CASL Perfusion MRI of the Kidney using Real-time Tracking, Free Breathing Navigator

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Introduction: Magnetic resonance (MR) of the abdomen is challenging because of the significant physiologic motion (primarily from respiration and peristalsis) and the vulnerability of data acquisition to positional changes in the organs. Abdominal imaging is typically achieved using breathholds, respiratory-gating (e.g., using a bellows), or (retrospective or prospective) navigator-gating. However, breathholds are poorly suited for sick patients or high reproducibility. Respiratory-gating is significantly less accurate and stable than navigators. Conventional navigator-gating is highly effective in minimizing motion-related effects but is poorly suited for continuous arterial spin labeled (CASL) perfusion MRI. Unacceptable acquisition deadtimes result from the narrow navigator acceptance window required to minimize control/label subtraction errors and the long repeat times (typical TRs of 3-6 s) required by CASL. A real-time tracking, free-breathing navigator was integrated with CASL to minimize motion effects and acquisition deadtimes. The technique was successfully applied in renal perfusion MRI.

Materials and Methods: All experiments were conducted on University of Pittsburgh's 1.5 T GE whole-body MRI (LX91, Milwaukee, WI) interfaced with a custom real-time workstation for navigator processing [1]. A 2D excitation pulse was used to measure the S/I displacement of the diaphragm, scaled to reflect kidney motion. The kidney displacement was converted to a frequency offset for the image excitation so that the position of the image slice would shift along with the position of the kidney. With this technique, the kidney appears fixed between acquisitions while static tissues like the abdominal muscle and skeleton change.

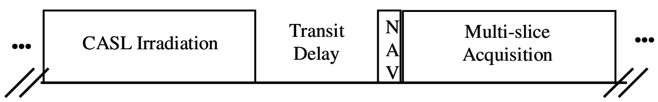

Figure 1: Multi-slice CASL sequence with real-time tracking navigator. The 2D navigator excitation, processing, and displacement frequency imaging offset occur within the transit delay period.

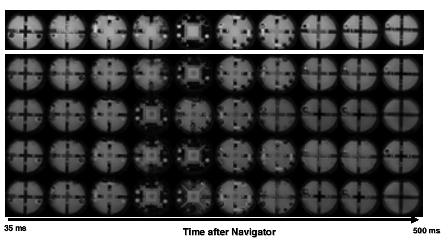

Figure 2: Initial results using real-time tracking navigator. The top row images were acquired without motion (10 slices, Flip: 90^0, TR: 1.5 s, TE: 8 ms, single-shot spiral, matrix 64x64). Periodic (sinusoidal) motion was created orthogonal to the axial image plane (10 mm amplitude at 10 mm/s) by rocking the patient table (bottom four rows). The first slice (acquired 35 ms after the navigator echo) appears fixed for all four time phases (leftmost column). The reproducibility of the slice positioning degrades with increasing time between the navigator and slice acquisition (from left to right with 45 ms/slice).

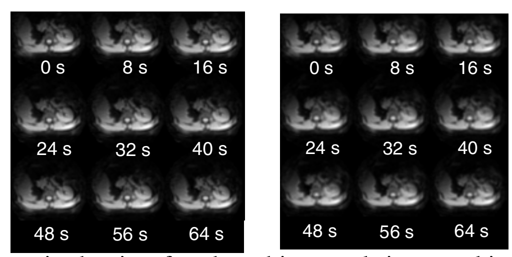

Figure 3: Axial image of left kidney from subject (right kidney was previously excised) showing improved reproducibility of kidney position with real-time tracking navigator correction (left set) versus without (right set). Neither acquisition used breathholds or acquisition gating. CASL with single-shot spiral acquisition was used with FOV: 32 cm; 64x64 matrix; linear surface receive coil; Thickness: 7 mm; Flip: 90^0; TE: 8 ms; 3.5 s labeling pulse train; and 8 s TR. Image times reflect the time elapsed from the start of sequence.

Figure 4: Renal perfusion (difference) maps acquired using free-breathing, real-time tracking navigator without acquisition gating at 1.5 T. The enhanced perfusion in the renal cortex versus the medulla is apparent. CASL perfusion was measured using simultaneous proximal and distal irradiation (SPDI) [2] using a single-shot spiral acquisition (parameters given in Fig. 3).

Results and Discussion: The real-time tracking navigator was shown to provide good motion compensation for 1-2 slices. Like conventional navigator techniques, the navigator displacement requires frequent updating (every ~100 ms) to provide accurate organ alignment required by CASL. The frequent updating restricts the number of slices that can be acquired during each TR and increases acquisition deadtime. We are developing predictive algorithms that will extend the useful lifetime of each navigator measurement, accurately predict the velocity (e.g., direction) of motion, and extend the motion compensation to permit a greater number of slices.

References: 1. Wang et. al., Radiology. 198(1): 55-60 (1996). 2. Talagala et. al., 6th ISMRM, Sydney 1998, p. 381.