Respiratory Gated Contrast Enhanced Imaging of the Liver

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Introduction. Dynamic contrast enhanced liver MRI is used to determine to blood supply to any liver lesion in order to detect and characterize that lesion. Current clinical protocols rely on repeated breath-holds, which limit spatial and temporal resolution and lead to decreased image quality in a substantial part of the patient population that is unable to sustain breath-holding. An imaging method which allows both free-breathing acquisitions as well as high spatial resolution is presented to overcome these problems.

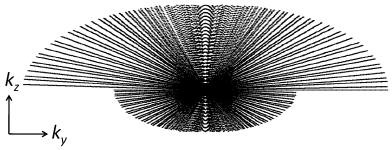

Fig 1 Radial sampling in $k_y k_z$ plane (normal frequency readout along k_x)

Materials and methods. A hybrid Cartesian-radial sampling technique [1] (Fig 1) was combined with retrospective motion correction [2] using a simultaneously respiratory bellows signal. The hybrid Cartesian-radial sampling technique maintains the linear frequency readout (k_x) but samples the $k_y k_z$ plane along a radial trajectory that takes into account the different FOV and resolution for the Y and Z directions. A golden ratio view order [3] was adapted to this non-uniform FOV and resolution in the Y-Z plane [1]. Seven healthy volunteers (5 male, 2 female, age 29±5 years) underwent an injection with 20cc of Gadolinium (Magnevist, Berlex). 5 minutes post injection, two fat suppressed 3D gradient echo acquisitions were performed in random order: 1) a 36s breath-hold (60 projections), and 2) a 3m25s free-breathing acquisition (350 projections, compared to 180 to satisfy Nyquist sampling). Other parameters: 384x384x48 matrix reconstructed to 512x512x96, FOV 34 cm, 4mm slice thickness, TR/TE 4.2/2.0 ms, BW ±90.91 kHz. Both acquisitions were reconstructed using non-Cartesian SENSE [4] and all images were scored for the presence of blurring and streaking artifacts using 4 point scale: 1) non diagnostic, 2) significant artifacts 3) moderate artifacts, and 4) no apparent artifacts. To validate the use of the bellows for respiratory gating, the sequence was modified to sample a low-resolution (384 (SI) x 6 (AP)) sagittal slab without RL encoding, with one phase encoding (in the AP direction) acquired immediately before each fat saturation pulse (Fig 2). The pulse sequence cycled through the phase encodings throughout the scan. All other pulse sequence elements such as RF pulse remained unchanged such that the acquisition of the low resolution images did not interfere with the steady state. The middle image column (corresponding to a coronal plane approximately intersecting the right hemi-diaphragm) was selected for displacement tracking (slab navigator or SlabNav) and correlated against the simultaneously acquired bellows signal.

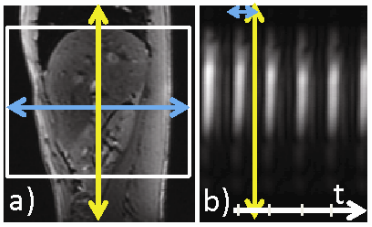

Fig 2. Slab Navigator with SI readout and low resolution AP encoding simultaneously acquired with imaging

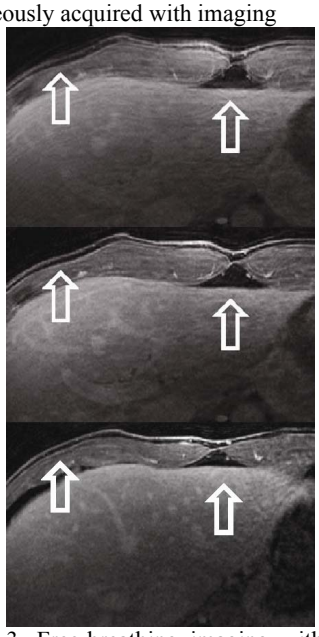
Fig 3. Free-breathing imaging without (a) and with (b) motion correction. Blurring artifacts in (a) are removed in (b). The breath-hold is shown in (c)

Results and Discussion. Diagnostic images were obtained in all subjects. Average image score for the free-breathing respiratory gated acquisition was 3.6±0.5 versus 3±0.8 for the breath-hold scan, with higher scores in 4, equal in 2, and worse in 1. When the free-breathing acquisition was reconstructed without motion correction, the average image score was 3.3±0.8. The breath-hold acquisition likely suffered from undersampling artifacts in the larger subjects. For the free-breathing acquisitions, motion correction was found to improve image quality in 2 subjects (Fig 3) with no improvement in image score for the rest. This demonstrates the motion robustness of the sampling technique, where motion correction serves to improve the consistency of the motion artifact suppression. The slab navigator time series had a 480ms temporal resolution. The tracked displacement had good correlation (r^2=0.75) with the bellows signal (Fig 4). Retrospective motion correction using the SlabNav signal produced similar motion artifact suppression (Fig 5)

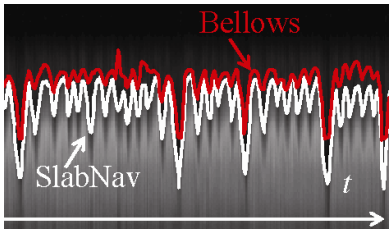

Fig 4 Comparison of bellows and slab navigator (r^2=0.75)

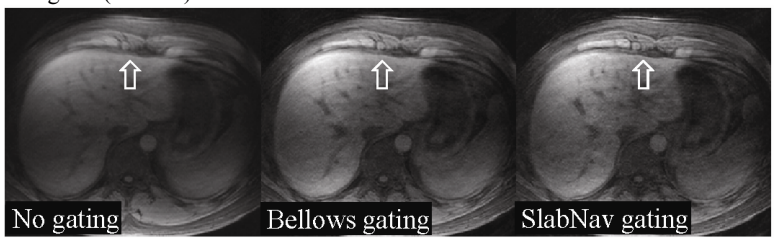

Fig 5. Comparison of bellows (middle)and SlabNav (right)respiratory gating for free breathing contrast enhanced liver imaging with reconstruction without respiratory gating (left)

Conclusion. These preliminary data show the feasibility of performing free breathing high resolution 3D contrast enhanced liver imaging.

References [1] Spincemaille, P, ISMRM 2010 p2899 [2] Thompson RB, MRM 2006 56(6):1301 [3] Winkelmann S et al., IEEE TMI 2007;26(1):68 [4] Pruessmann KP et al. Magn Reson Med 2001;46(4):638