Prospectively navigated multi-echo GRE sequence for improved 2D BOLD imaging of the kidneys

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Introduction: Renal hypoxia is thought to be a major factor in the development of chronic kidney disease (CKD) and end stage renal disease. Renal BOLD imaging is a method of measuring renal hypoxia by estimating T2*. Published renal BOLD data show ambiguous and contradictory results, possibly due to limitations in the underlying MR imaging. Because the kidneys move with respiration, published renal BOLD data have been limited to multi echo GRE performed during a single breath hold, which gives poor resolution and signal to noise ratio (SNR). We have implemented a multi echo GRE sequence with prospective navigation which allows motion artifact-free imaging over an arbitrarily long period of free breathing. Image time can be flexibly traded off for resolution and SNR. This method gives T2* maps of the kidneys with excellent resolution and SNR.

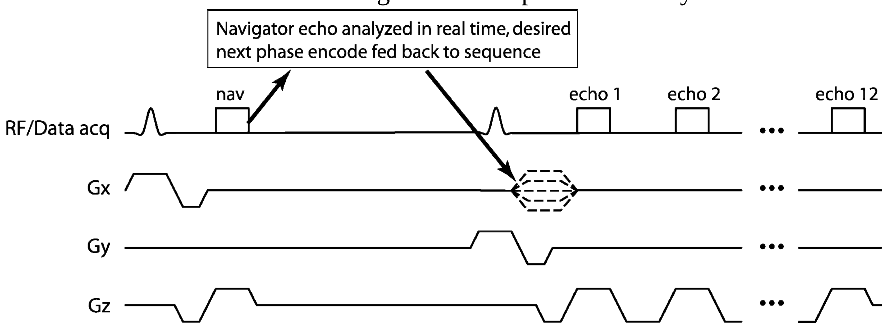

Figure 1: Pulse sequence diagram.

Methods: The prospectively navigated sequence sequence (Figure 1) runs with constant sequence repetition time (TR). A one-dimensional navigator echo is acquired at the beginning of each TR, typically prescribed in a sagittal plane intersecting the right hemidiaphragm. Navigators are used to define "bins" corresponding to different points in the respiratory cycle. A separate k-space with twelve images corresponding to different echo times is accumulated for each navigator bin. Navigators are analyzed in real-time immediately after being acquired. If a navigator is sufficiently similar to the navigator defining an existing k-space bin, the data from the current TR are assigned to that k-space bin. If the navigator is not sufficiently similar to any of the navigators defining existing bins, it defines a new bin. The selected bin is examined to see what k-space line should be acquired next, and this information is fed back in real-time to the running sequence, which then acquires that phase encode step. In our current implementation, k-space is filled centrically. The sequence finishes when one bin has a full k-space. A set of motion-free images corresponding to twelve different echo times is reconstructed from the full k-space bin. T2* estimation is performed by non-linear fitting of signal intensity from the twelve images to a monoexponential decay for each pixel. To date we have used the sequence in an IRB-approved protocol on a few subjects.

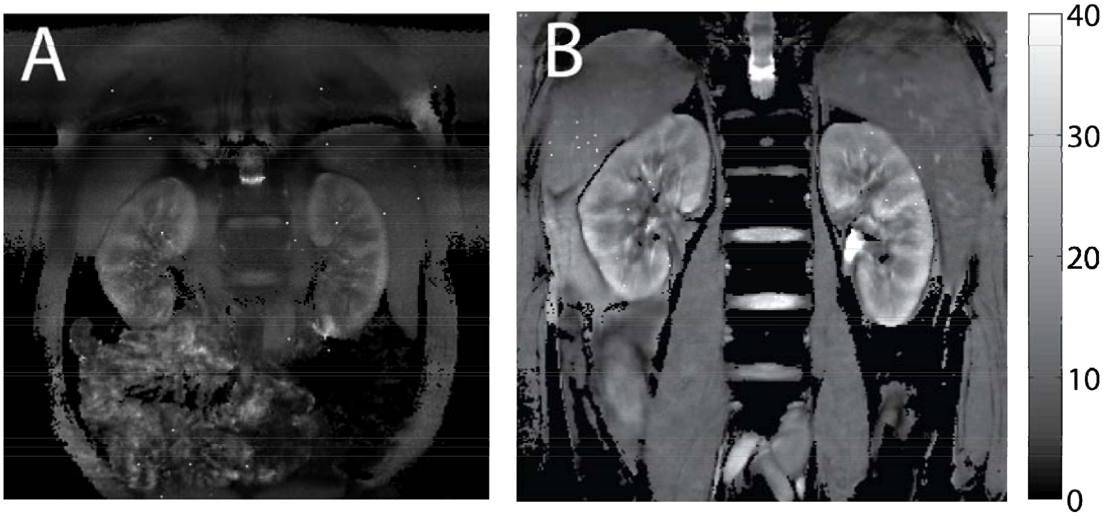

Figure 2: A) Typical T2* map with conventional 20 second breath hold scan (matrix size 256 x 256, FOV 32 x 32 cm). **B)** T2* map with free-breathing prospectively navigated sequence, 10 minute imaging time (matrix size 512 x 512, FOV 50 x 50 cm, 4 signal averages). Units are msec.

Results: Figure 2 shows a renal T2* map formed from a conventional 20 second breath-hold scan (panel A) and T2* map formed with the new sequence with free-breathing (panel B). SNR and resolution of the free-breathing scan are much greater than the conventional breath hold scan.

Discussion: Prospective navigation with real-time feedback has been used previously to reduce motion artifact, mostly in cardiac imaging (1-4). This technique has not been previously applied to a specific abdominal imaging scenario such as renal BOLD imaging. The free tradeoff of imaging time for resolution and SNR possible with our sequence can give renal BOLD T2* maps of unprecedented resolution and SNR, which will help to better evaluate renal BOLD as a potential tool to follow the course of CKD.

References: **1.** Sachs TS *et al., Magn Reson Med* 1995; 34(3):412-422. **2.** Wang Y *et al., Radiology* 1996;198(1):55-60. **3.** Oshinski JN *et al., Radiology* 1996; 201(3):737-743. **4.** Jhooti P *et al., Magn Reson Med* 2010;64(4):1015-1026.