Detection of subtle pulmonary disease on CR chest images: monochromatic CRT monitor vs color CRT monitor

Abstract To clarify the diagnostic efficacy of color soft-copy computed radiographic (CR) images of the chest in the detection of subtle pulmonary abnormalities. Twenty observers compared 87 soft-copy CR images on four types of CRT monitor (nonmagnified monochromatic CRT, magnified monochromatic CRT, nonmagnified color CRT, and magnified color CRT). Of 87 test images, 45 (including two identical sets of 12 images to test intraobserver variability) were abnormal and 42 (including two identical sets of 12 images) were normal. Of the 45 abnormal images, 15 showed subtle abnormalities, 15 showed mild abnormalities, and 15 showed obvious abnormalities. In the receiver operating characteristic (ROC) analyses, there were no statistically significant differences among the four types of CRT display formats in the detection of subtle abnormalities. Color CRT monitors can replace monochromatic CRT monitors without any loss in the ability to detect subtle interstitial lung disease.

Key words Interstitial lung disease · Picture archiving and communication system · Workstation · Computed radiography · Receiver operating characteristic

Introduction The picture archiving and communication system (PACS) has come to play an important role in radiologic practice, because PACS improves handling efficiency, provides useful image-analysis tools, and decreases the costs of the radiologic examination. In the implementation of PACS, computed radiography (CR) with storage phosphor plates is a suitable and important digital technique [1, 2]. Now, CR is applied to plain chest radiography, which is the most frequent examination in the diagnostic radiology department [3, 4, 5, 6, 7, 8].}

The ability to achieve acceptable diagnostic accuracy is the most important clinical criterion for the use of the PACS technology. In our previous study, monochromatic soft-copy images of chest CR were shown to be equivalent to screen-film (SF) images for primary interpretation of subtle interstitial lung disease [5].
In current PACS systems, information in addition to the radiographic images is often displayed on a color cathode-ray-tube (CRT) monitor. Color CRT monitors usually have lower spatial resolution power than monochromatic CRT monitors and are less expensive. If adequate diagnostic images and information can be seen on a color CRT, the start-up costs required for PACS use would decrease significantly.

However, there have been few reports which compare the diagnostic accuracy of soft-copy chest radiographs displayed on color compared with monochromatic CRT monitors. Although Takizawa et al. reported no significant differences in diagnostic performance between monochromatic CRT and color CRT [9], this study investigated the diagnostic efficacy of color CRT monitors only in the detection of simulated lung nodules. For the detection of subtle interstitial lung disease, no study has been reported using soft-copy chest CR images displayed on color CRT monitors. Therefore, as a continuation of our previous investigation [5], we examined the diagnostic ability of soft-copy CR images displayed on color CRT monitors in the detection of subtle interstitial lung disease.

**Materials and methods**

This is a new study generated from existing digital data used in our previous study [5]. Although materials and methods except color soft-copy have been detailed elsewhere [5], brief description is presented.

**Image collection**

A total of 80 matched, upright, posteroanterior CR plain radiographs of the chest were collected at five institutions [5]. Eighty patients (38 men aged 46–78 years and 42 women aged 42–79 years) underwent high-resolution computed tomography (HRCT) of the chest within 1 week of acquisition of frontal CR chest radiographs [5]. The final diagnosis (gold standard) for each case was established initially on the basis of findings of HRCT scans by the consensus of a panel of ten experienced radiologists who did not participate in the subsequent image-reading experiment [5].

If a pulmonary abnormality in either hemithorax was present, the panel categorized the findings to one of the following three levels according to the difficulty of detection, considering the severity and extent of abnormalities on CT scans. These categories included subtle (difficult to detect), mild (relatively easy to detect), and obvious (easy to detect) [5]. Here, 11 patients were eliminated for at least one of the following reasons: poor imaging technique; inconsistent patient positioning; abnormality too obvious; and overabundance of a particular abnormality [5]. Thus, 6 patients composed the introductory session, and another 63 patients were selected for the image reading test [5]. Some of the 63 patients had specific abnormalities on their radiographs, such as calcification, surgical clips, or pleural thickening. To minimize the learning effect of such abnormalities, hemithorax images (either right or left) obtained in each patient without these other abnormalities (other than interstitial lung disease) were selected as test images for the reading sessions [5]. Thirty-three of the 63 patients had pulmonary abnormalities on their chest radiographs, and the other 30 patients had normal chest radiographs [5].

The 33 patients had diffuse pulmonary diseases, which included pneumoniaonosis (n = 7), interstitial lung disease due to collagen diseases (n = 7), idiopathic pulmonary fibrosis (n = 5), diffuse panbronchiolitis (n = 4), bronchiectasis (n = 2), pulmonary sarcoidosis (n = 1), miliary tuberculosis (n = 1), cosinophilic pneumonia (n = 4), alveolar proteinosis (n = 1), and unknown (n = 1) [5]. The abnormalities were subtle in 11, mild in 11, and obvious in 11 patients [5]. Based on the HRCT findings, abnormalities were also divided into the following three types: reticular (n = 9); small nodules (n = 19); and ground-glass appearance (n = 5) [5].

To estimate intraobserver variance, a set of identical images were included in the test images, i.e., an identical set of 12 of the 33 abnormal images and an identical set of 12 of the 30 normal images were added to the test images [5]. After this addition, there were a total of 87 test images of hemithoraces [5].

**Image acquisition**

The CR images were obtained using storage phosphor plates (ST III, Fuji, Tokyo, Japan) and various parameters were used for making images similar to conventional screen-film images. These parameters varied depending on the equipment available at each institution [5]. These storage phosphor plates were read by the CR systems (model 7000, Fuji; or TCR 201, Toshiba, Tokyo, Japan), and these archived digital data (0.2-mm spatial resolution, 1760 x 1760 pixels, 10 bits) were stored on an optical-disk cartridge in a reversible image-compression mode [5]. All optical disks from each institution were collected, and CR images were processed with a sigmoid, long-contrast Hurter and Driffield curve and slight edge enhancement at high frequencies [5]. The enhancement factor was 0.5, with a frequency range of greater than approximately 0.35 cycles per millimeter. The gradation-processing parameters had the following values: rotation amount = 1.0; gradation type = E; rotation center = 1.6; and gradation shifting amount = -0.2 [5].

**Image reading test**

In the image reading experiment, two types of CRT monitors (monochromatic CRT and color CRT) were used for the soft-copy display. The monochromatic CRT monitor was 20-in. in size with 1568 x 1152 x 8-bit frame memory (HI-C 654, Fuji). This monitor operated at 67 Hz in a noninterlaced mode to eliminate a flicker, and had a maximum brightness level of 45-ft. lamberts. On the monochromatic monitor, soft-copy images were processed in the following three ways to put the advantage of soft-copy images to practical use: a default mode (weighting function = 0.5; kernel size = 57 pixels), a high-spatial-frequency enhanced mode (weighting function = 1.5; kernel size = 29 pixels), and a low-spatial-frequency enhanced mode (weighting function = 0.6, kernel size = 229 pixels). In the reading sessions on the monochromatic monitor, the observers were allowed to read all three kinds of processed images, and to change the window (contrast) and level (brightness) settings of the display. On the other hand, the color CRT monitor was 20-in. in size with 1280 x 1024 x 8-bit frame memory (FlexScan E65T, Nanao, Ishikawa, Japan). This monitor had a maximum brightness level of 30-ft. lamberts. Here, the image processor that were installed into the viewing workstation for the monochromatic monitor was different from the one for the color