Full 3D Renal BOLD MRI in Clinically Realistic Scan Times with 2D Volume Selective Excitation

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Target Audience: Investigators and clinicians interested in BOLD MRI of the kidneys

Introduction: Renal BOLD MRI has the potential to non-invasively depict renal hypoxia, a key factor in the progression of chronic kidney disease. However, published renal BOLD results are highly contradictory, likely because of limitations in MRI technique and data analysis. Renal BOLD is conventionally performed in a single breath hold, limiting imaging to a single 2D slice. Most published renal BOLD data are based on manual segmentation of cortex and medulla on a single 2D BOLD image, which introduces large potential bias. To provide more meaningful quantitative analysis of BOLD data, some researchers have attempted to define whole-kidney measures of hypoxia not requiring manual image segmentation, but have found that a single 2D image poorly represents the varied distribution of oxygenation throughout renal cortex and medulla (1). Full 3D coverage of the kidney is essential to eliminate the sampling bias inherent in the use of a single 2D image for analysis. Prospective respiratory navigation can extend imaging time beyond a single breath hold to obtain BOLD T2* maps with full 3D coverage of the kidney (2), but requires scan times in the order of 5 minutes for each kidney. 2D volume-selective excitation (2DVSE) can dramatically reduce the scan time required for full 3D renal BOLD. Using 2DVSE, we have achieved full 3D high-resolution BOLD imaging of a single kidney in just over 1 ½ minutes, a 2.8x reduction in scan time compared to conventional slab-selective excitation. This innovation opens the door to full 3D bilateral kidney coverage in a clinically realistic scan time, which may dramatically improve the usefulness of renal BOLD MRI clinically and as a research tool.

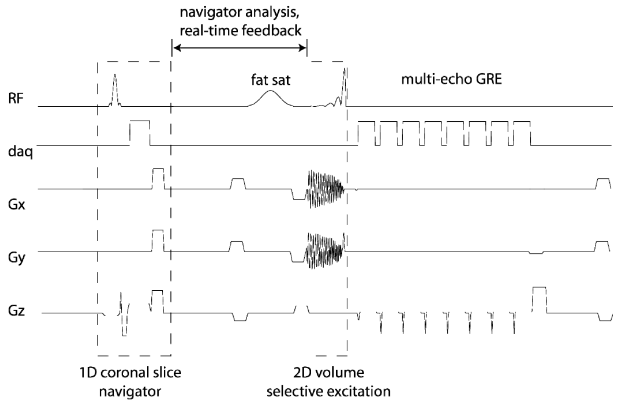

Figure 1: Pulse sequence diagram for 2DVSE renal BOLD sequence with prospective navigation.

Methods and Results: For 2DVSE, a thin slab sagittal navigator at the beginning of each TR is analyzed in real-time with feedback to the sequence to acquire the appropriate next phase-encode step based on the phase of the respiratory cycle (see pulse sequence diagram in Figure 1). Excitation is performed with an 8ms 2DVSE pulse based on a spiral excitation k-space that excites a 10 cm diameter cylinder with location and orientation prescribed by the operator along the major axis of the kidney. Data is acquired with a 3D multi-echo GRE with the frequency direction along the major axis of the kidney. Example source images and T2* maps from a 3D renal BOLD study of a normal subject with conventional slab-selective excitation and the new 2DVSE method are shown in Figure 2. The conventional excitation has a FOV of 240 x 120 x 80 mm, total imaging time of 4:39, compared to a FOV of 75 x 120 x 80 mm and imaging time of 1:41 for the 2DVSE method. Other sequence parameters are identical, including 1.9 x 1.9 x 2.0 mm resolution, FA = 25, TE = (5, 10, 15, 20, 25, 30 msec), ¾ partial k-space in phase encode and slice direction, GRAPPA with r=2, and navigation efficiency of 62–66%.

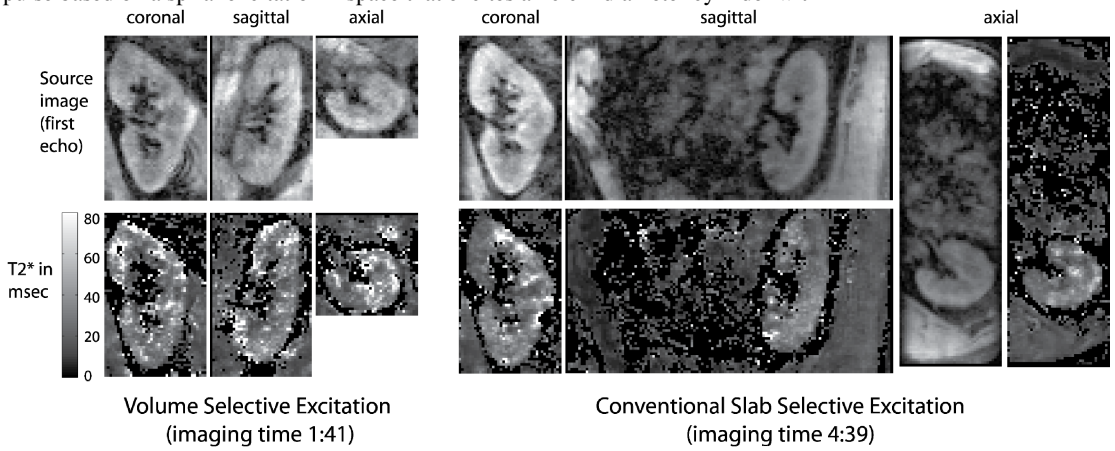

Figure 2: 2DVSE vs. conventional slab-selective excitation. Central planes from a full 3D renal BOLD scan are shown. Images are not cropped and reflect actual FOV. 2DVSE allows imaging over a smaller FOV, decreasing scan time by a factor of 2.8.

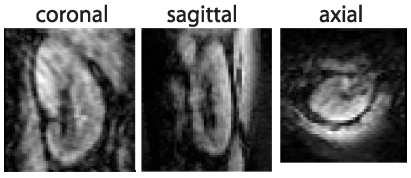

Figure 3: 2DVSE 3D BOLD source images with slightly larger acquisition FOV show the cylindrical shape of the excitation profile created by the 2DVSE pulse, including the kidney but excluding most of the rest of the abdomen.

Discussion: The use of a 2DVSE pulse dramatically reduces the field of view in one phase encoding dimension, thereby decreasing the total required imaging time. With conventional slab selective 3D imaging, the fastest coverage of a single kidney is with a sagittal slab with frequency encoding in the head-to-foot direction and phase encoding side-to-side and anterior-posterior, as in Figure 2. With the 2DVSE pulse, the anterior-posterior extent of the FOV is reduced, resulting in a 2.8x decrease in imaging time.

Conclusion: 2DVSE reduces imaging time and makes full 3D BOLD imaging possible in clinically realistic imaging times on the order of 90 secs.

References: 1). Morrell G *et al.,* 21st Meeting ISMRM. Salt Lake City 2013. p 1569. **2).** Saad A *et al., Radiology* 2013;268(3):770-778

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