Understanding renal DTI at 3T: FA and MD changes with water loading

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Introduction: Diffusion weighted MR (DWI) primarily measures restriction to the motion of water molecules in the voxel being interrogated, but can also be sensitized to active, incoherent flow processes. DWI has been explored in kidney imaging because both parenchymal structure and fluid flow in the kidney are important reflections of renal function and may change in disease states (1-3). Most of these studies have measured changes in the directionally averaged mean diffusivity (MD) / apparent diffusion coefficient (ADC) (1-4). However, renal medulla is composed of closely packed radially oriented tubules carrying directional flow of the gloemerular filtrate from the corticomedullary junction to the renal papilla. The directional sensitivity obtained with diffusion tensor imaging (DTI) may provide better insight in the structure and function of the renal tubules. Fractional anisotropy (FA) is measure of directionality of the diffusion and has been shown to be higher in medulla with respect to the cortex (5-7). It is unclear if medullary FA is predominantly a measure of tubular structural arrangement or if it is significantly influenced by the tubular flow; antiparallel flow patterns in the tubular loop of Henle could conceivably induce an anisotropic incoherent motion effect. In response to this question, our goal for this study was to investigate the effect of tubular flow on the renal FA measures in normal healthy volunteers by evaluating changes in response to water loading (which increases tubular flow). We would expect increase in FA with water-loading if tubular flow contributed to the renal anisotropy measurements.

Methods: Using an IRB approved HIPAA compliant protocol, 6 normal healthy subjects (1M, 5F; mean age 33 years) underwent renal DTI at 3T. Subjects underwent imaging at baseline in a dehydrated state (nothing by mouth for 6 hrs) and after oral water loading (800 ml water over 60 min). Imaging parameters are as follows: TR/TE = 1000/69 ms, BW = 1370 Hz/px, b = 0, 500 s/mm^2, 6 directions, 3 averages, 2 x 2 x 6 mm resolution. 3 coronal slices were acquired in a breath-hold (BH) acquisition. This BH acquisition was repeated 3 times for total of nine averages. Post-processing (including unilateral 2D image registration and null image exclusion) was performed off-line to generate mean diffusivity (MD) and fractional anisotropy (FA) data sets. Region of interests (ROIs) were placed over the cortex and medulla in the upper, middle, and lower poles of kidneys on b0 images and were copied to MD and FA map. Average renal cortical and medullary MD and FA, and percent change (% Δ) were calculated for scans before and after water loading in each subject.

Results/Discussion: Baseline cortical and medullary FA shown in table are qualitatively and quantitatively consistent with previous studies which have shown higher FA in the medulla (5-7). This has been attributable to tubules and their orientation as confirmed by DTI which depict radial directed patterns in medullary compartments (Fig 1). This study also showed higher MD in cortex compared to medulla at baseline also previously demonstrated. Medullary and cortical FA decreased significantly with water loading ($p < 0.05$). Medullary and cortical MD also increased significantly with water loading ($p < 0.05$). Since water-loading is known to increase tubular flow, these results suggest that flow plays little or no role in baseline medullary diffusion anisotropy. An alternative process explaining these results might be tubular dilatation with water loading, which would ease diffusion restrictions, increasing MD and decreasing FA.

	Cortex (pre)	Cortex (post)	Cortex % Δ	Medulla (pre)	Medulla (post)	Medulla % Δ
FA	0.15 ± 0.03	0.13 ± 0.01	-16 ± 12.6	0.33 ± 0.04	0.30 ± 0.02	-9.7 ± 5.4
MD	2.20 ± 0.1	2.30 ± 0.15	4.4 ± 3.9	1.89 ± 0.07	2.08 ± 0.13	10.2 ± 6.4

Conclusions: The water loading data of this preliminary study indicated a trend to faster, more isotropic diffusion with water loading. Our results suggest that FA is less a marker of filtration rate in renal tissue and more an independent marker of tubular structure.

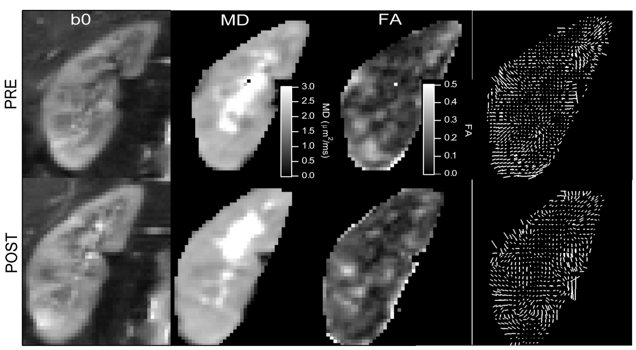

Figure 1: Example DTI images in a volunteer pre- and post-water loading: Unweighted (b0), mean diffusivity (MD), fractional anisotropy (FA), and FA-weighted principal eigenvector.

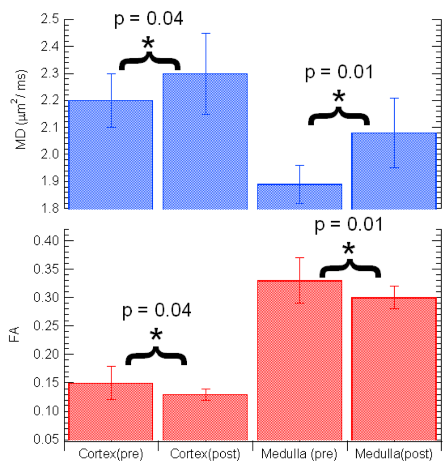

Figure 2: Healthy volunteer MD and FA group averages (N=6) before and after water loading.

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