Preliminary study on the automated detection of breast tumors using the characteristic features from unenhanced MR images

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ABSTRACT

Breast cancer incidence tends to rise globally and the mortality rate for breast cancer is increasing in Japan. There are various screening modalities for breast cancer, and MRI examinations with high detection rate are used for high-risk groups, which are genetically prone to develop breast cancer. In the breast MRI examination, unenhanced T1 and T2 weighted images shows no significant difference in signal value between tumor and normal tissue. Therefore, tumors are identified with use of contrast enhanced kinetic curve obtained by dynamic scan using contrast agent. Some computer aided diagnosis methods using dynamic contrast enhanced MR images also have been proposed. However, contrast agent produces the allergic reaction in rare case; it should not be used for screening examinees. Here, MRI provides the anatomical and functional information by using various sequences without contrast agents. According to the reports, this information can discriminate between tumor and normal tissue. In this study, we analyzed unenhanced MR images by using plural sequences and developed an automated method for the detection of tumors. First, we extracted the breast region from the T1-weighted image semi-automatically. Next, using the threshold determined by considering the signal intensities of tumor and normal tissue, a thresholding method was applied for diffusion-weighted image to extract the first candidate regions. After labeling processing, the breast region removes outside candidates from Initial candidates. Then false positives are reduced by the rule-based classifier. Finally, we examined the remaining candidates as possible tumor regions. We applied the proposed method to 54 cases of MR images and evaluated its usefulness. As a result, the detection sensitivity was 71.9% and the abnormal regions were clearly detected. These results indicate that the proposed method may be useful for tumor detection in unenhanced breast MR images.

Keywords: MRI, Computer-aided detection (CAD), Breast cancer

1. INTRODUCTION

Breast cancer incidence tends to rise globally and the mortality rate for breast cancer is increasing in Japan. There are various screening modalities for breast cancer, and MRI examinations with high detection rate are used for high-risk groups, which are genetically prone to develop breast cancer. In the breast MRI examination, unenhanced T1 and T2 weighted images shows no significant difference in signal value between tumor and normal tissue. Therefore, tumors are identified with use of contrast enhanced kinetic curve obtained by dynamic scan using contrast agent. Some computer

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aided diagnosis methods using dynamic contrast enhanced MR images also have been proposed [1]. However, contrast agent produces the allergic reaction in rare case; it should not be used for screening examinees. Here, MRI provides the anatomical and functional information by using various sequences without contrast agents. According to the reports, this information can discriminate between tumor and normal tissue [2-4]. So the purpose of this study is to develop the automated detection scheme of breast tumors by the analysis of various unenhanced MR images.

2. METHODS

2.1 Image dataset

Dataset consisted of 54 Japanese women with breast MR images from 2009 to 2012, examined for the purpose of cancer spread diagnosis. The MR images were scanned using SIEMENS unit (signaHDxt 3T) and their sequences were T1-weighted image, contrast enhanced T1-weighted image and diffusion-weighted image. The spatial resolution of the T1-weighted image was $0.62 \times 0.62 \times 0.9$ mm^3 and that of the diffusion–weighted image was $1.37 \times 1.37 \times 2.95$ mm^3. Among 54 abnormal cases, there were 74 tumors detected by radiologists.

2.2 Method overview

Figure .1 shows the flow chart in our proposed method. First, the breast region is extracted from the T1-weighted image semi-automatically. Next, a threshold processing was applied for diffusion-weighted image to detect the first candidate regions. The breast region removes outside candidates from Initial candidates. Then false positives (FPs) are eliminated by the rule-based classifier.

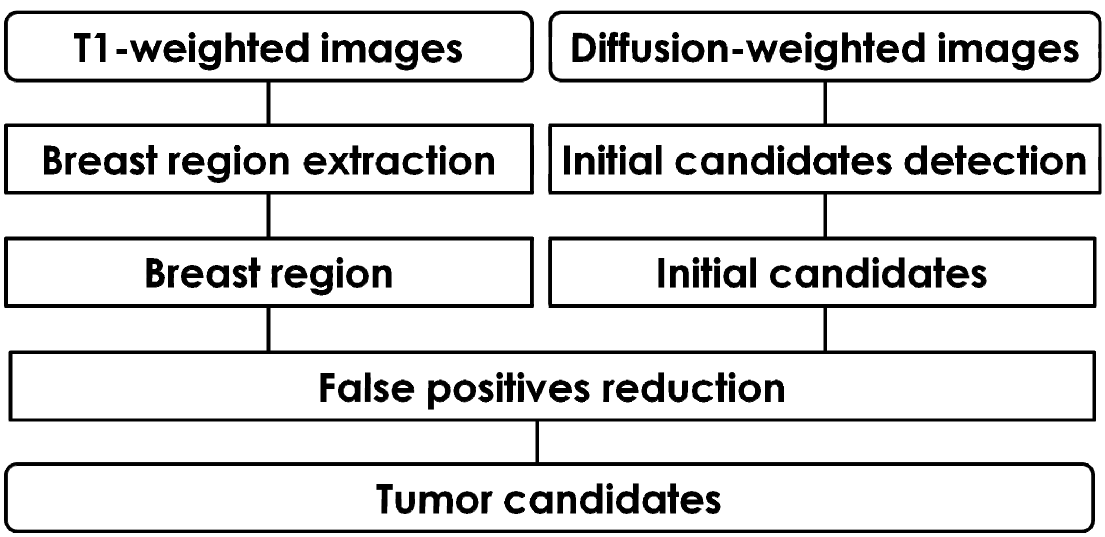

Fig.1 An overview of the proposed method. Breast region is extracted from T1-weighted image. Initial candidates are detected using diffusion-weighed image. Above results are combined to remove the outside candidates, and false positives are reduced by the rule-based classifier.

2.3 Extraction of breast region using T1-weighted images

Breast region is extracted from T1-weighted images (Fig.2.a). First, the whole body regions are obtained by contour tracking in each slice (Fig.2.b). Next the slice of the top of nipple is selected. As shown in Fig.3, the bilateral outermost points of the trunk body and the sternum point on the slice are gained; a quadratic function is made from these points. Above-mentioned processing is applied for the breast bottom end and upper end slice. Subsequently, a curved surface as the trunk body region is generated by interpolating among three functions (Fig.2.c). The breast region is obtained by removing the trunk body from the whole body (Fig.2.d). If the extraction of breast region fails, the above- mentioned nine points for generation of the trunk body are set manually.

2.4 Initial candidates detection using diffusion-weighted images

After correcting the resolution for diffusion-weighted image, the thresholding method is applied for diffusion-weighted images to detect the initial candidate regions.

2.5 False positives reduction

After labeling processing, initial candidates outsides the breast region are eliminated using the extracted breast region determined by the T1-weighted image. However, there are approximate 20 FPs per case in the eliminated results. Therefore, FPs inside breast regions are identified by the rule-based classifier. The rule-based classifier distinguished FPs using the volume of candidate region. The number of pixel in candidate region was calculated as the volume; the candidates having the volume smaller than determined value were eliminated.

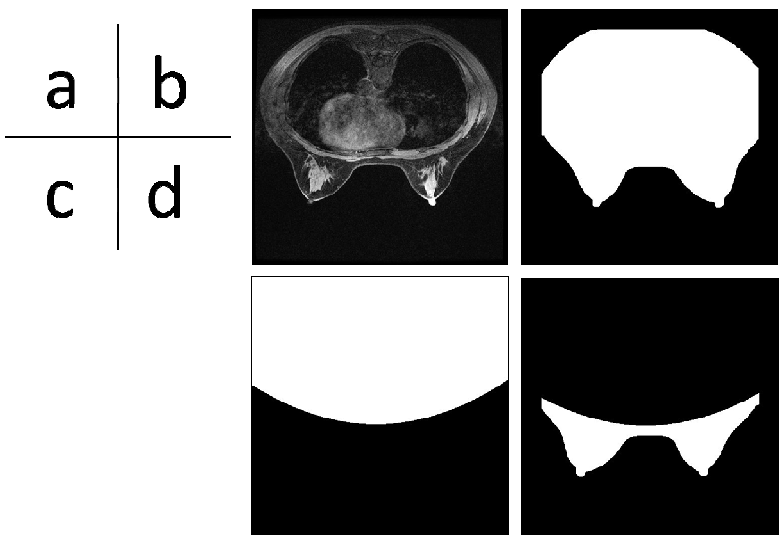

Fig. 2 The results of extracting breast region using T1-weighted images. The whole body (b) is extracted from T1-weighted image (a). The trunk body (c) also is extracted. Removing the trunk body from the whole body makes the breast region (d).

Fig.3 Red points in T1-weighted image show three acquired points to generate the trunk body region.

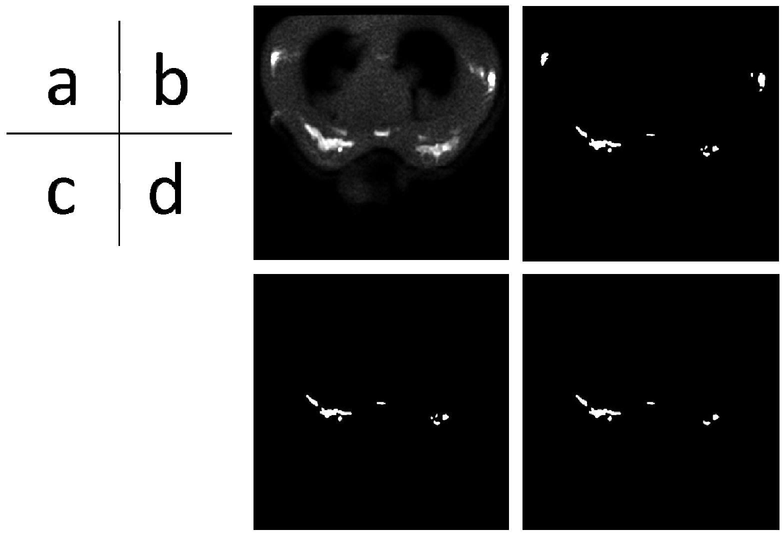

Fig.4 The experimental results of detecting initial candidates using diffusion-weighted images. Diffusion-weighted image (a) is binarized to make initial candidates (b).Then outside candidates are removed by breast region (c). Finally, false positives are eliminated by the rule-based classifier (d).

3. EXPERIMENTS

The breast region extraction and detection sensitivity were evaluated manually. In addition, the proposed method was evaluated by 3-fold cross-validation. Through the validation, two parameters - the threshold value for initial detection and the minimum volume for FP reduction - were adjusted. The threshold value for initial detection was determined by considering the signal intensities of tumor and normal tissue. As a same manner, minimum volume for FP reduction was determined considering the volume of tumor and normal tissue.

Because of the low intensity of skin, the extraction of the breast region was failed in 2 cases. In cross-validation, the detection sensitivity was 71.9% and the number of FPs per case was 9.9 per case.

Figure 5 shows the results that the tumor was detected correctly. On the other hand, Fig.6 shows the results that the tumor was not detected. Because the tumor was small, we guessed the rough resolution of diffusion-weighted image buried the signal intensity.

4. CONCLUSIONS

In this study, we have proposed a semi-automated scheme for detecting breast tumor in unenhanced MR images using combined T1-weighted and diffusion-weighted images. Proposed method detects the breast region from T1-weighted image and the initial candidates from diffusion-weighted image. After the FP reduction using breast region, the remained candidates are reduced addictively with the rule-based classifier. As a result, detection sensitivity was 71.9% and FPs were 9.9 per case. These results indicate that the proposed method may be useful for the tumor detection in unenhanced breast MR images.

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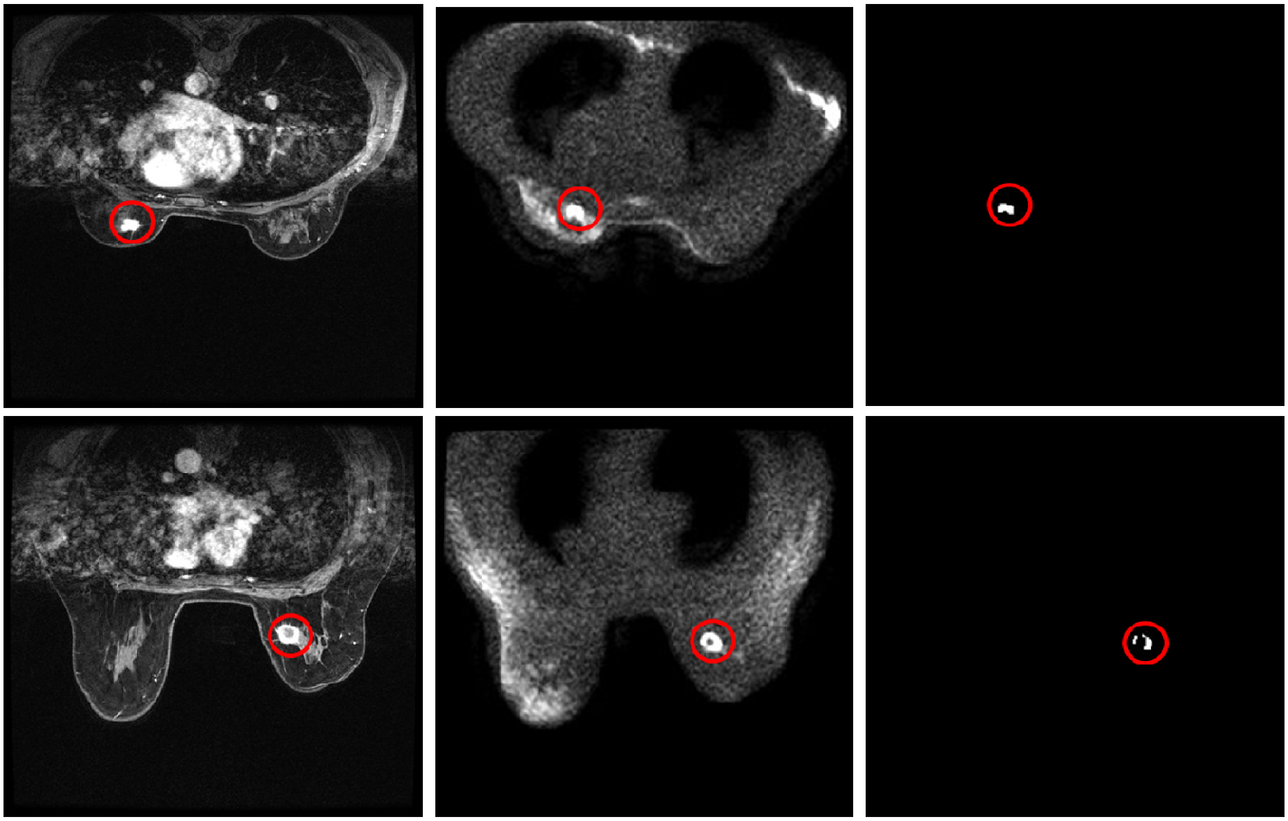
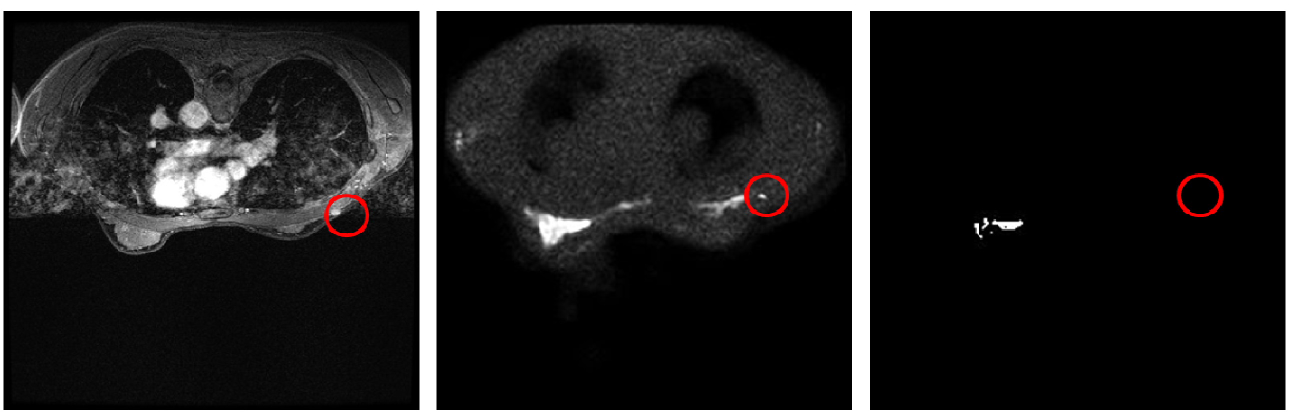


(a) Contrast enhanced T1WI (b) Diffusion-weighted image (c) Tumor candidate

Fig.5 Tumors detected by proposed method. Each line shows a different case. Red circles show the tumor locations in each images. (a) shows the exact location of tumor identified by radiologist.



(a) Contrast enhanced T1WI (b) Diffusion-weighted image (c) Tumor candidate

Fig.6 Tumor not detected by proposed method. Red circles show the tumor locations in each images. (a) shows the exact location of tumor identified by radiologist.

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