AUTOMATIC PELVIC BONE REGISTRATION OF LOW-FIELD MRI TO 3T-MRA FOR VASCULAR INTERVENTIONS.

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INTRODUCTION

Partial or complete obstruction of peripheral arteries is assigned as peripheral arterial occlusive disease (PAOD) and is caused by atherosclerotic plaques. Guiding the endovascular treatment by low-field MRI (LF-MRI) could possibly be used to overcome the problems of ionizing radiation, the used contrast agents[1], and the ergonomic injuries caused by lead aprons[2]. LF-MRI is characterized by an open magnet design but has poor spatial resolution when temporal resolution is maximized to 3-5 frames per second[3].

Fusion with pre-operative magnetic resonance angiography (MRA) or computed tomography angiography (CTA) may tackle this problem of poor spatial resolution. This fusion would enable the possibility to provide a high spatiotemporal resolution arterial roadmap to the PTA operator during the intervention, as illustrated in Figure 1.

The overall goal of this work was to devise an automatic segmentation method of the pelvic bone from an LF-MRI scan, followed by rigid registration with 3T-MRA data.

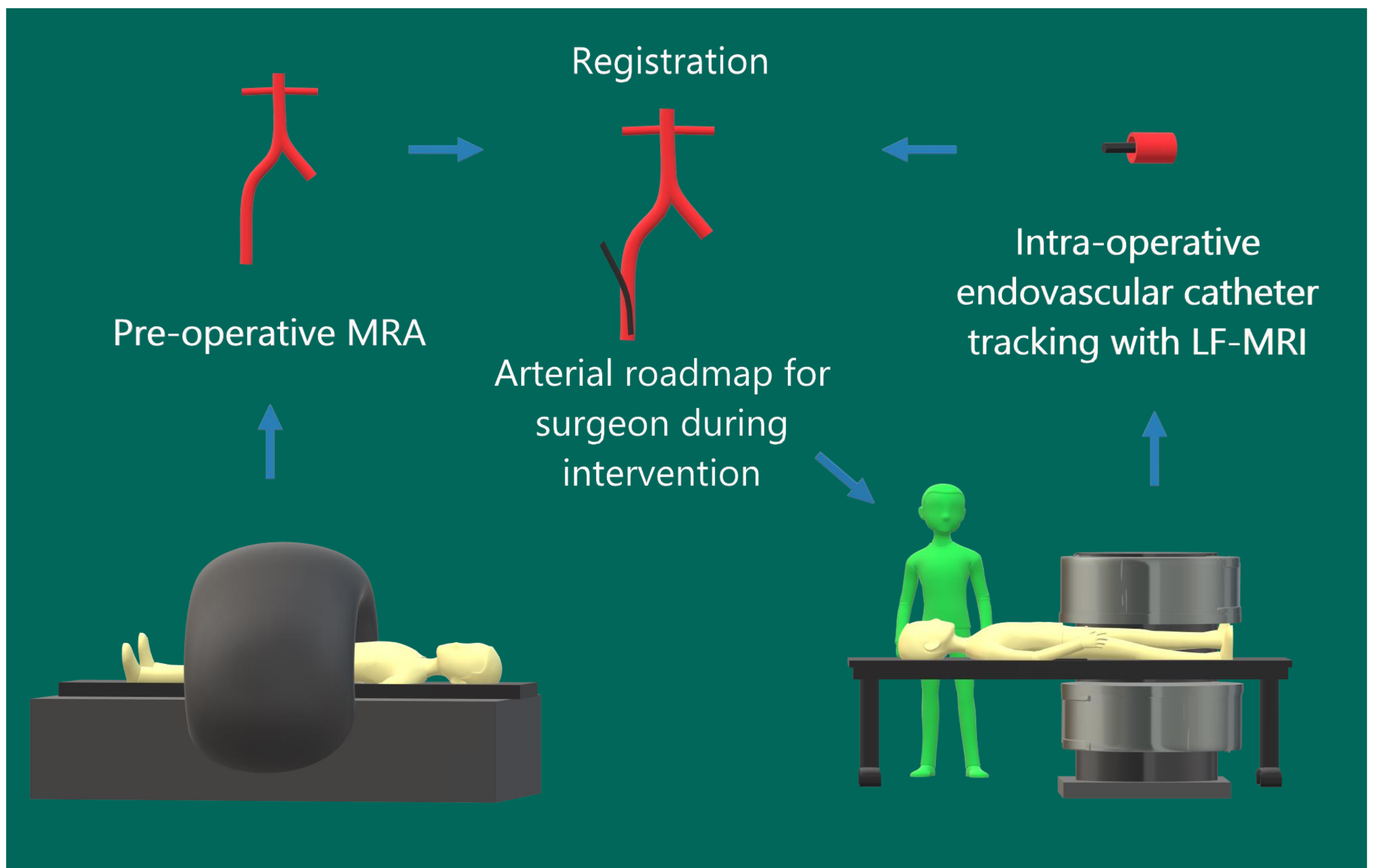

Figure 1. Overview of LF-MRI application as intra-operative endovascular catheter tracking modality during PTA.

METHODS

Scans - From the same volunteer, a dual echo steady-state free precession sequence (DESS) was used to depict the pelvic bones on LF-MRI (0.25T) and a non-contrast enhanced (NCE) MRA (3T) sequence (NATIVE SPACE) was for angiography. Due to the limited FOV (max. 270 mm) of the LF-MRI system, only half of the pelvic bone could be segmented.

Segmentation – Automatic LF-MRI pelvis segmentation was achieved by combining Laplacian-based edge detection, thresholding, morphological operations, Gaussian blurring and filling, which was compared with manual segmentation. The 3T-MRI pelvis was manually segmented out of the unsubtracted NATIVE SPACE images.

Registration - The two segmented volumes were automatically fused by an inhouse developed converging algorithm that corrects successively for translational and rotational differences. Translational deviation was estimated in a spherical pattern with a shrinking radius, and the rotation parameters converge towards an optimum by decreasing the angular step size. Automatic registration after maximal 30 iterations was assessed with the Root Mean Square Error (RMSE) of five pre-defined bony landmarks in both volumes. Manual registration was performed using the Procrustes algorithm[4].

Similarity - Similarity between both manually and automatically segmented volumes were examined with the following similarity measures: Sorensen-Dice, Jaccard, Russel and Rao, Driver and Kroebel and the Ochiai coefficient. The developed registration algorithm used all of these measures separately for registration resulting in different RMSEs.

RESULTS

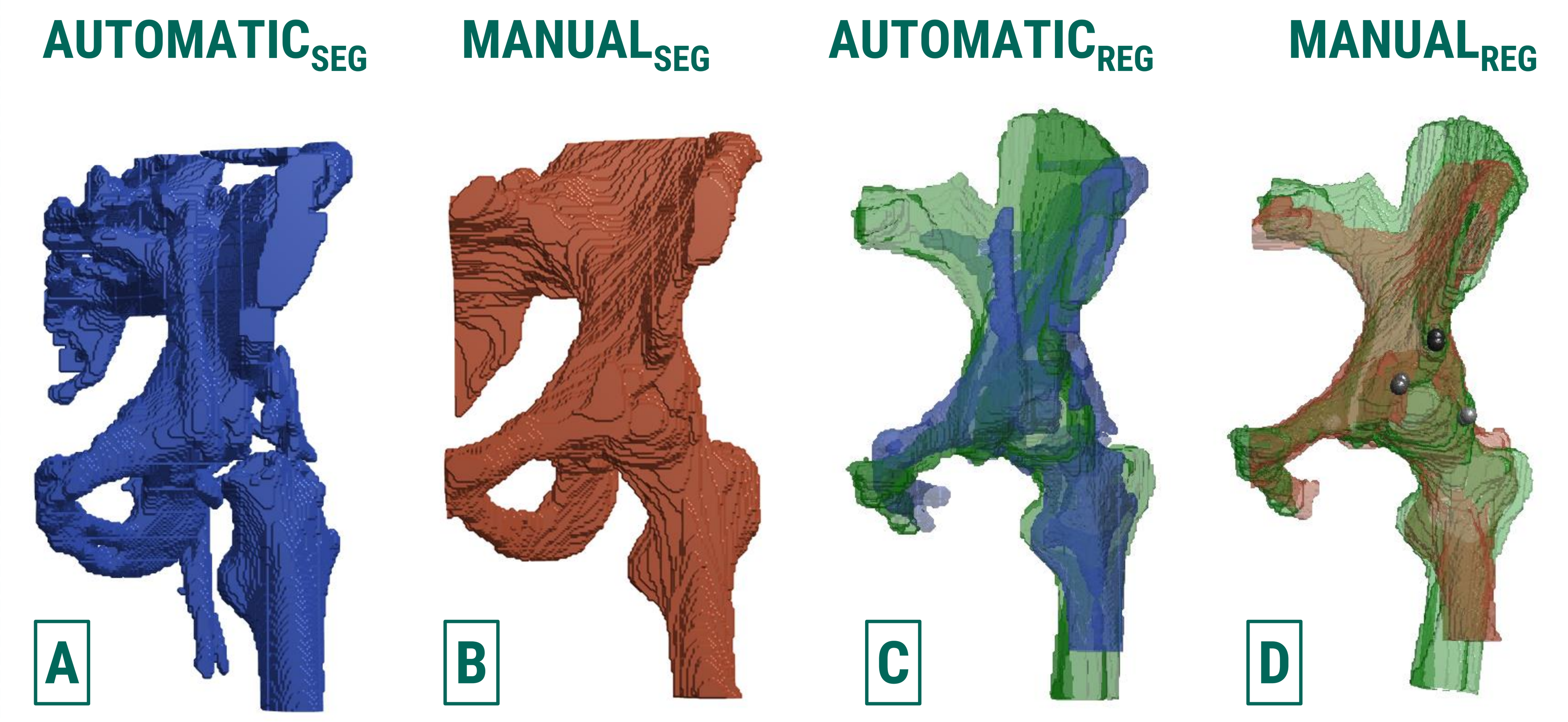

Figure 2. (A) Automatic pelvis segmentation from LF-MRI. **(B)** Manual pelvis segmentation from LF-MRI. **(C)** Automatic volume registration of automatically segmented pelvis (*blue volume*) to manually segmented 3T-pelvis (*green volume*). **(D)** Manual points registration on manually segmented LF-pelvis (*red volume*) and manually segmented 3T-pelvis (*green volume*). Note that the altered femur position between LF-MRI and 3T-MRI did not affect this registration.

	SEGMENTATION	REGISTRATION
COEFFICIENT	SIMILARITY [0-1]	RMSE [mm]
Manual	-	2.33
Jaccard	0.490	4.27
Sørensen-Dice	0.657	4.27
Russel and Rao	0.0653	3.34
Driver and Kroebel	0.660	3.33
Ochiai	0.659	3.56

Table 1. Similarity indices of automatically segmented volume with reference volume after registration, and RMSE of five allocated points on volumes after automatic registration with 30 iterations.

DISCUSSION

Currently, the registration results are hampered by unintended inclusion of the femur which position may vary between different scan moments (see the difference between Figure 2.C and 2.D). Final registration accuracy can be improved by removing the femur from the segmented volume. In addition, the registration error may decrease by addressing the transformation as a 6D problem, instead of two separate 3D problems. To emphasize the potential value of the achievements reached in this study, Figure 3 shows an NCE 3T-MRA that was manually segmented but automatically registered to LF-MRI with the obtained transformation parameters. A roadmap like this image should be sufficient for the surgeon during endovascular interventions (see also Figure 1).

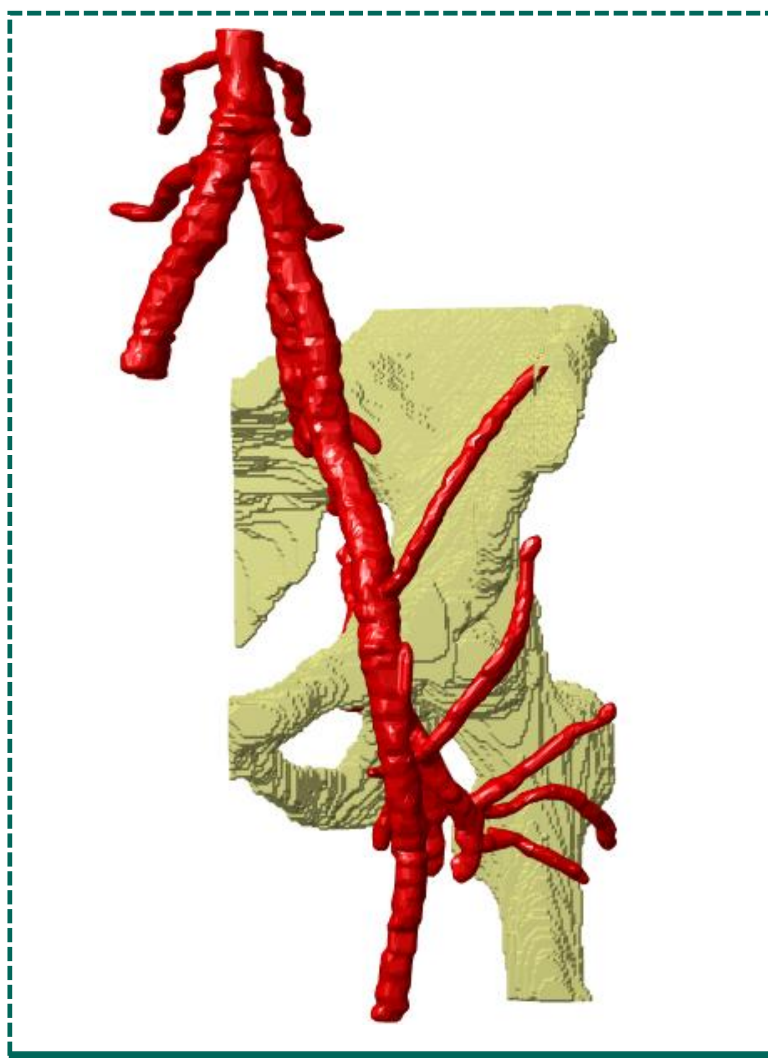

Figure 3. Manually segmented left part of the pelvis from LF-MRI with 3T-MRI-derived arteries, transformed with automatically found registration parameters.

CONCLUSION

With this fusion method an MRI-based arterial roadmap for PTA can be achieved. This method could also be applied in other vascular domains. A method for automatic segmentation of the LF-MRI reconstructed pelvic bone was shown with a Driver and Kroebel similarity index of 0.66.

Automatic registration of the segmented pelvic bone on LF-MRI to a 3T-MRI derived pelvic bone was managed with an RMSE of 3.3 mm.

REFERENCES

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