

ABSTRACT

The purpose of this study is to develop an automated detection system algorithm for low-contrast objects in the ACR 464 CT phantom, test the algorithm using images with rotational variations, and analyze the quantitative effects (noise and object diameter) on low-contrast detectability (LCD). The software for the automated detection system was developed using MATLAB R2013a. A threshold segmentation method was used to obtain the centroid of the central coordinate by segmenting the phantom (89 HU) and the centroid of the reference coordinate by segmenting the largest object (95 HU). The central and reference coordinates were used as template masks to determine the coordinates of other low-contrast objects, and each coordinate was assigned a region of interest (ROI). Additionally, a background ROI was positioned at the center of the image. For each object and background ROI, CT numbers and noise values were calculated. The contrast-to-noise ratio (CNR) parameter was determined based on the contrast between the CT number of the object and the background, divided by the noise. The threshold for low-contrast object detection was defined as a cut-off CNR value of one. Objects with a CNR equal to or above the cut-off were considered resolved, while those below the cut-off were considered unresolved. The algorithm was tested to ensure the system's reliability across various types of images, including tilted image variations. The algorithm was evaluated on rotational image variations of 0° , 22.5° , 45° , and 60° and validated using a one-way ANOVA statistical analysis. The effects of noise and object diameter were tested using module #2 of the ACR 464 CT phantom with $CTDI_{vol}$ variations of 21.42, 26.77, 32.13, 37.48, 42.84, and 53.55 mGy. Validation was conducted using a paired-sample t-test statistical analysis comparing manual measurements (using micro DICOM viewer software) and automated measurements (using this software) across $CTDI_{vol}$ variations. The analysis aimed to investigate the effects of noise and object diameter on LCD detectability. The algorithm testing results showed that the smallest resolvable object size was 4 mm for the rotational image variations. For the $CTDI_{vol}$ variations of 21.42, 26.77, 32.13, 37.48, 42.84, and 53.55 mGy, the minimum resolvable object sizes were 5, 5, 4, 4, 4, and 4 mm, respectively, for both manual and automated measurements. The results indicated that larger object diameters lead to increased contrast and CNR, while object diameter had no effect on noise. The CNR calculations showed no significant differences (p -value > 0.05) across rotational image and $CTDI_{vol}$ variations. Increasing $CTDI_{vol}$ reduced noise and increased CNR, improving LCD detectability. The automated LCD detection system proved reliable for various image variations, including rotational images. ROI placement was sufficiently accurate for both rotational image and $CTDI_{vol}$ variations. Additionally, $CTDI_{vol}$ was found to influence noise and CNR.

Keywords: low-contrast detectability, contrast-to-noise ratio, automatic method, template matching, the quantitative effect of LCD