Deformable Registration with Tumor Volume Preservation in Dynamic Contrast Enhanced MR Breast Images

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Introduction: The perfusion analysis of tumors in dynamic contrast-enhanced MR breast images provides important diagnostic information for distinguishing benign lesions from malignancies and monitoring therapy. Since DCE-MR breast images acquired at different time points result in local deformation from respiration and cardiac pulsation as well as changes in patient's position and orientation, deformable registration is needed for the accurate perfusion analysis. However, different enhancement on same tissues of pre- and post-contrast enhanced images makes the deformable registration to change not only the shape but also the volume of breast tumor. Thus, we propose a demon-based deformable registration with rigidity constraint to preserve tumor volume in DCE-MR breast images. In addition, density correction in each breast tissue (fat, muscle, and glandular tissue) is proposed to reduce density changes due to the uptake of the contrast agent.

Methods: DCE-MR breast images were acquired on a Siemens Magnetom Sonata 1.5T MR scanner. A dataset consisted of one pre-contrast enhanced image and four post-contrast enhanced images. The first post-contrast time point occurred 1.4min after the injection, followed by 2.4, 4.2, and 5.6min post-contrast time points. In-plane resolution was $0.38\times0.38mm^2$ and slice thickness was 1.0-1.4mm. Matrix size was 448×448 pixels and the number of sagittal slices was 96. To reduce the enhancement difference between pre- and post-contrast enhanced MR breast images, the breast skin is extracted by using maximum gradient profile searching and the other breast tissues are classified into three areas (fat, muscle, glandular tissue and tumor) using k-means clustering. Then the density of each breast tissue except tumor region is corrected by using histogram matching. To constrain local rigidity of a tumor, the tumor is localized in the subtracted images and is segmented in post-contrast enhanced images using an adaptive thresholding and morphological operator. Finally, to deform breast tissues with the preservation of tumor volume, tumor regions are rigidly transformed by averaging the magnitudes of deformation vector fields in narrow band and the other breast tissues are deformed by using demon-based deformable registration. For regularization, narrow-band propagated from tumor region is defined and adaptively weighted from 0.0 to 1.0.

Results: The registration results using the proposed method were visually assessed. Figure 1 shows that breast tissues with benign or malignant tumor were well deformed with tumor volume preservation by the proposed method. Malignant tumor showed higher enhancement than that of benign tumor. Deformed source after deformable registration (c,i) reduced the tumor volume while deformed source after deformable registration with rigidity constraint (d,j) preserve the tumor volume. With density correction, the proposed deformable registration (e,k) significantly reduces the effect of movement artifacts in subtracted contrast-enhanced images as well as efficiently preserves the tumor volume. To evaluate the performance of deformable registration with and without density correction, SSD were measured in whole breast and each breast tissue except tumor. Figure 2 shows the result of the SSD measure in each breast tissue for two subjects with malignant tumor. This result shows that SSD generally decreased after deformable registration with rigidity constraint (RC) and density correction (DC) than that without density correction. Especially, in glandular tissue with high enhancement, SSD measure is considerably reduced after density correction.

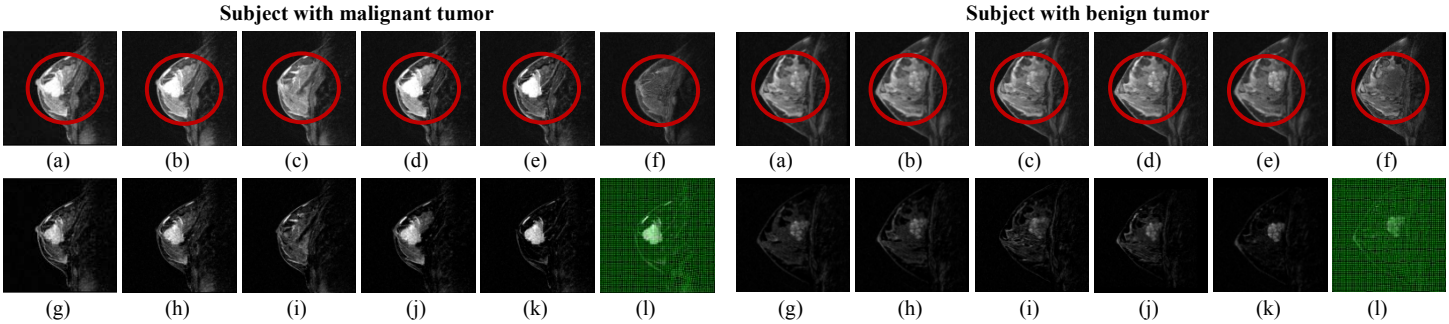

Fig.1. Results of deformable breast registration with rigidity constraint and density correction in sagittal view: (a) source, (b) rigid transformed source, (c) deformed source, (d) deformed source after proposed method with RC, (e) deformed source after proposed method with RC and DC, (f) target, (g) regular subtraction, (h)-(k) subtracted images after rigid registration, after deformable registration, after proposed method with RC, after proposed method with RC and DC, and (l) deformable grid after proposed method with RC and DC.

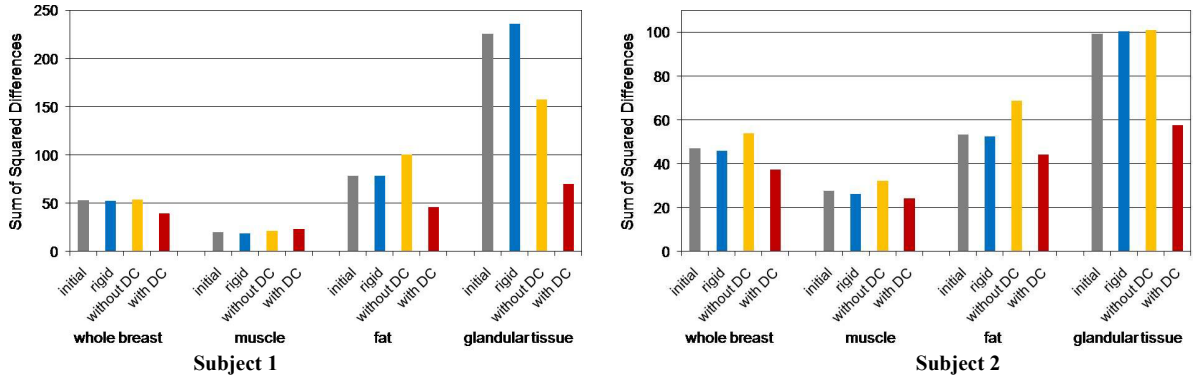

Fig.2. Results of accuracy evaluation in deformable breast registration with and without density correction: SSD measure in whole breast, muscle, fat, and glandular tissue

Conclusions: The proposed deformable registration can efficiently correct global and local motions of breast tissue with tumor volume preservation by using rigidity constraint and density correction. Our deformable registration can be used for distinguishing benign lesions from malignancies and monitoring therapy.