An inversion recovery phase-contrast EPI scan for rapid simultaneous encoding of velocity and T_1 data for the single kidney glumerular filtration rate

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Introduction Current techniques do not allow simultaneous acquisition of velocity and T_1 data in a single rapid MRI scan. These parameters which are needed to determine the single kidney glumerular filtration rate using MRI require separate independent scans.[1, 2] This study offers a new pulse sequence approach that solves this and reveals a trend that relates T_1 to velocity.

Methods A conventional inversion recovery EPI pulse sequence was modified to build the new technique. The modification included adding a new control variable at the user interface that executes blocks of new and sophisticated codes to enable through-plane phase contrast velocity sensitivity. In doing so, a triple-lope flow encoding gradient waveform gets added to the slice select direction of the EPI pulse sequence portion of the scan. These codes were from a phase-contrast gradient recalled echo pulse sequence used for flow imaging. The design involved a process of identification, isolation, and merging of these foreign codes into the main design, and multiple simulation trials. Additionally, a new loop was added to the design that repeats the scan twice to encode two sets of data, with a slightly changed triple-lope flow waveform, consistent with the theory of phase-contrast imaging in 1D. A difference in their waveforms contrasts their first-moments and velocity phase shifts, and therefore subtracts out systematic phase errors. The final pulse sequence design was built and simulated on a SGI Indigo2 workstation and the executable files were transferred to a 1.5-T MR imaging system (Signa; GE Medical Systems, Milwaukee, WI) for testing. To test the technique, a phantom experiment was designed that consisted of a peristaltic pump, a solution of $MnCl_2$, and 12.7mm ID Tygon tubing that formed a closed circuit. The pump was set to generate flow at a continuous steady rate that is roughly close to the mean flow within the normal human renal artery, at 667 ml/min. This corresponds to a mean velocity of 8.7cm/s with the 12.7mm ID tube used. Also, a fast spin echo scan of the solution in stationary state determined that the solution has a T_1 of around 900ms. Furthermore, three vials containing stationary fluids were placed around the tube for background zero velocity subtraction. The scan generated magnitude, real, and imaginary images, and the velocity images were reconstructed from the last two. The tasks of image interpolation and reconstruction, iterative threshold-based ROI detection and analysis, and velocity and T_1 estimation were done by a MATLAB script made for the purpose.

Results and Conclusions The results demonstrate a strong tendency for velocity to stabilize towards the reference value (8.7 cm/s) at the highest signal levels during the plateau periods of the signal recovery curves. This repetition of reliable velocity samples allow for a dynamic assessment of this parameter and consequently of the renal glumerular filtration rate. Furthermore, T_1 was slightly underestimated (by 27%) which is likely to occur because of the signal loss that relates to flow induced phase shifts that the signal equation now accounts for. Figure 1 illustrates the velocity and signal recovery waveforms with a numerical sample of a fitted T_1 estimate. These findings show promise for the use of the technique for the dynamic clinical evaluation of the renal glumerular filtration rate in comfortable breath-hold scan durations.

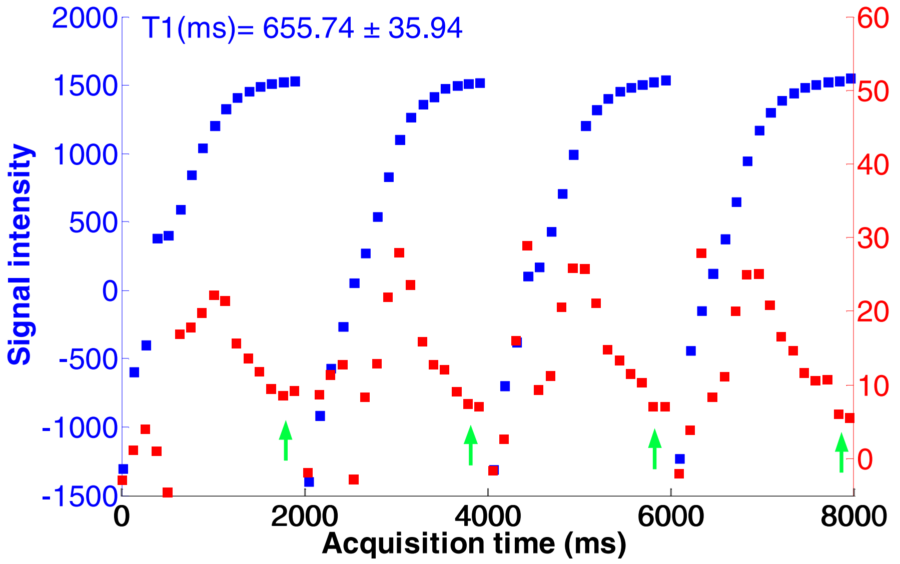

***Fig. 1**: The signal and velocity waveforms for four signal recovery passes. The arrows point toward areas where reliable velocity samples are observed. The scan parameters used are: TR=2000ms, IT=17ms, TE=MinFull, FA=90°, VENC=100ms, Matrix=64x128, FOV=20cm, Slice thickness=7mm, and total scan time < Breath-hold.*

References

1. Dumoulin CL, et al. *Magn Reson Med* 32:370-378, 1994
2. Niendorf ER, et al. *Radiology* 206:791-798, 1998