Original Investigation

The Yellow Scale Is Superior to the Gray Scale for Detecting Acute Ischemic Stroke on a Monitor Display in Computed Tomography

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Rationale and Objectives: The purpose of this study was to compare the efficacy of the color scale with regard to focal detection with computed tomography in acute ischemic stroke.

Materials and Methods: Computed tomography images of the brain of 19 patients diagnosed with acute stroke, based on magnetic resonance diffusion-weighted images obtained within an onset of 24 hours, and the images of five normal patients were displayed in each color look-up table on a monitor. The detection of acute stroke was compared among 15 radiologists. The images were compared in the gray, green, yellow, red, and blue scales of the look-up tables. The observers recorded acute ischemic stroke as "present" or "absent." They also located the position of the stroke lesion and described the degree of their conviction as to whether a lesion existed. Detection was evaluated by receiver operating characteristic analysis. The area under the receiver operating characteristic curves was compared. In addition, reduced fatigue and the ease in image observation were compared.

Results: Compared to the other scales, the yellow scale had a significantly higher area under the receiver operating characteristic curve, which indicated that this scale allowed better detection of acute ischemic stroke. The gray scale produced the least fatigue in image observation.

Conclusions: The detection of acute ischemic stroke is improved by changing the display monitor from the gray scale to the yellow scale. From the perspective of color psychology, yellow is associated with higher arousal, cheerfulness, confidence, creativity, and excitement. Therefore, the yellow scale may be suitable for a medical imaging display.

Key Words: Acute ischemic stroke; monitor display; yellow scale; gray scale; ROC analysis.

INTRODUCTION

Stroke is the second leading cause of death worldwide, and many researchers have analyzed the developmental mechanism and the defense against stroke (1–7). If cerebral infarction is detected early and a patient receives appropriate treatment such as thrombolytic therapy, then the survival rate and convalescence are improved. In particular, adaptation to ischemic cerebrovascular disorder of recombinant tissue-type plasminogen activator is an epoch-making therapy (8–12). Patients can expect a good outcome after stroke onset if these treatments are administered early (ie, within 4.5 hours) (13). Computed tomography (CT) of the brain is generally performed as an emergency study when a stroke is suspected. CT of the brain provides cerebral infarction views such as early CT sign without bleeding, and the aforementioned treatments can be applied. Therefore, early diagnosis is necessary. However, interpreting cerebral infarction with few contrast changes is difficult, even for expert radiology physicians.

In recent years, an image monitor has often been used for the interpretation of a radiograph image. On an image monitor, the gray scale display (which was initially used for backlight and film diagnosis) is commonly used, although a color display can be used to determine a monitor diagnosis. However, in one report (14), the detectability of a low-contrast image was improved more by a color scale than by the gray scale. Changing the color scale of the monitor may improve the detectability of an acute cerebral infarction. In this study, we investigated whether the detectability of an acute cerebral infarction would be improved by using a color scale on the imaging monitor.

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MATERIALS AND METHODS

Image Evaluation

In this study, we used the clinical image data from 39 patients (age, 58–84 years; mean age, 74.6 years). The ethical review board approved this study, and all patients provided informed consent. The evaluated patients underwent CT imaging of the brain and magnetic resonance imaging scans of the brain within 10 hours after the onset of acute cerebral infarction. Forty-six CT images of the brain, which consisted of 39 slices containing infarction lesions from 39 patients and 7 slices containing no lesions, were used in this experiment. Twenty-four sets of images were used, consisting of 19 images (which were derived from the 39 images) with infarction lesions and 5 images derived from images without lesions. These sets were chosen at random. With each set of images, a different image was selected. Five sets of images in total were evaluated in this study. Each set of images was displayed on the computer screen using ImageJ software (ImageJ, 1.47v: http://imagej.nih.gov/ij). Using the color look-up table (LUT) feature in this software, the image was evaluated with the display in the gray, blue, red, yellow, and green color scales. The LUTs for these colors are shown in Figure 1. Five CT images of the brain corresponding to each color are shown in Figure 2.

Observation Evaluation

The observers were 15 radiologists with 2–40 years of interpretation experience. They did not have color blindness. Each observer chose one set of images from each color table, and thus observed five sets in total. For the observation method, an observer evaluated the presence or absence of acute cerebral infarction at five categorized levels of conviction. If an observer affirmed the presence of an infarction, they also described the position of the lesion. The observer had no previous knowledge such as clinical manifestations. The observation time and the adjustment of the window level and the window width were entrusted to the observers. In addition, after the observers had finished reading all sets of images, they ranked each color with regard to reduced eye fatigue and ease in viewing. Reduced fatigue is an index that indicates the degree to which an individual does not have eye fatigue when interpreting images. Ease in viewing is the degree to which an observer can easily view an image.

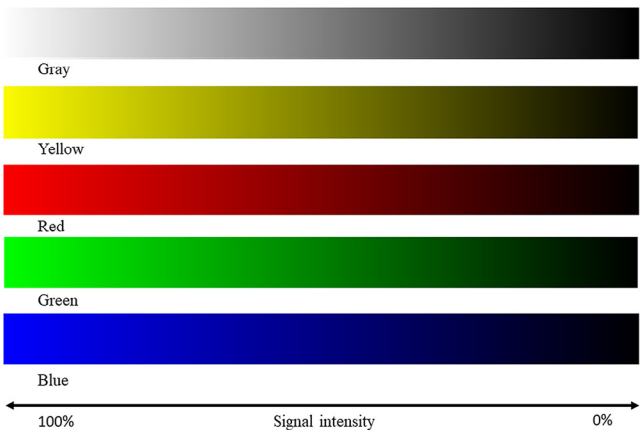

Figure 1. The look-up table of gray, yellow, red, green, and blue. (Color version available online.)

Analysis of the Evaluation

Receiver operating characteristic (ROC) analysis was conducted on the data with regard to the presence or absence of ischemic lesion and the category of conviction. In addition, the area under ROC curves (AUCs) was calculated. The AUC indicated lesion detectability. For the AUCs of the 15 observers, Kruskal-Wallis one-way analysis of variance was performed, and the significant difference authorization was assessed by Mann-Whitney statistical analysis. A statistical analysis was similarly conducted with regard to reduced fatigue and ease in viewing.

RESULTS

The mean ROCs of the 15 observers are shown in Figure 3. The yellow scale was high in the observation properties in the ROC. Figure 4 presents the box-and-whiskers plot of the AUCs of the 15 observers. The AUC was significantly high in the yellow scale. The AUCs of the gray, green, and red scales were not significantly different from each other, and the blue scale was significantly lower than the other colors. The box-and-whiskers plot in Figure 5 shows the results of reduced fatigue in image observation. The reduction in fatigue in image observation was significantly greatest with the gray scale, followed by (in decreasing order) the yellow, green, red, and blue scales.

Figure 6 shows the box-and-whiskers plot of the participants' answers regarding the ease in image observation. For ease in image observation, the gray scale was significantly higher than the red, green, and blue scales. However, the yellow scale was not significantly different from the gray scale.

DISCUSSION

Many investigators have evaluated monochrome display monitor after switching from the film-screen system for image interpretation in radiography to monitor diagnosis. In particular, the spatial resolution necessary for a diagnosis has been discussed. However, no report exists concerning low-contrast detectability in the color scale when using a color display monitor. We compared the detectability of an infarction on the color scale, with the gray scale CT image as particularly important for the diagnosis of acute cerebral stroke.

The difference between certain color scales in the detectability of an infarction lesion is associated with the visual properties of the eyes for color. Many previous studies have investigated the color-sensitivity function of the human eye