Preliminary Evaluation of 3D mGRE Sequence for Renal BOLD MRI at 3.0 T

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INTRODUCTION

BOLD MRI applied to the kidney has been shown to be useful in functional evaluation in both health [*Kidney Int*. 1999; 55:294-8] and disease [Diabetes Care. 2002; 25:575-8]. To-date all such evaluations in humans have either been carried using single shot echo planar techniques [*Circulation*. 1996; 94:3271-5] or 2D breath-hold multiple gradient echo (mGRE) techniques [*J Magn Reson Imaging*. 1997; 7:1163-5]. The 2D mGRE technique while quite efficacious in terms of R_2* mapping, it necessitates multiple acquisitions to achieve spatial coverage. Availability of 3D mGRE techniques would be beneficial for faster spatial coverage especially in a clinical setting where BOLD MRI may be one of many anatomical or functional sequences. In this study, we have evaluated a 3D implementation based on spoiled gradient echo sequence to acquire 10 to 12 slices within a single breath hold interval.

METHODS

These studies were performed on a short bore 3.0 T Twin Speed scanner with Excite technology (General Electric Medical Systems, Milwaukee, WI) using a 3D mGRE sequence with 8 echoes (TR/TE/Flip Angle/BW/slice/Matrix = 25.5 ms/1.86-22.9 ms/10°/83.3 kHz/5 mm/256x160 and 36 to 42 cm FOV with 80% phase FOV). The sequence also employed 70% under-sampling along slice direction and either 12 (axial) or 10 (coronal) slices were prescribed. The choice of echo times were consistent with known values of T_2* in the renal medulla (~25 ms) [*J Magn Reson Imaging*. 2004; 20:901-4]. For comparison, data was acquired with a 2D mGRE sequence with 8 echoes (TR/TE/Flip Angle/BW/slice/Matrix= 35 ms/7.59-23.4 ms/20°/62.5 kHz/5 mm/256x160 and 36 to 42 cm FOV with 80% (coronal) phase FOV) was used to obtain 4 matched slices in a single breath-hold of 19 s. We also acquired data using the current standard prescription at our laboratory, *i.e*. a 2D mGRE sequence with 16 echoes (TR/TE/Flip Angle/BW/slice/Matrix= 60 ms/7.59-41.4 ms/30°/62.5 kHz/5 mm/256x256 and 36 to 42 cm FOV with 80% phase FOV) to acquire 4 matched slices with 1 slice per 13 s breath-hold.

R_2* maps were constructed on an AW workstation (General Electric Medical Systems, Milwaukee, WI) using FUNCTOOL by fitting a single exponential function to the signal intensity *vs.* echo time data. An 8 element-coil array was utilized for signal reception. The studies were performed in 5 healthy male subjects (mean age 33.6 ± 7.0 years) who gave informed consent on a protocol approved by the Institution Review Board. In one subject data was also acquired pre- and post-furosemide administration (20 mg *i.v*.) on a different day.

RESULTS

Figure 1 shows representative anatomical images and corresponding R_2 * maps obtained for each of the 6 acquired slices when using a 3D mGRE sequence on a healthy subject. Table 1 is a summary of R_2* values calculated with each of the three different acquisitions. There was very good agreement between measurements between different techniques. When comparing the R_2* values obtained by the 3D sequence with either 2D R_2* prescriptions the differences did not reach a statistical significance in the renal medulla, while there was a significant difference observed in the cortex but the magnitude of difference was small.

Figure 2 shows one representative slice of the 6 acquired pre- and post-furosemide. Consistent with our previous reports we see the medullary R_2* approaches that of the cortex post-furosemide.

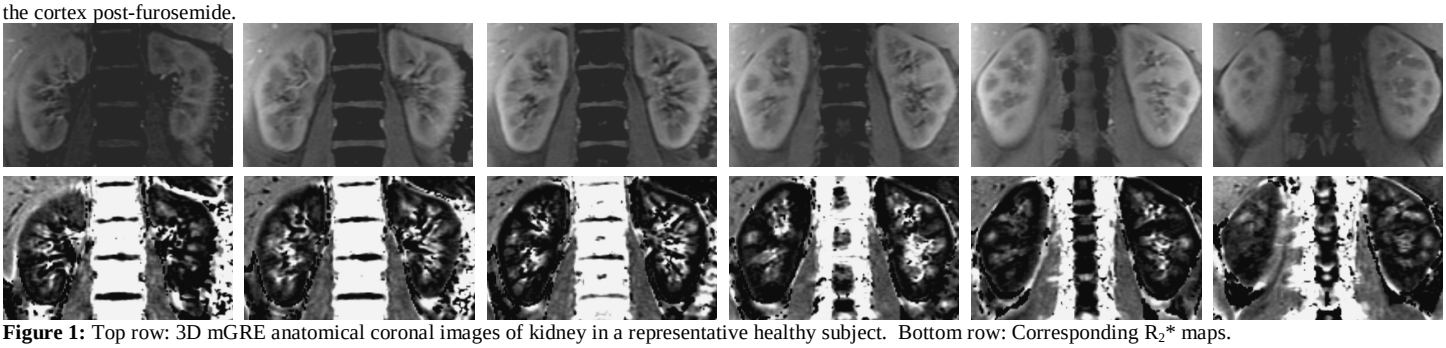

Figure 1: Top row: 3D mGRE anatomical coronal images of kidney in a representative healthy subject. Bottom row: Corresponding R_2* maps.

Table 1: Comparison of R_2* values between 3D and 2D mGRE sequences. Shown are mean ± std.dev. for cortex and medulla over all subjects. A single mean value for each subject was obtained by placing at least one pair of ROIs (cortex and medulla) in each slice acquired.

	Cortex R_2* (s^{-1})	Medulla R_2* (s^{-1})
3D (8 echoes)	18.5 ± 2.6	37.7 ± 3.8
2D (8 echoes)	20.5 ± 2.9 †	36.6 ± 3.0
2D (16 echoes)	22.0 ± 3.1 †	36.7 ± 2.2

† implies $p<0.05$ by paired two tailed T-test when compared to 3D mGRE.

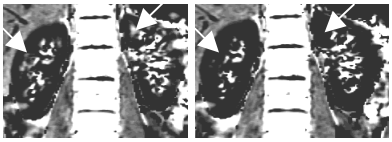

Figure 2: R_2* maps obtained pre- and post-furosemide.

DISCUSSION

Preliminary data presented here clearly support the feasibility of a 3D mGRE sequence for intra-renal oxygenation measurements by BOLD MRI. The image quality and R_2* quantitation are comparable to the 2D mGRE technique. To account for potential differences in measured R_2* values with voxel size [*Proc. ISMRM* 2004; 562], we performed a three way comparison. The 2D mGRE sequence was performed with 2 different prescriptions. One was the standard of practice at our laboratory (16 echoes and 256x256 matrix size). The other was with comparable voxel size to the 3D prescription and using only 8 echoes. While the magnitude differences in R_2* values between any two acquisitions were small, the differences in cortical values were found to be statistically significant. The effect of furosemide evaluated in one subject showed similar response to what has been reported earlier.

The 3D implementation should be useful in significantly improving the temporal resolution of BOLD MRI in the kidney without sacrificing spatial coverage. This could be of special interest when evaluating novel pharmacological maneuvers such as NOS inhibitors which are typically administered as continuous infusions [*Proc. ISMRM* 2004; 565]. The availability of 3D mGRE would particularly impact the potential clinical applications such as in the evaluation of renal transplants [*Proc. ISMRM* 2004; 882], and renal artery stenosis [*Kidney Int*. 2004; 65:944-50] where spatial coverage cannot be compromised. 3D implementation should allow for thinner slices when and where necessary.

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