Accurate and automatic slice repositioning for longitudinal carotid imaging studies

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Introduction: When follow-up MR exams are used to monitor the progression or regression of carotid artery plaques, accurate repositioning of slices relative to the original exam is crucial for properly assessing disease progression. This task is made more difficult by the flexible nature of the neck and head. We describe a method for accurate, automatic prospective slice repositioning for carotid imaging. This is an extension of a previous method that used prospective registration of T1-weighted brain images to reposition ^{1}H spectroscopy voxels for longitudinal exams (1). The new method uses a multi-resolution Gaussian pyramid approach to registration and applies this to time-of-flight (TOF) images to focus the registration on the carotid arteries alone and not surrounding tissues.

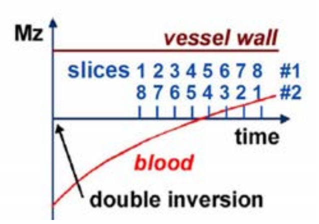
Methods: Using the Insight Toolkit (2), a mutual information (MI) based image registration algorithm tailored for TOF images was developed. While MI is generally used to register images with different contrast properties, *e.g.* T1 and T2, the intent in this application is to ignore soft tissue as much as possible and focus on the registration of vessels. To this end, a multi-resolution Gaussian pyramid is employed, with many iterations performed at five scales. While the algorithm is slower than single-resolution algorithms, the convergence properties are better for images with few features, *e.g.* TOF. Once the anatomy has been registered, carotid imaging is performed using a variation of a multi-slice black blood sequence (3). Here a multi-slice double-inversion fast spin echo sequence is executed, with two averaged excitations, where the slice order is reversed for the second excitation relative to the first (Figure 1). In this way the residual blood signals from slices not on the T1-null cancel when the excitations are averaged.

A normal healthy volunteer was imaged on a 1.5T MR scanner (GE Healthcare, Milwaukee WI) after giving proper informed consent. A 3” surface coil was placed on the right side of the volunteer’s neck and TOF images (5.1ms/17ms, 4mm slices, 29cm FOV, 60^{o} flip) were acquired followed by black-blood carotid images (11.5ms/769ms, 324ms TI, 4mm slices, 12cm FOV). The volunteer then was repositioned on the scanning table to simulate the time lapse between follow-up imaging sessions. After acquisition of follow-up TOF images, our registration method was used to determine the transformation between the baseline and follow-up patient orientations. This transformation was used to prescribe the imaging geometry for the follow-up black blood sequence.

Results: Figure 2 shows the unregistered black blood images. The yellow arrows on the difference image indicate the translational errors in repositioning. More subtle errors occur with out-of-plane rotation and translation. Figure 3 shows TOF images from baseline and registered follow-up. There is good alignment of the right main carotid, even while the soft tissue of the anterior neck is slightly out of alignment. After registration, the transformation obtained from the TOF images is used to prescribe the image geometry for the black blood sequence. In Figure 4, the left image is baseline, middle follow-up and right is difference, showing proper alignment of the vessel and misalignment of the soft tissue of the neck (white arrow). The slice position is at the level of the carotid sinus.

Discussion: This automatic method for registration of carotid arteries appears promising, and is planned for use in patients. Without this registration step, accurate repositioning of the slices is extremely difficult with highly anisotropic spatial resolution such as those in Figure 4 (0.47mm x 0.47mm x 4mm). As the prospective registration is rigid, a non-rigid registration post-processing step is planned to correct for tissue deformations.

Figure 1: *A multi-slice double inversion FSE pulse sequence averages 2 acquisitions, and reverses slice order on second acquisition (#2), thus canceling residual blood signal.*



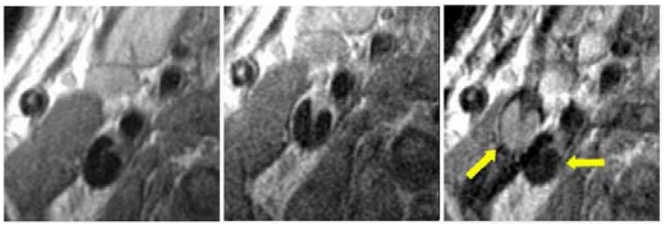


Figure 2: *Manual repositioning error. Left image is baseline, middle is follow-up, right is difference image. The differences are both in- and out- of-plane translation and rotations. Gray indicates good registration agreement, while black and white show misregistration in difference image*

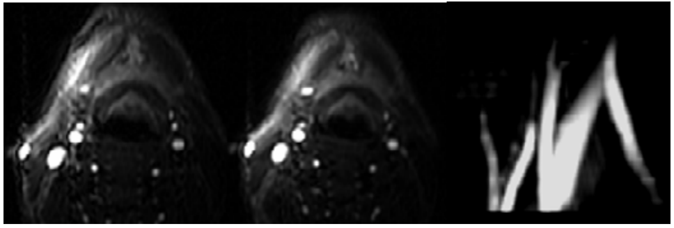


Figure 3: *Registered time of flight images. Left is baseline, middle is follow-up and right is MIP rendering. The registration algorithm matches the contrast arising from flow, largely ignoring low-contrast soft tissue.*

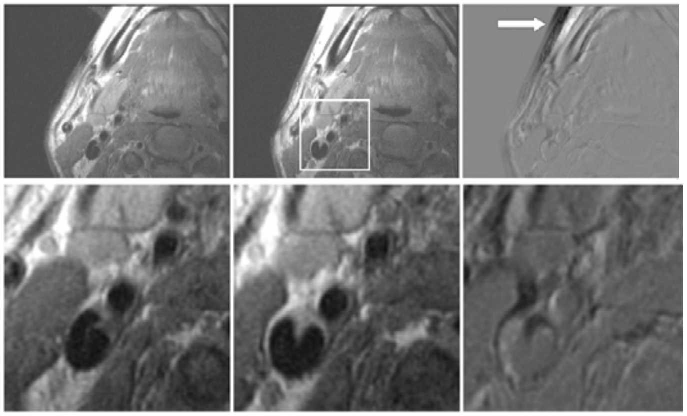


Figure 4: *Automated repositioning, shown for 1 of 6 slices. Left image is baseline, middle is follow-up, right is difference image. There is good agreement in the carotid region while soft tissue is mis-registered (white arrow). Bottom row is zoomed view.*

References: 1. Hancu I, et al., NMR in Biomed 2005;18 2. Ibanez L, ITK Software Guide, 2005. 3. Hardy CJ, et al., 12th ISMRM, 2004, p. 450.