Functional MRI Assessment of Renal Fibrosis in Rat Models

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Introduction

Renal fibrosis is a common consequence of chronic kidney diseases which affects a large population. Therefore, it is important to establish imaging based noninvasive biomarkers to monitor the progression or regression of renal fibrosis instead of biopsy. Magnetic resonance imaging (MRI) could provide both high spatial resolution and excellent tissue contrast for visualization of kidney morphology. Moreover, MRI is capable of assessing pseudo perfusion (D_f) and perfusion fraction (Pf) with intra-voxel incoherent motion (IVIM) imaging (1), tissue oxygenation with T_2* mapping (2), macromolecular composition with T1rho imaging (3) and kidney function (eGFR) with dynamic contrast enhanced (DCE) imaging (4). This study is aimed to evaluate the sensitivity of these MRI techniques to the renal fibrotic changes in a rat model.

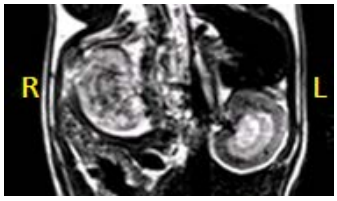

Fig1: A coronal anatomical scan shows both kidneys.

Methods

A total of 4 rats were scanned at early (2-5 days) and late (25-35 days) time points after surgical intervention (unilateral ureteral obstruction to induce renal fibrosis) on a Siemens Tim Trio 3T scanner using an 80mm inner diameter 8-channel rat body coil (RAPID, USA) under a stable anesthetized condition. Axial images of 80mm FOV, 2mm slice thick and sub-millimeter in-place resolution were acquired for different functional MRI techniques with following parameters, respectively: **IVIM** with10 b-values of 0 - 750 s/mm^2. **T2***: with 10 TEs of 8 - 66 ms; **T1rho**: with 9 TSL times of 5 - 80 ms; **DCE**: with150 dynamic measurements at a temporal resolution of 1.01 s. before and after a 15s injection of 1.1 ml GD-DTPA through rat tail with a power injector. Functional data were processed and analyzed using custom MATLAB programs or analysis tools installed in the MRI console workstation.

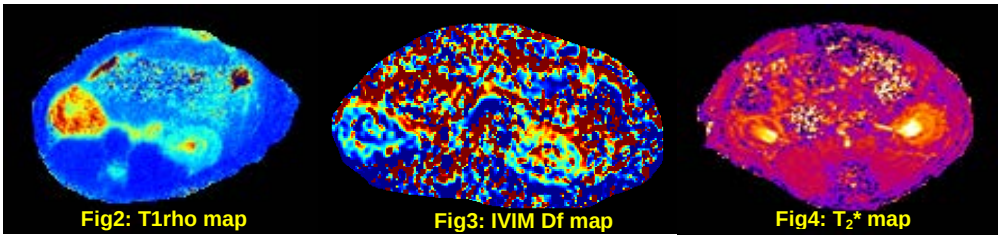

Fig2: T1rho map **Fig3: IVIM Df map** **Fig4: T_2* map**

		Early	Late
IVIM_D_f	R kidney	6.3±0.12	11.2±3.77
	L kidney	13.0±3.49	13.0±3.27
	Muscle	18.0±3.22	18.8±2.98
IVIM_Pf	R kidney	7.2%±0.10%	19.3%±1.03%
	L kidney	15.2%±1.59%	18.5%±2.76%
	Muscle	8.4%±2.55%	10.3%±1.87%
T_2*	R kidney	29.7±2.2	19.9±4.1
	L kidney	28.0±11.6	24.6±7.8
	Muscle	21.9±3.0	19.5±1.3
T1rho	R kidney	93.0±12.1	104.7±7.64
	L kidney	95.0±15.7	98.2±12.3
	Muscle	36.3±0.9	36.2±1.2

Table 1: Kidney and muscle IVIM / T2* / T1rho values at different time points

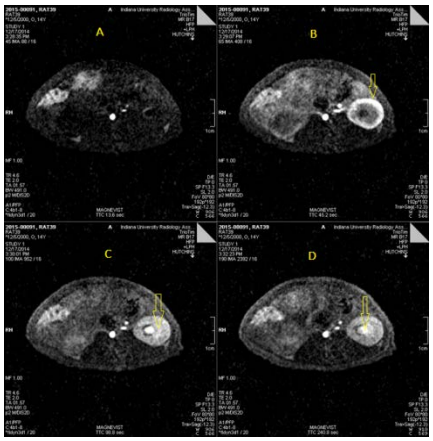

Fig5: Axial DCE scan images. (A) Baseline image before contrast agent injection. (B) Peak contrast image approximately 45s after injection (C) Image taken approximately 95s later showing increased medullar contrast (D) An image in about 4mins later showing the collecting system.

Results

Figure 1 shows an anatomical image of the obstructed (**R**) and healthy (**L**) rat kidneys. Figures 2-4 show example T1rho map, IVIM D_f map, and T_2* map, respectively. Quantitative results based on ROI measurements are summarized in table 1. Changes consistent with the expected progression of fibrosis were observed in the obstructed kidney (**R**) while the healthy kidney (**L**) and muscle region remained stable. Figure 5 shows the DCE-MRI images at baseline as well as 45s, 95s and 240s after contrast infusion. The timing and intensity of signal changes are clearly different between two kidneys. Quantitative results of DCE-MRI data and comparison with PET study is reported in a separate abstract.

Discussion

High quality anatomical and functional images of rat kidney can be obtained on a clinical 3.0T MR scanner with dedicated small animal coils and optimized imaging techniques. The findings suggest that IVIM, T_2*, T1rho and DCE can be used to assess and monitor different aspects of physiological changes in kidney fibrosis.

References

1. HH Wu, et al. Chin Med J (Engl). 2015 Mar 5;128(5):626-31; 2. LP Li et al. Invest Radiol. 2014 Jun;49(6):403-10; 3. YX Wang et al. Radiology. 2011 Jun;259(3):712-9; 4. F Zimmer, et al. 2013, PLoS ONE 8(1): e53849