Usefulness of Novel Temporal Subtraction Technique with Small Region of Interest for Finding Suspicious Lung Nodule on Digital Chest Radiographs

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INTRODUCTION

The temporal subtraction (TS) technique is a useful method to improve the confidence level in deciding suspicious pulmonary nodules [1, 2]. The TS images, however, often include some artifacts (Fig. 1) caused by different positioning and breathing phases between the previous and current chest radiographs (CXRs) used for obtaining subtraction images. The conventional TS technique uses entire images, which have a matrix size 512 × 512. We proposed a new technique using a smaller size (96 × 96) as a region of interest (ROI), to improve depiction ability. The purpose of this study is to develop a novel TS technique using a smaller ROI, and demonstrate the usefulness of this technique.

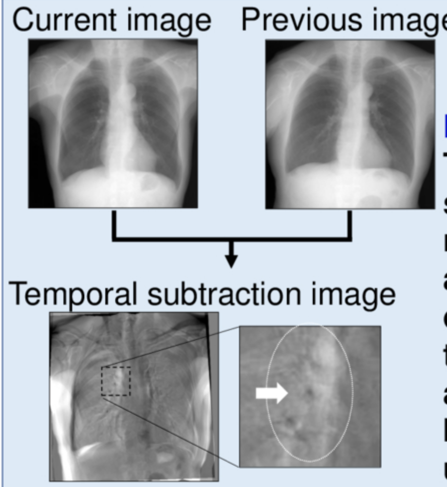

Fig. 1 An example of a TS image with a simulated pulmonary nodule (white arrow) and artifacts (ellipse in dotted white line) due to different positioning and breathing phases between two images used for subtraction.

METHOD

Fifty cases, with both current and previous CXRs, were used in our study. A simulated pulmonary nodule with a Gaussian distribution (σ: 0.5) was superimposed on the hilar region of both the lungs in each current image. The overall scheme of our novel TS technique is shown in Fig. 2. First, the region for subtraction (96 × 96), including the simulated nodule was extracted from each current image manually and used as a template image for the novel TS technique. A similar region was searched from the previous image based on the template matching technique [3]. The previous image was rotated to find the best match region between the two images. Then, the similar region in the previous image was warped by using the "demons" algorithm [4]. Finally, a novel TS image with a smaller ROI (96 × 96), which was determined based on preliminary experiments, was obtained by subtracting the template image from the warped similar region of the previous image (Fig. 3). The software for the novel TS technique was developed in MATLAB 2019b (Mathworks Inc., Natick, MA, USA). The simulated pulmonary nodule and the background region are set as shown in Fig. 4. The depiction ability of the simulated pulmonary nodule was evaluated using the contrast-to-noise ratio (CNR) (Eq. (1)). Avg_B and Avg_S indicate the background and average pixel value, respectively. N_B indicates the number of pixels in the background.

$$CNR = \frac{|Avg_S - Avg_B|}{RMS_B}, \quad RMS_B = \sqrt{\frac{\sum_{i=0}^{N_B}(P_i - Avg_B)^2}{N_{B-1}}} \quad (1)$$

The current image with a simulated nodule → Determine the suspicious region (the template) → Search a similar region (96 × 96) from the previous image based on the template matching

The previous image → Search a similar region (96 × 96) from the previous image based on the template matching → Image warping

→ Subtract the template from the warped similar region in the previous image (96 × 96) → The novel temporal subtraction image (96 × 96)

Fig. 2 Algorithm for the novel TS technique using a small ROI (96 × 96).

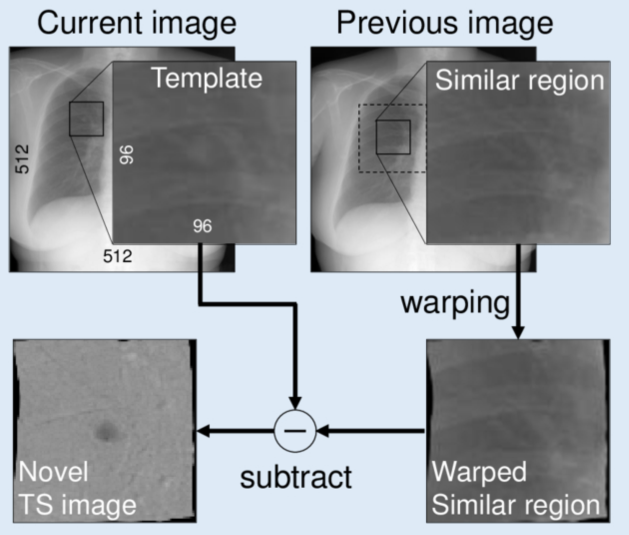

Fig. 3 Demonstration of novel TS image.

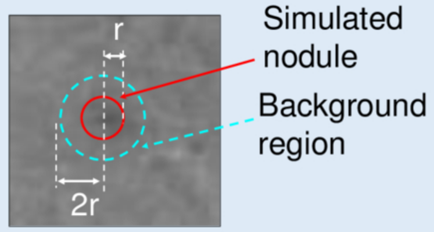

Fig. 4 An example of the simulated pulmonary nodule (red circle) and background region (blue dotted circle) on the TS image for calculating the CNR. The background region is a circular region with a radius twice as that of the simulated pulmonary nodule.

RESULTS AND DISCUSSION

Figure 5 shows the CNR of the novel TS technique normalized by that of the conventional TS technique. Our technique, compared to the conventional TS technique, showed an improvement in 72% of cases, which included both the right and left lungs. Figure 6 shows examples of (a) effective cases and (b) ineffectiveness cases for a novel TS image. We found that our novel TS technique, which used a small ROI (96 × 96), tended to subtract normal anatomical structures around the simulated pulmonary nodule more accurately than the conventional TS technique. This result indicated that our proposed method would be effective in improving the image quality of the TS image.

However, the remaining 28% of cases did not improve their depiction ability because of other new artifacts. This was because artifacts were caused locally on the novel TS images because of small changes around the hilar region of the lungs in the two images. Furthermore, artifacts caused by different breathing phases and small differences in shape and location of normal anatomical structures such as the ribs, heart, and aortic arch, in the two images might have affected the novel TS image. Therefore, other algorithms need to be developed to further reduce artifacts in the novel TS images.

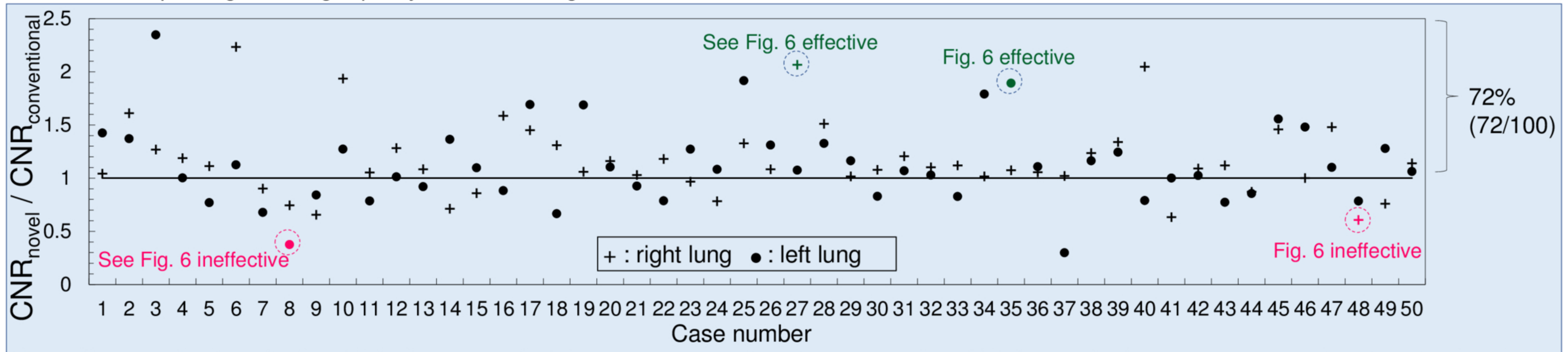

Fig.5 Changes in the relative CNR of the novel TS image compared to the conventional TS image in the case of arranging the simulated nodules around the hilar region of both the lungs in 50 cases. If the plots are above 1.0, the depiction ability of the novel method improves.

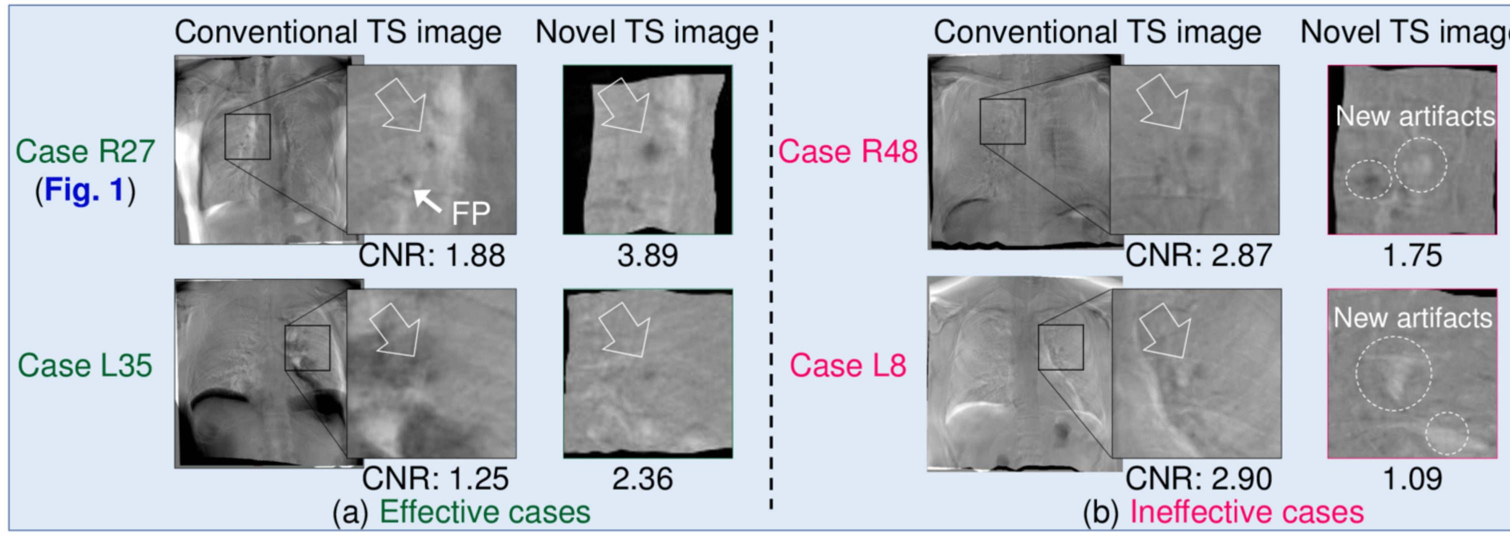

Fig. 6 Typical examples of (a) effective cases and (b) ineffective cases for the novel TS technique with a small ROI (96 × 96). The number in each TS image indicates the CNR. The arrows indicate the simulated pulmonary nodules on TS images. White dotted circles indicate the unnecessary artifacts that make it difficult to determine the existence of a suspicious pulmonary nodule.

CONCLUSIONS

The novel TS technique using a small ROI, compared to the conventional TS technique employing the entire image, improved the depiction ability of pulmonary nodules around the hilar region of the lungs.

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