High-Resolution Diffusion Tensor Imaging (DTI) of the Human Kidneys using a Free-Breathing Multi-Slice Targeted-FOV Approach

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Target Audience: Clinicians interested in a non-invasive diffusion tensor imaging (DTI) technique suitable for imaging patients with kidney disease where the injection of contrast agent may be contraindicated.

Purpose: To obtain high-resolution fractional anisotropy (FA) maps and color-coded diffusion-orientation maps of the kidneys using a free-breathing targeted-FOV (TFOV) DTI method, and to provide measures of the medullary and cortical FA quantified over the entire kidney volume.

Background: FA values of the medulla obtained by DTI can be used to assess the function of renal allografts after kidney transplant[1,2]. Higher spatial resolution and reduced image distortions can be achieved by TFOV methods[3-6].

Methods: ***MR imaging:*** A multi-slice TFOV technique[5,6] (previously used for spinal cord and prostate DTI) was extended to free-breathing kidney DTI using a navigator-triggered technique. Twelve healthy subjects were scanned at 3T after informed consent with two implementations: i) TFOV "D" for dual-kidney imaging, and ii) TFOV "S" optimized for targeted imaging over a single kidney. Each subject was scanned with TFOV D (TR/TE=5000/80ms, FOV=$220\times126mm^2$, SI phase-encode direction, 12 slices, 5.5mm slice thickness, 2 signal averages, $2\times2mm^2$), followed by a scan with TFOV S where a single kidney, either the right or left, was imaged (TR/TE=5000/106ms, FOV=$120\times72mm^2$, LR phase-encode direction, 8 slices, 5.5mm slice thickness, 3 signal averages, $1.2\times1.2mm^2$). Each scan consisted of 15 diffusion-encoding directions with b=450s/mm^2 and a b=0s/mm^2 image. ***Image reconstruction and analysis:*** Affine registration was performed on the individual diffusion-weighted images using FSL[7] prior to averaging to correct for residual motion and effects of eddy currents. Grayscale and color FA maps were computed, along with in-plane diffusion tensors. Medulla and cortical ROIs were drawn on all contiguous slices. FA maps and the mean FA values were qualitatively and quantitatively compared.

Results: High consistency was seen in the grayscale FA maps (Fig1a,b), color-coded FA maps (Fig1c), and diffusion tensors (Fig1d) across subjects and between dual- and single-kidney scans. The mean medulla / cortical FA values were 0.38 ± 0.017 / 0.21 ± 0.019 for the dual-kidney scan, and were 0.35 ± 0.032 / 0.20 ± 0.014 for the single-kidney scan (plotted in Fig1e). There was no significant difference between dual-kidney and single-kidney scans for the medulla or cortical FA (both with $p>0.05$, computed with paired t-test) for the same number of signal averages. The mean FA between the medulla and cortex was significantly different ($p<0.001$ for both dual- and single-kidney scans).

Discussion and conclusions: High-resolution FA maps and color-coded diffusion orientations were obtained of the human kidney during free-breathing. Targeted-FOV DTI with multiple contiguous slices allowed the medulla and cortical FA to be quantified over the entire kidney volume. High-spatial resolution renal DTI has the potential to improve characterization and non-invasive assessment of kidney function. **References:** **1.** Hueper K et al. Eur Radiol. 2011 Nov;21(11):2427-33. **2.** Lanzman RS et al. Radiology. 2013 Jan;266(1):218-25. **3.** Jin N et al. J Magn Reson Imaging 2011;33:1517–1525. **4.** Jeong EK et al. Magn Reson Med 2005;54:1575–1579. **5.** Wheeler-Kingshott CAM et al. Neuroimage 2002;16:93–102. **6.** Wilm BJ et al. Magn Reson Med. 2007 Mar;57(3):625-30. **7.** Jenkinson M, Smith S. Med Image Anal. 2001 Jun;5(2):143-56.

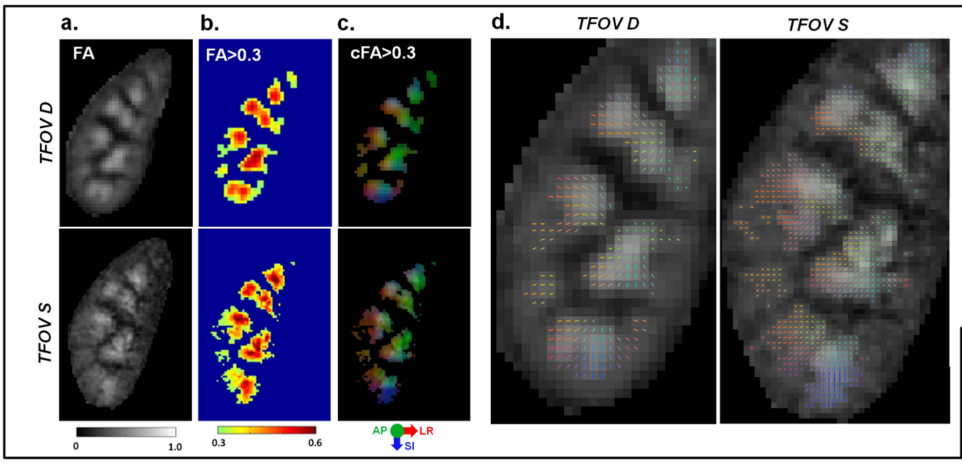

Figure 1: Maps of the **a)** grayscale FA, **b)** FA>0.3, and **c)** color FA are shown (red=LR, green=AP, blue=SI). **d)** Diffusion-tensor maps are overlaid onto the grayscale FA image. **e)** Mean medullary and cortical FA are shown for ROIs over all slices.