Prospective motion correction of 3D GRASE PASL acquisitions with volume navigators

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Target audience: Clinicians and researchers interested in perfusion imaging with arterial spin labeling (ASL) in patient populations that tend to move during imaging.

Introduction: The use of 3D encoding in ASL results in higher SNR than conventional slice-by-slice methods. The potential impact of the method in the clinic, especially in evaluating stroke, is mitigated by its sensitivity to patient head motion due to (1) segmented k-space acquisition and (2) subtraction artifacts from successive acquisition of control and label images within the scan. We present an implementation of volumetric EPI-based navigators (vNavs) with 3D encoding [1] for real-time prospective motion correction in a 3D gradient and spin echo (GRASE) ASL sequence [2,3]. vNavs are ideally suited to this type of sequence, as they are 3D encoded with a small flip angle, therefore minimally impacting image contrast. They are inserted into the intrinsic gaps in the pulse sequence during the inversion delay time, therefore additional motion correction and characterization is achieved without increasing total acquisition time.

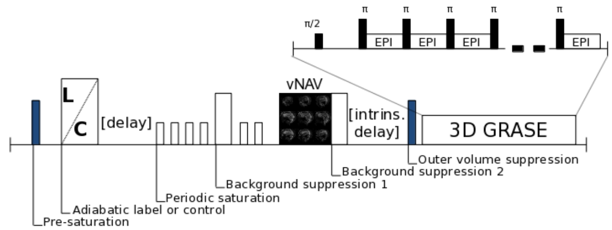

Figure 1: Schematic of the prospective motion corrected 3D GRASE PASL sequence.

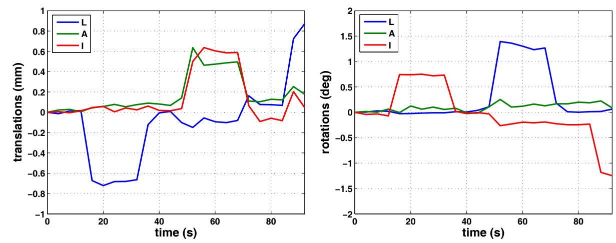

Figure 2: Detected/corrected rotation/translation parameters during acquisition with real-time prospective motion tracking.

Methods: A schematic of the 3D GRASE sequence with vNavs is shown in Figure 1. The navigator is inserted before the second background suppression pulse (BS2) which maintains the double inversion recovery timing required for nulling gray and white matter. The navigator volume is registered to the reference volume during the time immediately after the BS2 pulse so that the very next 3D GRASE volume and subsequent labeling and suppression pulses are corrected.

The technique was tested in a healthy human volunteer using a 3 T scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen) with a 32 channel head coil. Parameters for the sequence were: 3D segmented GRASE with pulsed ASL (PASL) preparation (FAIR Q2TIPS), TR 2 s, TI 2.4 s (gray/white suppression), bolus duration 700 ms, fat suppression, TE 17.9 ms, 64 x 64 matrix, FoV 210 ms (3.3^2 mm^2), 42 x 3 mm axial slices, BW 1628 Hz/px, T_{acq} 1:40 min:s. Parameters for embedded vNav: 3D EPI, TR 11 ms, TE 5 ms, 32 x 32 matrix, 32 sagittal slices, 6/8 partial Fourier partition encoding, 8^3 mm^3 voxels, BW 4734 Hz/px, T_{acq}/nav 275 ms.

The volunteer was imaged with the standard sequence without navigators and the modified sequence with navigators, with and without motion correction, in a stationary position and while deliberately moving.

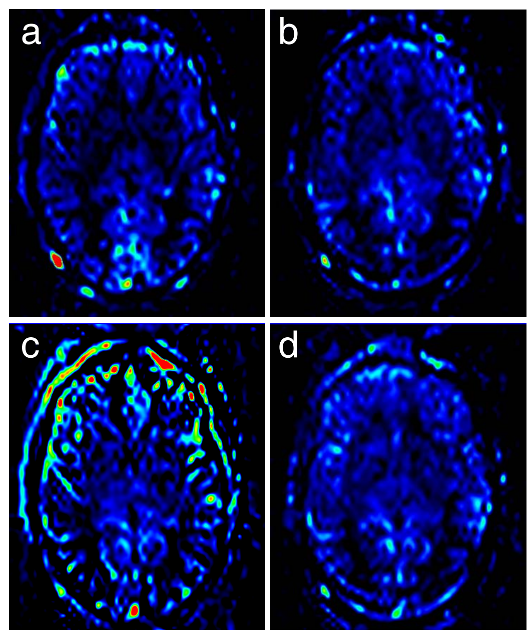

Figure 3: Perfusion weighted (FAIR Q II) images from 1:40 min:s 3D GRASE acquisitions. (a) standard sequence, no motion, (b) navigated sequence, no motion, no correction, (c) motion, no correction, (d) motion, correction. Slice (a) is oriented differently.

Results: Figure 2 shows detected rotation/translation parameters during the acquisition with motion tracking. Motion was qualitatively similar during all scans with motion measured using the navigators with or without correction. Figure 3 shows the perfusion weighted images for the standard sequence without motion, and navigated sequence with/without motion and correction.

Discussion: Results shown in Figure 3 (a, b) suggest embedded vNavs have a negligible effect on perfusion contrast. Figure 3c shows considerable damage to the perfusion map due to motion. Figure 3d shows recovered perfusion contrast in a scan with similar motion and motion correction.

Conclusion: Embedded vNavs are effective in suppressing artifacts caused by motion during 3D GRASE PASL acquisitions. Motion-corrected perfusion weighted images are generated on the scanner with no need for additional post-processing and motion tracking does not increase total acquisition time.

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References: [1] Tisdall et al., MRM 68:389-99, 2012. [2] Günther et al. MRM 54:491-8, 2005. [3] Luh et al., MRM 41:1246-54, 1999.