ROC Analysis for Diagnostic Accuracy of Fracture by Using Different Monitors

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Background: The purpose of this study was to compare diagnostic accuracy by using two types of monitors. **Methods:** Four radiologists with 10 years experience twice interpreted the films of 77 fracture cases by using the ViewSonic P75f+ and BARCO MGD221 monitors, with a time interval of 3 weeks. Each time the radiologists used one type of monitor to interpret the images. The image browser used was the Unisight software provided by Atlastiger Company (Shanghai, China), and interpretation result was analyzed via the LABMRMC software. **Results:** In studies of receiver operating characteristics to score the presence or absence of fracture, the results of images interpreted through monochromatic monitors showed significant statistical difference compared to those interpreted using the color monitors. **Conclusion:** A significant difference was observed in the results obtained by using two kinds of monitors. Color monitors cannot serve as substitutes for monochromatic monitors in the process of interpreting computed radiography (CR) images with fractures.

KEY WORDS: Picture archiving and communication system, receiver operating characteristic curve, ROC

INTRODUCTION

Medical images are commonly interpreted by using workstations and computer monitors with picture archiving and communication systems (PACS), instead of traditional hard-copy images;^{1,2} cathode ray tube (CRT) monitors are used to interpret radiographs, mammograms, and computed tomography (CT) and magnetic resonance imaging (MRI) examinations. For economic reasons, some middle- and small-scale hospitals adopt color CRT monitors commonly used on personal computers instead of monochromatic CRT monitors.^{3,4} Color monitors are inferior to monochromatic CRT monitors in terms of spatial resolution, gray levels, contrast and brightness.

The ability to achieve acceptable diagnostic accuracy is the most important clinical criterion for the use of PACS technologies.⁵⁻⁷ Some studies have compared the diagnostic accuracy of soft-copy radiographs displayed between color and monochromatic CRT monitors, and have concluded that there was no significant difference between them in the interpretation of computed radiography (CR) chest and hand images.^{8,9} However, to our knowledge, there have only been a few reports comparing the diagnostic accuracy of soft-copy fracture interpretation using color or monochromatic CRT monitors. The purpose of this study was to examine if the choice of monitors would affect the diagnostic accuracy of the process.

MATERIAL AND METHODS

A total of 77 skeletal trauma cases were selected by three nonobserving radiologists. Forty-seven cases were abnormal with single subtle fracture and 30 cases were normal. Two or more CR images were available in each case. In this study, subtle fracture was defined as an abnormality that is minimal or

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Table 1. Four radiologists' A_z values using two types of monitors

A_z Values	Monochromatic monitor	Color monitor
A	0.9852	0.9581
B	0.9662	0.9574
C	0.9877	0.9497
D	0.9604	0.9682

hidden by overlapping structures, requiring careful inspection to be recognized. Radiological follow-up, including plain radiography and CT, was performed to verify the lesions. The results of 12 cases without available radiological follow-up were determined by two experienced musculoskeletal radiologists who did not participate in this test.

Image Reading Test

The parameters of original image acquisition were as follows: KODAK ACR-2000, 70 kV, 20 mA s. The size of the images was 2560×2048 pixels with 12 bits per pixel. The images were transmitted to PACS, and the radiologist used diagnostic workstations for interpretation. Two types of CRT monitors were used during the experiment: (1) a monochromatic CRT monitor (BARCO MGD221, curved pane), which was 21 in. in size, with a maximum resolution of 1280×1600 pixels and a maximum luminance of 360 cd/m^2 ; (2) a color CRT monitor (ViewSonic P75f+, flat pane), which was 17 in. in size, with a maximum resolution of 1280×1024 pixels and a maximum luminance of 300 cd/m^2 . Before each experiment, the monochromatic CRT monitors were calibrated through the MediCal software to ensure that image quality corresponded with the standard of DICOM 14. There was no calibrating software available for the color CRT monitors, so each was calibrated manually to ensure that the displays were as close to the level of the monochromatic monitor as possible.¹⁰ Each of

Fig 1. ROC curves for radiologist A by using two types of monitors. **Fig 2. ROC curves for radiologist B by using two types of monitors.**

the four radiologists, who had more than 5 years experience, twice interpreted the CR images through these monitors. These radiologists were blind to the clinical history, physical findings, patient identity, and final diagnostic results. A period of 3 weeks separated the interpretations; different monitors were used each time to minimize the effect of observer recall. Each time the radiologists interpreted the CR images through only one kind of display. The image browser used was Unisight software from Atlastiger Company (Shanghai, China). The duration for viewing each case was 3 min. The observers could adjust the brightness and contrast of the images freely. Each observer was asked to determine the presence or absence of fracture as follows: 1 = definitely absent, 2 = probably absent, 3 = equivocal, 4 = probably present, 5 = definitely present. Interpretation results were analyzed via the LABMRMC software.

Fig 3. ROC curves for radiologist C by using two types of monitors.

Fig 4. ROC curves for radiologist D by using two types of monitors.

RESULTS

The A_z values for all radiologists are shown in Table 1. Receiver operating characteristic (ROC) curves are shown in Figures 1–4. The average A_z values for all radiologists increased from 0.9579 with the color monitor to 0.9748 with the monochromatic monitor. This difference was statistically significant ($P = 0.0017$). Monochromatic monitors were observed to perform better than color monitors. Basically, color monitors could not serve as substitutes for monochromatic monitors in the interpretation of CR images of subtle fractures.

DISCUSSION

With the development of PACS, it is important to understand aspects that affect diagnostic accuracy. Spatial resolution may be the most important component, especially for conventional radiography, which may be more difficult to interpret compared with CT and MRI because of the overlapping structures and the high resolution of the images. Monochromatic monitors possess a higher spatial resolution and can better display contrast. Moreover, regular quality assurance checks (by manufacturers) can be made on monochromatic monitors to ensure the consistency

of display of digital medical images. Color monitors are inexpensive and can largely reduce medical costs for middle- and small-scale hospitals, although some details may be lost in the process. Plain CR images constitute the primary method to diagnose fractures, because they cost less. It is important for radiologists to understand the extent to which diagnostic accuracy is affected by the different spatial resolution.

In this study we demonstrated that there was a significant difference in the diagnostic results between monochromatic and color monitors. This suggests that the use of conventional color display can not be acceptable for the primary diagnosis of fracture.

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