AUTOMATIC REGISTRATION OF MULTISPECTRAL MR VESSEL WALL IMAGES OF THE CAROTID ARTERY

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Introduction

The detailed assessment of atherosclerosis of the carotid artery requires high resolution imaging of the vessel wall using multiple MR sequences with different contrast weightings. These images allow manual or automated classification of plaque components inside the vessel wall. During scanning, patient movement may cause misalignment between the sequences. Registration is required to correct for these misalignments. Manual alignment is the current procedure, but is time-consuming; therefore automatic image registration has been applied in a number of studies. In previous work, automatic registration was only performed in 2D[1-3], while patient movement occurs in 3D, and no quantitative validation was performed[2-4]. The purpose of this study was 1) to develop an optimal 3D automatic registration method, and 2) to perform a quantitative validation of the registration results with a gold standard.

Methods and Materials

Images from fifty TIA/stroke patients with ipsilateral <70% carotid artery stenosis, with adequately visualized vessel wall boundaries and no imaging artifacts, were randomly selected from a larger cohort. MR images were obtained on a 1.5T scanner using a dedicated carotid surface coil (both Philips Healthcare). Five MR pulse sequences were obtained around the carotid bifurcation, each containing nine transverse slices: T1W TFE, TOF, T2W TSE, and pre- and post-contrast T1W TSE as described in [5]. Acquired pixel size was 0.39x0.39 mm^2 and slice thickness was 3.0 mm. All images were reconstructed to have a pixel size of 0.2x0.2 mm^2 in plane. The data was manually segmented by delineating the lumen contour in each vessel wall sequence, which acts as the ground truth. In this study the pre-contrast T1W TSE was used as the reference sequence. In addition, an expert manually aligned the images to this reference by applying an in-plane translation to each image slice.

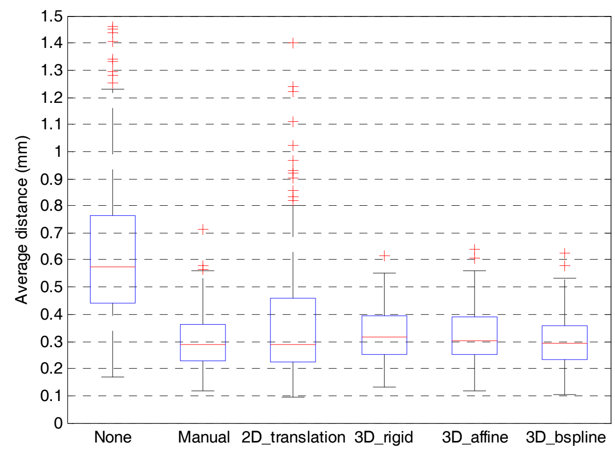

Figure 1, box plot of different registration methods.

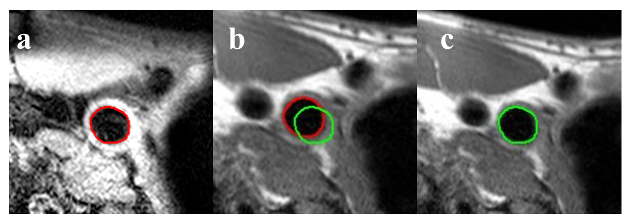

Figure 2, a) T1W TSE, b) T1W TFE showing misalignment between T1W TSE and T1W TFE lumen segmentations, c) registered image.

Automatic image registrations using various transforms were investigated, being 2D translation per image slice, 3D rigid transform, 3D affine transform and 3D B-spline transform. In order to prevent the automatic registration to align the studies to the dominant neck-air boundary, a circular image mask centered over the lumen was used. Mutual information was chosen as image similarity metric, a tri-linear interpolator, and stochastic gradient descent as optimizer. In all cases various mask sizes were tested to obtain the optimal mask size. Similarly, for the 3D B-spline transform, different grid sizes of the B-splines were tested. The different registration methods were applied using publicly available `elastix` software[6].

Evaluation of the automatic registration was performed by comparing the lumen segmentation of the reference image after registration with the lumen segmentation of the moving image. To compare the results of 2D and 3D registrations, all contours were converted into 3D tubular meshes and the distance between the tubular meshes was used to quantify the accuracy. A smaller distance indicates a better registration result.

Results

The box plot in Figure 1 shows the distribution of the residual registration distance. The first box shows the distance without applying any form of registration. The second box shows the results after manual registration of the expert. The remaining columns show the different automatic registration strategies. The performance of the 3D B-spline registration is very close to the manual alignment. Paired t-tests showed that there is no significant difference between the manual alignment and the 3D B-spline registration ($p<0.05$). The optimal mask size was a circle with a diameter of 1 cm. The optimal grid size for the 3D B-spline registration was 15 mm.

Discussion and conclusion

Different methods for the automatic registration of multispectral MR vessel wall images of the carotid artery were investigated and quantitatively validated. Registration using a 3D B-spline transform performed equally well as the manual alignment by an expert, with final result in the order of the in-plane voxel size. These results show that automatic image registration can replace the manual alignment reducing the amount of time needed analyzing carotid vessel wall images.

References & Acknowledgements: [1] Biasiolli, L. et al., Proc. SPIE, 2010;7623;76232N. [2] Hofman, J.M. et al., Magn Reson Med, 2006;55(4):790-9. [3] Liu, F. et al., Magn Reson Med, 2006;55(3):659-68. [4] Fei, B. et al., Proc. IEEE EMBS, 2003; 646 – 648. [5] Kwee, R.M. et al., PLoS One, 2011;6(2). [6] Klein, S. et al., IEEE Transactions on Medical Imaging, 2010;29(1):196-205. This research was supported by the Center for Translational Molecular Medicine and the Dutch Heart Foundation (PARISk).