Validation of a Nonrigid Registration Algorithm for Longitudinal Breast MR Images

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INTRODUCTION There is considerable interest in quantitatively comparing MR images of the breast at different times e.g. pre- and post treatment for breast cancer. Such comparisons are essential for developing MR imaging biomarkers of treatment response. We have modified the adaptive bases algorithm (ABA) [1] and proposed a new method [2] whereby longitudinal dynamic contrast enhanced MRI (DCE-MRI) data sets are co-registered to a common image space, thereby retaining spatial information so that serial DCE-MRI parameter maps can be compared on a voxel-by-voxel basis. Although the visual assessment shows the proposed method can successfully register the breast MR images acquired at different time points (Fig. 1), this approach needs to be validated quantitatively. In this study, we propose a novel validation method to simulate the deformation of the longitudinal breast MR images and evaluate different nonrigid registration algorithms.

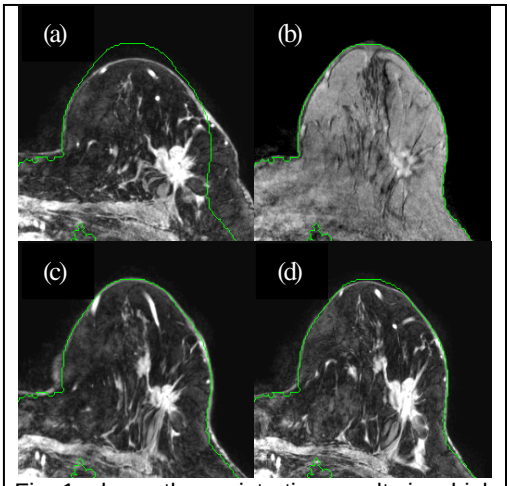

Fig. 1. shows the registration results in which the pre-treatment breast MR image (a) was registered to the post-treatment image (b) after ABA (c) and after the proposed method (d). Note the new method not only registered the normal tissues accurately, but also prevented the tumor from being distorted.

METHODS For each patient, a 3D T_1 weighted high resolution isotropic volume examination (THRIVE) scan was acquired (pre- and post-treatment) with a fat-nulling inversion pulse and the following parameters: TR/TE/α/NSA = 6.98/3.6ms/10°/1. There are four steps in the validation: simulation, transformation, registration, and comparison. To simulate the images after treatment, the tumor in the original images is contracted, and the contracted area is filled using texture from healthy tissue. Second, to simulate breast deformation caused by patient repositioning associated with the post-treatment scan, the simulated (contracted tumor) images are co-registered to the actual post-treatment images using a surface registration. This approach makes the simulated deformation quite realistic and provides a *known* displacement for every voxel in the images; thus, this displacement can be considered as "truth" and used to evaluate registration methods. Next, the proposed and original ABA registration algorithms are applied to register the pre-treatment to the simulated post-treatment images, respectively. Through comparing the deformation generated by these two algorithms with the true deformations, we can assess the accuracy of the proposed registration algorithm.

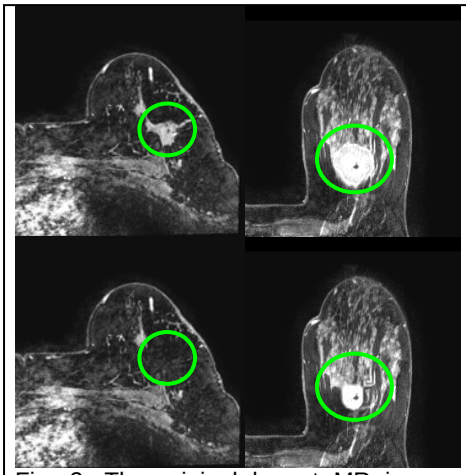

Fig. 2. The original breast MR images from two different patients (1st row) and the corresponding simulated images (2nd row) with tumors shrunk by ~100% and 70%, respectively.

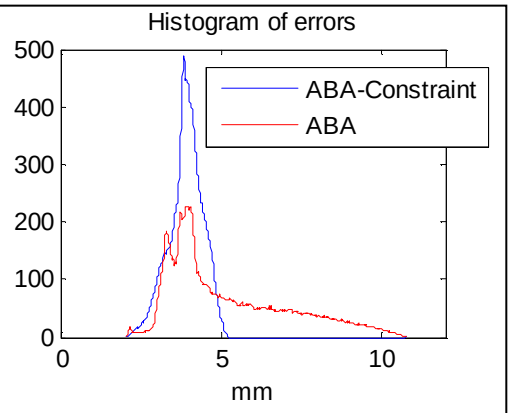

Fig. 3. The histogram of errors is calculated through comparing the proposed method and ABA with the known deformations. Note that the proposed method leads to a more accurate registration, as well as a smaller mean error and smaller standard deviation, compared with the unconstrained ABA algorithm.

RESULTS Fig. 2 shows two original breast MR images and the corresponding simulated images. Fig. 3 displays the histogram of voxel displacement errors for one data in Fig. 2, after the displacements of voxels in the tumor area were compared with the known displacements. Thus far, we verified the proposed method and ABA on four data sets with tumors contracted by 70~80%; the mean errors are 2.67±1.02 mm and 3.64±1.65 mm, respectively. Thus, the proposed method leads to smaller (~36%) displacement error and smoother deformations compared to ABA.

CONCLUSIONS Future efforts will include studying (in a larger number of patient data sets) the accuracy of the registration results when the tumors are contracted by different percentages, and investigating if longitudinal registration can lead to more accurate methods of predicting treatment response.

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REFERENCES: 1. Rohde et al., IEEE TMI 2003. 2. Xia Li et al., SPIE 2009.