A robust automated multi-modality registration tool applied to abdominal aortic aneurysm

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PURPOSE

This study aims to evaluate the accuracy of a new method for multimodality registration of vascular structure. Registration of multi-modality and multi-parameter imaging is challenging because of the large variations in image contrast and non-stationary artifacts. This paper presents an accuracy evaluation for an automatic registration method for T2 weighted (T2W), pre- and post-contrast T2* weighted (T2*W) MR images, and CT images used in a study of abdominal aortic aneurysms (AAA).

METHODOLOGY

Data acquisition: The MA3RS study, led by the Clinical Research Imaging Centre, University of Edinburgh is investigating inflammatory markers for AAA growth and rupture[1]. 71 patients currently under the UK aneurysm surveillance programme with aneurysm diameter >4cm were imaged. Imaging protocol: 3D isotropic axial T2W fast spin echo with and without fat suppression, and T2*W multi-gradient-echo multi-slice axial 2D images acquired at baseline (3T Verio, Siemens Healthcare, Germany), followed by administration of 4mg/kg of ultra-small superparamagnetic iron oxide (USPIO) contrast agent (Rienso, Advanced Magnetics Inc, USA). MRI coverage was obtained from above AAA to aortic bifurcation. 36 hours later the MRI protocol was repeated. Uptake of USPIO in AAA on the post-infusion T2*W images indicates inflammatory macrophage uptake[1]. A standard contrast enhanced CT dataset covering the aorta was acquired at baseline (Aquilion ONE, Toshiba Medical Systems, Japan). Figure 1 shows the variation in appearance and artifacts between acquisitions. To quantify USPIO uptake, pre- and post-contrast T2*W images must be spatially registered, along with the T2W images and CT images to provide USPIO localisation.

Registration and Evaluation: For the purposes of this study the abdominal aorta could be adequately aligned using a rigid-body transform. To account for differences in contrast between images a mutual information similarity metric with top-down k-means binning strategy was used. The DIRECT global optimization was used to search for the optimal transform. A multi-resolution framework was adopted for efficiency, together with an axial-ROI tracking method all implemented in MATLAB. To access registration accuracy, a graphical user interface (GUI), shown in figure 2, was developed to allow a suitably experienced clinician to manually "correct" registration (if required), by adjustments to the translations and rotations. Differences between manual and automatic registration transforms were then analysed for T2W-T2*W registration, $T2^*W_{baseline}$-$T2^*W_{post\text{-}contrast}$, and T2W-CT.

RESULTS

Mean translational and rotational errors in x, y, z and mean Euclidean error for MR registrations are shown in Table 1. The mean translational error is 2.56mm, and 59.6% T2W-T2*W and 54.5% T2*W-T2*W registrations achieved sub-pixel accuracy. The largest translational error is <7.0 mm, >50% of the registration results require no manual correction. Results of registering pre-contrast-T2*W to CT are shown in Table 2. The mean translational error is 4.2 mm, and mean rotational error is <0.7^0 in all dimensions. >35% of results require no manual adjusting and in >50% cases the manual correction along each axis was ≤1 pixel.

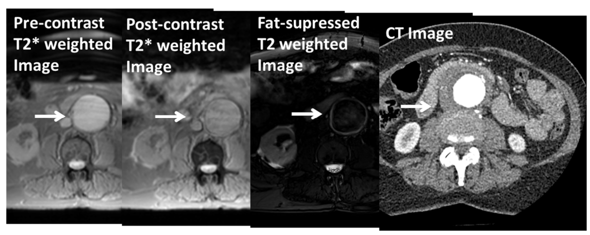

Figure 1 Images involved: from left to right, pre- and post-contrast T2*W image, T2W image with fat-suppression, CT image, white arrow pointing to aorta.

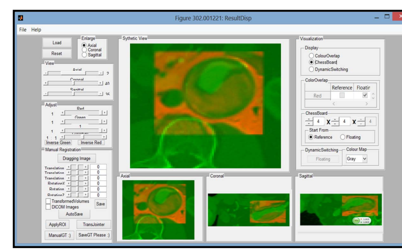

Figure 2 The GUI used to collect manual registration results showing aligned CT-MR volume using overlapped colour channel.

DISCUSSION

We have investigated the accuracy of a new method for aligning AAA in multi-modality and multi-parametric imaging. >50% of performed registrations gained sub-pixel accuracy. Using manual "corrections" to validate the results may cause over-estimated errors when rotational adjusting involved. Inter-parametric MR registration gained better results than MR-CT registrations because of larger non-rigid distortion and morphological irrelevances in the latter case. However, this may also be caused by the larger coverage of the CT volumes. As a result, small rotations will cause relatively larger changes in translation. Performance of registration can be improved by modifying parametric settings, e.g., increasing number of iterations, searching space, bin numbers, etc. Non-rigid registration can be easily integrated into this registration framework.

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Table 1 MR image registration errors, including, translational and rotational errors in x, y, z and mean Euclidean errors and rotational errors calculated as the an equivalent single rotation resulted by the rotational errors of x, y, and z. Translational error represents in number of pixels and rotational error in degrees where all images were down sampled to 1.5625mm per pixel.

axis	T2*W-T2*W				T2W-T2*W			
	Translation	Rotation	Euclidean Translation	Rotation Angle	Translation	Rotation	Euclidean Translation	Rotation Angle
x	1.0556	0.7037	1.76	0.81	0.9032	0	1.55	0.04
y	1.1296	0.2407			1.2984	0		
z	1.0833	0.5556			0.4919	0.0323		

Table 2 T2*W-CT registration errors, including translational and rotational errors in x, y, z and final Euclidean errors and rotational errors calculated as an single rotation composed by rotation errors around x, y and z. Translational error represents in number of pixels and rotational error in degrees where all images were down sampled to 1.5625mm per pixel.

Axis	Translation	Rotation	Euclidean Translation	Rotation Angle
x	1.0455	0.3409	2.70	0.69
y	1.7500	0.0909		
z	0.9091	0.3182		