

Feasibility of kidney DTI using parallel transmission in normal volunteers

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Introduction:

Diffusion weighted (DW) imaging is a promising imaging technique for the functional assessment of kidneys. Diffusion-tensor (DT) imaging uses multiple diffusion sensitizing directions to evaluate anisotropic microstructure. Microstructure is a key factor in renal physiology, where cortex contains randomly oriented structures, while medulla holds more aligned vessel and tubular networks. DT imaging has been applied to renal tissue in studies that demonstrate higher fractional anisotropy (FA) in the renal medulla in comparison with the isotropically structured cortex [1]. Parallel transmission (pTX) uses multiple excitation coils driven by independent RF pulse waveforms to subdivide the transmit field into multiple spatial regions each controlled by a separate transmit channel. pTX has been shown to enable the design of spatially selective pulses with mitigated excitation inhomogeneity and off-resonance effects. Despite the promising initial results of DTI of the human kidney, kidney DTI using spin-echo echo planar imaging (EPI) typically suffers from many imaging artifacts including susceptibility-related distortions, motion artifact, and low spatial resolution. We hypothesized a 2D spatially selective RF excitation pulse combined with a reduced field-of-view single-shot echo planar readout (Zoomed-EPI) could provide superior DTI image quality of the human kidney in healthy volunteers.

Material and Methods:

The study was approved by the institutional review board and was compliant with the Health Insurance Portability and Accountability Act, and all subjects gave written informed consent. Four consecutive healthy volunteers without any history of renal disease (three males, one female; mean age 28 (24-30 years); nonfasting conditions) were included in this study. Each volunteer was imaged on a 3T scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) with a prototype 2 channel transmit system. Single-shot echo-planar free-breathing Zoomed-EPI DW images [2,3] were acquired with the following parameters: 10-14 coronal sections with a slice-thickness of 4mm, no intersection gap; field of view, 83 x 400; acquisition matrix, 64 x 308; repetition time, 4000; echo time, 65 msec; six diffusion directions; and parallel imaging factor of two. A total of 2 b-values ($b = 0$ and 500 sec/mm^2) were applied. The sequence was focused on the right kidney (Fig 1.). The total duration of the Zoomed-EPI sequence was 5.28 minutes. In one volunteer a standard EPI DW imaging sequence was acquired with similar voxel size, diffusion directions and b-values.

The right kidney images were co-registered by using a two-dimensional rigid body transform algorithm. MR images at the same b value were then averaged by using locally developed software (Firevoxel; NYU Medical Center, New York, NY). DT processing was performed with custom software written in Igor Pro (Wavemetrics). ADCs along each direction were derived from the DW images and were used to estimate the DT. The DT eigenvalues were calculated and used to derive the mean diffusivity and FA. DT imaging parametric maps were generated of MD, FA, direction-encoded color maps, principal diffusivities, and primary diffusion eigenvector. ROIs were placed on the $b = 0 \text{ sec/mm}^2$ images on cortex and medulla (maximum of 10 ROIs) by a radiologist and were applied to the parametric maps, where voxel averages over the ROI of each parameter were derived.

Results:

In general, the Zoomed-EPI DTI technique allowed for high signal-to-noise ratio and low distortion diffusion images of the kidney (figure 2) compared to the standard EPI DTI technique (figure 3). Medullary anisotropy was present in all volunteers. DT tractography was possible in all volunteers and the results of 1 volunteer are presented in figure 4. The mean ADC of the medulla and cortex were respectively, 2.04 (SD 0.14) and 2.21 (SD 0.12). The mean FA of the medulla and cortex were 0.34 (SD 0.08) and 0.13 (SD 0.04), respectively. All parameters showed significant different corticomedullary difference. The diffusion parameters (ADC, MD, λ_1 , λ_2 and λ_3) showed significant higher cortical values.

Discussion:

The Zoomed-EPI DTI technique provides superior image quality of the kidney to standard single-shot, twice refocused spin echo EPI in clinically relevant scan times and with minimal artifacts. Measurements of healthy kidneys showed normal diffusivity compared with the literature. These results suggest Zoomed-EPI DTI may be valuable for clinical assessment of kidney pathology.

References:

1. Ries M, Diffusion tensor MRI of the human kidney. J Magn Reson Imaging 2001;14(1):42-49
2. Rieseberg S, Two-dimensional spatially-selective RF excitation pulses in echo-planar imaging. Magn Reson Med. 2002; 47(6):1186-93
3. Schneider R, Evaluation of 2DRF echo-planar pulse designs for parallel transmission. Proc ISMRM 2012 # 3459

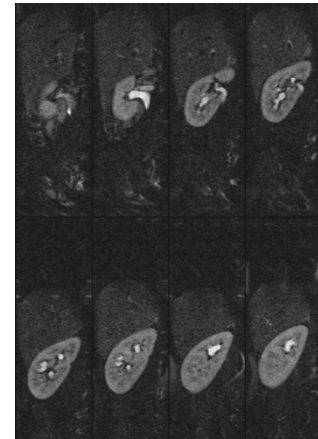


Figure 1: Eight of the 10 images of the right kidney collected in a healthy volunteer.

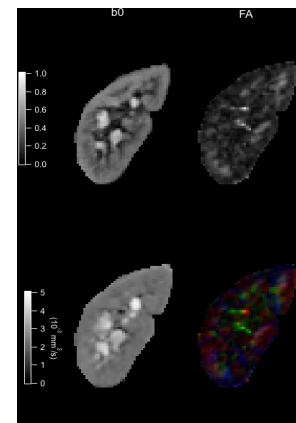


Figure 2: Kidney Zoomed-EPI DT images. Images obtained with $b = 0 \text{ sec/mm}^2$, FA map, MD map, and direction-encoded color map. Medullary anisotropy is evident in the FA map.

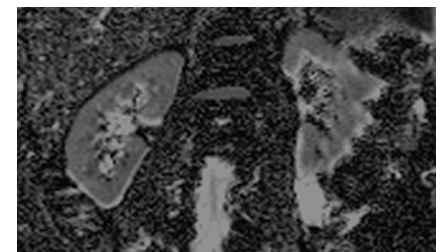


Figure 3: Note the susceptibility-related distortions

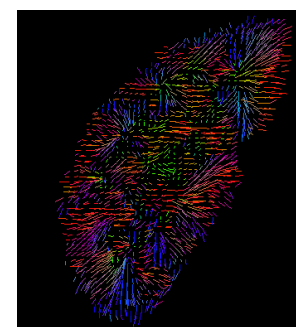


Figure 4: Direction-encoded color map.