Comparison of Rigid Registration Methods for Time-of-Flight MRA datasets

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Purpose:

Intra-patient registration of Time-of-Flight (TOF) MRA image sequences acquired at different time points is an important step for quantitative analysis of cerebrovascular diseases and therapy outcomes. The registration of TOF datasets allows for example a quantification and improved visualization of recanalized vessels after lysis therapy in case of an ischemic stroke. Apart from this, registration of TOF image sequences enables the quantitative analysis of aneurysm coil therapy outcome [1]. However, accurate registrations are required to achieve reliable quantitative results. So far, no study has been performed comparing different rigid registration methods with special focus on TOF image sequences. Therefore, the aim of this study was to evaluate different rigid registration approaches for aligning TOF MRA image sequences.

Material and Methods:

Twenty clinical TOF datasets consisting of two image sequences from different time points were available for this evaluation. Ten of these datasets were acquired from patients with an occlusion of the middle cerebral artery. For each patient, one TOF baseline image sequence (BL) was recorded before lysis therapy and one follow-up image sequence (FU) approximately 24 hours after lysis therapy. The remaining ten datasets were acquired from patients with aneurysms. Here, the BL image sequence was acquired before endovascular coiling and the FU image sequence approximately 6 month after the intervention. All TOF MRA measurements were performed on a 1.5T Avanto scanner (Siemens, Erlangen, Germany) using TR=39ms, TE=7ms, flip angle=25°, an in-plane image resolution of 0.4mm², slice thickness of 0.7mm, and a FOV of 150 × 200mm².

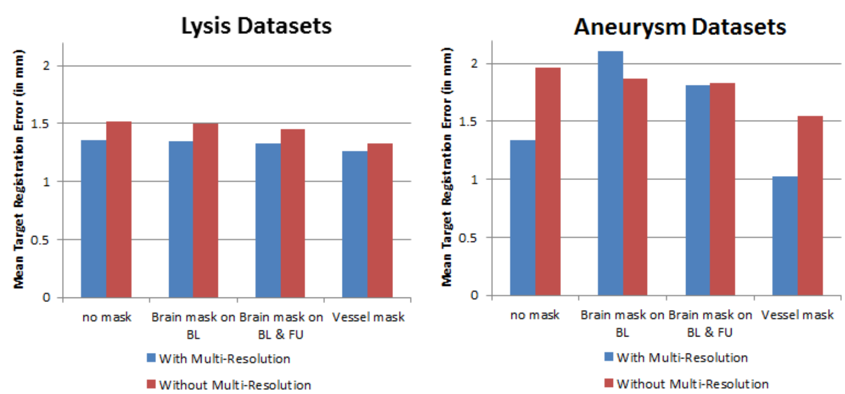
These TOF datasets were then used for intra-subject registration, whereas in each case the FU image sequence was registered to the first BL image sequence. As non-linear or shear differences were not expected, rigid transformation were used in each case. The optimal transformations were calculated by minimizing the mean squared distance of the intensities.

Overall, eight different rigid registration results were evaluated in this study. First, the optimal transformations were calculated based on all voxels of each two image sequences. Second, the brain tissue was segmented in the BL image sequence using the approach described in [2] and used for a masked registration approach, in which only voxels within the mask are contributing to the similarity measure. Third, the brain tissue was also segmented in the FU image sequence and used together with baseline segmentation within a masked registration approach. Fourth, the cerebrovascular system was segmented in the image sequence exhibiting less vessel structures (lysis: BL image sequence; aneurysm: FU image sequence) using the approach presented in [3] and used for a masked registration. Finally, the optimal transformations for these four registration approaches were calculated with and without a multi-resolution framework using three levels.

For quantitative evaluation of the registration accuracies, the mean target registration error (TRE) was calculated for each dataset and registration approach. Therefore, two observers independently placed 308 landmarks at distinctive vessel locations in the baseline and follow-up image sequences. The mean target registration error was then calculated for each dataset and transformation with: $TRE = \frac{1}{n}\sum_{j=1}^{n} t\left(L_J^{FU}\right) - \left(L_J^{BL}\right)$, whereas n denotes the number of corresponding landmarks L in the baseline (BL) and follow-up (FU) image sequence and t the calculated transformation.

Results:

The results of the quantitative evaluation of the eight registration approaches are displayed in Fig. 1 averaged for both observers. In general, it can be seen from these results that the multi-resolution registration approaches perform better compared to the registration approaches without multi-resolution strategy. Furthermore, the results suggest that the best registration results can be obtained using a segmentation of cerebrovascular system as a mask. With this setup, a mean TRE of 1.2 mm for the lysis datasets and 1 mm for aneurysm datasets was achieved. The TRE calculated for the two observers exhibited a mean difference of 0.13 mm.



Conclusions:

The results of this study suggest that rigid registration of TOF MRA datasets should be performed using a multi-resolution framework and a segmentation of the cerebrovascular system as a mask to obtain the highest registration accuracies for further quantitative analysis steps.

References:

[1] Ries T. et al. Neuroradiology 2011,53(8):593-8, [2] Forkert ND. et al. Methods Inf Med. 2009;48(5):399-407, [3] Forkert ND. et al. Methods Inf Med. 2011;50(1):74-83.