Blood-oxygen level dependent (BOLD) imaging in Native and Transplanted Kidneys on 1.5T and 3.0T

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Introduction: Functional magnetic resonance imaging (fMRI) of the kidney can measure the filtration ability of the kidney, as well as regional blood flow and intrarenal oxygen bioavailability [1-3]. The reproducibility of these functional parameters is an active area of research. Blood-oxygen level dependent (BOLD) imaging can evaluate regional changes of oxygen bioavailability in the cortex and medulla separately. With the increasing commercial availability of 3.0T scanners and the potential advantage of increased signal to noise ratio and spatial resolution, our group evaluated the reproducibility and feasibility of MR blood-oxygen level dependent (BOLD) measurements in kidneys on 1.5T as well as 3.0T in native and transplanted kidneys.

Methods: The reproducibility study included nine subjects (6 females, 3 males; age range, 32-65 years, mean age 49.7±11.9 yrs) with normal functioning native kidneys as assessed by serum creatinine and estimated glomerular filtration rate (eGFR) and eight transplanted kidney subjects (3 females, 9 males; 21-66 years, mean age 50±15). MR BOLD imaging was performed on a 1.5 T MRI scanner (Signa HDx, GE Healthcare, Waukesha, WI, USA) and a 3.0T MRI scanner (Signa HDx, GE Healthcare, Waukesha, WI, USA) for each subject using an 8-channel cardiac coil on the same day approximately 1 hour apart after withholding fluids for four hours and undergoing a blood and urine exam before each study. Each subject also underwent fMRI of the kidney at both field strengths on 2 different days: Day 1 and Day 2 (time interval 1-56 days, mean 14.2±19.5 days). MR BOLD sequence parameters used at 1.5T (TR = 87ms, TE = 7-42ms, 256x128, slice thickness = 5mm, NEX = 1) and 3.0T (TR = 87ms, TE = 7.3-27.7ms, 192x128, slice thickness = 4.5mm, NEX = 1) remained the same on both the days to assess reproducibility. There were three slices prescribed in the coronal plane to the kidney. Additionally two BOLD acquisitions were obtained on each day at 1.5T to test for the same day BOLD reproducibility. R2* color maps were generated and multiple ROIs were placed in the cortex and medulla of each kidney on all three slices to record the R2* values using Functool® on the Advantage workstation (GE Healthcare, Waukesha WI). Adequate ROI placement was considered as 5 or more ROI's for medulla and 3 for cortex. Mean cortical R2* values were obtained by averaging values from all ROIs in the cortex and mean medullary R2* were obtained by averaging values from all ROIs in the medulla. To test reproducibility of BOLD imaging, coefficient of variation within and between subjects were calculated for cortical and medullary R2* values obtained from both 1.5T and 3.0T.

Table 1

Coefficient of Variation	1.5T R2* (1/second)				3.0T R2* (1/second)			
Within subjects	Medulla		Cortex		Medulla		Cortex	
	Right	Left	Right	Left	Right	Left	Right	Left
	4%	4%	4%	4%	3%	5%	5%	5%
Between Subjects	7%	7%	6%	6%	13%	7%	11%	6%

Table 1: Demonstrating reproducibility of R2* values obtained on BOLD imaging at 1.5T and 3.0T in normal native kidney subjects.

Results: For normal natives, at 1.5T, the average R2* value for cortex was 12.12 sec^{-1} ±0.84 and 19.95 sec^{-1} ±1.43 for medulla while the R2* value at 3.0T for cortex was 18.36 sec^{-1} ±1.21 and 30.39 sec^{-1} ±3.62 for medulla . Data on 1.5T could be processed successfully in all but one subject for the right kidney due to susceptibility artifact from bowel. At 3.0T BOLD data could be adequately processed on seven subjects for both days, while it could not be processed for Right kidney on day1 in one subject and on either of the kidneys on day 1 in other subject due to dephasing from the air in the lung and susceptibility artifacts from bowel. Later subject was the same one that also showed bowel artifact at 1.5T. The coefficient of variation (CV) for R2* values obtained at 1.5T and 3.0T within a single subject and between subjects in normal natives are given in Table 1.

Out of the twelve subjects with kidney transplants, 8 subjects completed scanning on both days on 3.0T while 4 subjects completed one of the two days. The 3T data could be successfully processed in only 5 of the 12 subjects. In the remaining subjects (>50%), an adequate number of ROIs could not be placed due to susceptibility artifact from bowel gas as well as motion of the transplant in the iliac fossa (Figure 1). In previously published experience with BOLD processing in 30 transplanted kidneys imaged at 1.5T, adequate data was obtained in all cases [4-5].

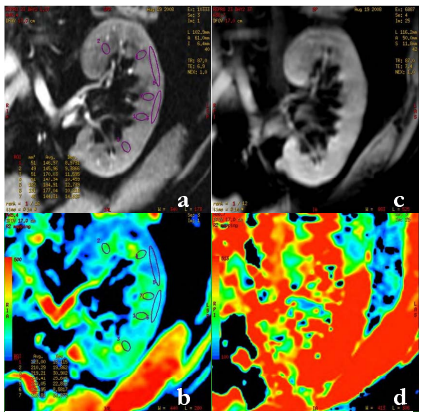

Figure 1.Grey scale images at first TE on 1.5T(a) and 3.0T(c) and corresponding R2* maps of transplanted kidney showing adequate ROI placement at 1.5T (a), no ROI could be placed at 3.0T (b) due to artifact affecting the whole kidney.

Conclusion: For normal native kidneys, BOLD MR imaging at 3.0T had a comparable reproducibility to 1.5T within the same subject while reproducibility between subjects showed a higher variation for medullary R2* values on 3.0T compared to 1.5T. However, initial experience in processing of BOLD images at 3.0T in transplanted kidneys has been challenging and is prone to a significant amount of susceptibility and motion artifact possibly limiting the utility of 3.0T assessment of transplant subjects using present methods.

References: [1] Rusinek H, Kaur M, Lee VS. Curr Opin Nephrol Hypertens. 2004 Nov;13(6):667-73. Review, [2] Prasad PV. Am J Physiol Renal Physiol. 2006 May;290(5):F958-74. Review, [3] Li LP, Halter S, Prasad PV. Magn Reson Imaging Clin N Am. 2008 Nov;16(4):613-625. Review, [4]Sadowski EA, Fain SB, Sara AK et al. Radiology. 2005 Sep;236(3):911-9, [5]Djamali A, Sadowski EA, Muehrer RJ, et al Am J Physiol Renal Physiol 2007;292(2):F513-22.