

### 3D Renal BOLD Imaging with a Prospectively Navigated Free Breathing Pulse Sequence

Glen Morrell<sup>1</sup>, Jeff L Zhang<sup>1</sup>, Josh Kaggie<sup>1</sup>, and Vivian S Lee<sup>1</sup>

<sup>1</sup>Utah Center for Advanced Imaging Research, University of Utah, Salt Lake City, Utah, United States

#### Target Audience: Investigators and researchers using BOLD imaging to study renal function and disease

**Introduction:** We have previously demonstrated a free-breathing prospectively navigated pulse sequence for improved renal BOLD imaging (1). By extending the possible imaging time beyond a single breath hold, this sequence allows flexible tradeoff of imaging time with signal to noise ratio (SNR), spatial resolution, and extent of coverage of the kidneys. Here we demonstrate that this sequence can perform renal BOLD imaging over the entire 3D volume of the kidney in a reasonable imaging time and < 2mm voxels.

**Methods:** The prospectively navigated sequence uses navigators to define "bins" corresponding to different points in the respiratory cycle. A separate k-space is accumulated for each navigator bin. Navigators are analyzed in real-time and the corresponding bin is examined to see what k-space line should be acquired next for centric k-space ordering. This information is fed back in real-time to the running sequence, which then acquires that phase-encode step. The sequence finishes when one bin has a full k-space. Desired navigation efficiency (i.e. fraction of acquired data that appears in the final image) is set by the user, and the sequence dynamically calibrates the discrimination threshold for bin assignment throughout the duration of the scan to meet this desired efficiency. A set of motion-free images corresponding to six different echo times is reconstructed from the full k-space bin. For full 3D coverage of the kidney, the following sequence parameters were used: 256 x 256 x 32 matrix size, 1.1 x 1.1 x 2.0 mm resolution, TE 5, 11, 17, 23, 29, 35 msec, TR = 95 msec, parallel imaging with GRAPPA reduction factor = 4, navigation efficiency = 25%, fat saturation.

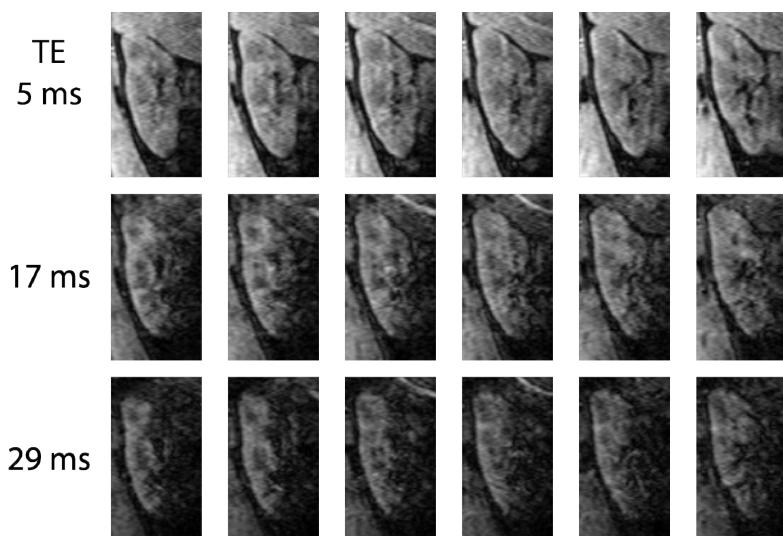


Figure 1: Six successive sagittal slices from a 32-slice full 3D renal BOLD kidney study. Three of the six acquired echo times are shown. Image resolution is 1.1 x 1.1 x 2.0 mm, total imaging time 10 min.

an entire imaging slice without manually defined ROIs (2,3). However, Saad *et al.* recently showed that even with a whole-slice method of renal BOLD analysis, results varied widely for different slices spaced closely in the kidney. Full 3D coverage of the kidney with our renal BOLD sequence removes the variability of 2D BOLD results caused by selection of a particular slice.

**Conclusion:** Our sequence makes full 3D renal BOLD possible in reasonable imaging time. Future refinements include segmented echo-planar readout with reduced number of echo times and 2D selective excitation to limit the imaging field of view to further reduce the required imaging time and to eliminate motion artifacts from structures outside the kidney.

**References:** 1). Morrell G *et al.*, Prospectively navigated multi-echo GRE sequence for improved 2D BOLD imaging of the kidneys. 21st Meeting ISMRM. Salt Lake City 2013. p 1569. 2). Ebrahimi B *et al.*, Compartmental analysis of renal BOLD MRI data: introduction and validation. Invest Radiol 2012;47(3):175-182. 3). Saad A *et al.*, Human Renovascular Disease: Estimating Fractional Tissue Hypoxia to Analyze Blood Oxygen Level-dependent MR. Radiology 2013;268(3):770-778.

#### Advantages of full kidney 3D renal BOLD acquisition:

- Improved SNR relative to 2D.
- Elimination of bias and error in BOLD data analysis caused by selection of slice or regions of interest
- Correction of T2\* for B0 inhomogeneity