workstations at the conclusion of the examination. Readers were allowed to use any available computer feature for viewing, including tile mode, cine mode, stack mode, and windowing as needed. Experience with the use of computer workstations varied among the readers, as some were familiar with the workstation while others had limited experience with it. Each reader was asked to record the length of time it took to detect abnormalities and interpret the study. The staffing radiologist, using films, the workstation, and input from clinicians to evaluate the case, dictated the final report. The findings of the final report were compared with those listed on the questionnaire.

RESULTS

Mean reading time for 32 cases was 118 seconds. The Medweb JAVA plug-in viewer loaded the first image within 30 seconds of selecting the case for review. Full uncompressed 16-bit images allowed

different window settings to better assess for pathology. Cine viewing and tile mode viewing was possible. Multiple monitors allowed viewing various hanging protocols. There was no significant discrepancy in the diagnosis between electronic and conventional film images with these limited 32 cases. The radiology reporting software ran concurrently on the PC reading station. Windows98 software allowed increased workspace by controlling the two monitors. Key diagnostic images were electronically transmitted to referring physicians. On-call radiologists were able to access images through the internet.

In the past, two sets of films were routinely produced for every CT scan performed in the department, requiring up to 20 sheets per case. One set was made available to the clinical team and the other for the interpreting radiologist. Since the institution of mini-picture archiving and communication systems (PACS), only one set of 20 on one film is produced. In addition, abdomen/pelvis cases are filmed with one window setting and studies with large numbers of reconstructed images are filmed with alternating images. These changes have decreased our film usage significantly by eliminating the second copy and decreasing the number of images filmed per case. Faculty and residents are now more comfortable using the computer for interpretation and consultation.

DISCUSSION

Previous investigators have compared computer workstation review of examinations against standard film review for utility and accuracy. Kato et al have shown that image interpretation times of computed radiology (CR), CT, and MRI studies for 237 examinations using diagnostic workstations was 5.11 minutes, and for 219 examinations read with conventional hard-copy film, the time was 4.98 minutes. They used a workstation with 6 monochrome 1024 monitors.¹ Beard et al found that the average time needed for an interpretation on a single-screen workstation was 5.65 minutes and that use of the workstation was faster than the alternator.² In 1994, Beard reported an average interpretation time of 6.17 minutes for the workstation and 6.03 minutes for film, including loading and unloading films. All interpretations were of clinically acceptable accuracy. In 1993, the hardware platform for their workstation cost less than \$11,500.³ Beard also reported that CT workstations

have a wide variation in the number and size of monitors available for the display of the medical images ranging from a single $1,024 \times 1,204$ -pixel monitor, to eight $2,500 \times 2,000$ -pixel monitors. Image display times varied considerably, ranging from as fast as .11 seconds to as slow as 26 seconds for a single monitor. They determined that workstation readings became faster as the display area increased and the display time decreased.⁴ With earlier versions of Windows PC software, expensive video cards and additional software were needed to use more than one monitor. Windows98 can control up to nine monitors. The monitors can act as one large desktop or each can display individual programs.⁵ The costs of Windows98 and single PCI video cards are significantly less than dual or quad video cards and software.

Lyndon B. Johnson General Hospital is a teaching hospital for The University of Texas-Houston Medical School. In a typical month, we perform approximately 600 CT and 150 MRI examinations for clinical indications such as trauma, infection, and initial tumor evaluation. Final interpretation may be delayed because the hard copy images may be "unavailable" for reading. Films may be unavailable because they are needed in the operating room or for consultation with the attending physician or they were transferred with the patient to another hospital. Unless these studies are available promptly, a critical finding may be delayed or missed until the images are reviewed with a faculty radiologist.

An alternative solution to this problem is to refilm or double film all studies. The cost of double-filming these studies is significant. The price for 500 sheets of dry laser film is approximately \$900 and \$550 for regular laser film. Mayo Clinic investigators reported the average cost of a single film over its lifetime is \$4.50. This price included film, laser camera cost, handling, and storage. The total cost of film per examination was estimated to be \$6.25.⁶

Our limited study shows the feasibility of a web-based platform for review and interpretation of digital radiology studies. Computer review of lost or stolen films provides for more timely patient care. Since studies with significant findings are usually the ones that disappear, interpretation of these studies on the workstation allows selected findings to be refilmed for patient care. Interesting cases can be saved in an electronic teaching file from the workstation and sent to photographic

services via e-mail. Studies can be automatically transferred to a DICOM server at the conclusion of an examination, decreasing lag time from printing, sorting, and hanging of the film for interpretation. Wavelet compression of the DICOM images allows for after-hour interpretation of studies from home PCs with a phone-line internet service.

In the future, hardware and software may continue to improve rapidly. Inexpensive DICOM options are becoming available that are durable and easy to configure. The use of a familiar web-based platform may encourage PACS acceptance from nonradiologist physicians. Using standard PCs and internet/intranet software allows workstations to serve multiple purposes. Studies can be reviewed, reports signed, literature searches performed, lectures prepared, and papers written all on one platform. Our demonstration review workstation is an off-the-shelf Pentium 220-MHz PC with 160 MB of RAM and two 1K 17-in color monitors. A Medweb JAVA plug-in runs with both Netscape and Microsoft Internet explorer for the transfer and

review of images. An Osiris viewer (University Hospital of Geneva, Switzerland) is also used for viewing DICOM data. The workstation cost was less than \$4,000 in June 1997. The Medweb server runs on a Pentium 333-MHz PC that cost less than \$1,000 in September 1998.

CONCLUSION

Dual-monitor PC workstation viewing of cases is suitable for interpretation in a reasonable amount of time. As radiologists become more familiar with monitor viewing, this method may become faster and more sensitive than film viewing. Computer viewing of studies is becoming more important with pressure to reduce film usage and after-hour teleradiology viewing. Studies can be automatically transferred to DICOM servers at the conclusion of an examination, decreasing the lag time from printing, sorting, and hanging films. Use of standard PC hardware and software allows the development of multipurpose cost-effective radiology review stations.

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