DTI of Human Kidney at 3T - Simultaneous and Reliable Determination of Fractional Anisotropy, ADC and Perfusion Fraction

T. Binser[1], H. C. Thoeny[2], C. Boesch[1], and P. Vermathen[1]

[1]Dept. of Clinical Research, University of Bern, Bern, Switzerland, [2]Dept. of Radiology, Inselspital Bern, Bern, Switzerland

Introduction: Previously it has been shown that diffusion-weighted MRI (DWI) has potential to assess renal function. Only very few studies have employed diffusion tensor imaging (DTI), which grants in addition to the apparent diffusion coefficient (ADC) the fractional anisotropy (FA) [1-3]. In kidneys determination of FA could be especially interesting because it may allow for assessing structure and potential derangements of renal tubules. DWI scans are often performed with several averages for a sufficiently high signal-to-noise ratio (SNR). If these multiple repetitions are applied in different directions, additional structural information can be obtained without time penalty. In kidney not only diffusion, but also microperfusion contributes to the signal decay in DWI scans [4] and these contributions may be separated, yielding besides ADC_{tot} the diffusion coefficient (ADC_D) and the perfusion fraction (F_P) [5]. This feasibility study aimed at determination of reliability to simultaneously assess ADC_{tot}, ADC_D, F_P and FA in the kidney within clinically acceptable measurement times.

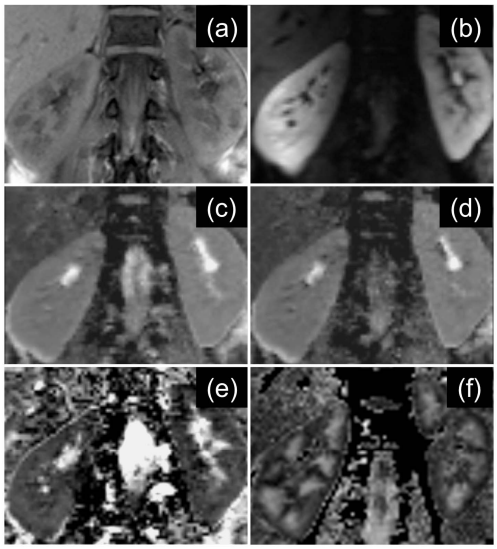

Fig. 1: A T_1-weighted FLASH (a) shows the renal anatomy. The diffusion-weighted images (here b=0s/mm^2 (b)) are the basis of the maps calculated: ADC_{tot} (c), ADC_D (d), perfusion fraction F_P (e) and fractional anisotropy FA (f).

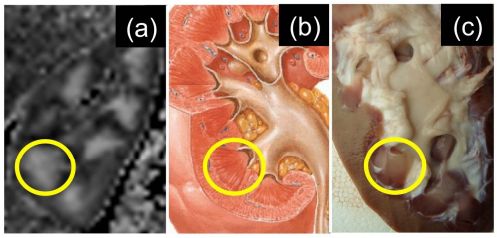

Fig. 2: FA map (a), schematic drawing (b) and a photograph (c) of a kidney. Please note the high coincidence of the medullary tissue (circled).

	Medulla	Cortex
ADC_{tot} [10^{-5}mm^2/s]	212±17	227±15
ADC_D [10^{-5}mm^2/s]	195±15	207±14
F_P [%]	10±3	12±3
FA [%]	43±2	18±2

Tab. 1: Mean values (± sd) for the apparent diffusion coefficient ADC_{tot}, the diffusion coefficient ADC_D, the perfusion fraction F_P and the fractional anisotropy FA.

Methods: Thirteen healthy volunteers (9 female, 4 male, age=27.1±6.8, range=21y-47y) were measured on a 3T whole-body MR scanner (Siemens Trio Tim, Erlangen, Germany). A diffusion-weighted single shot echo-planar imaging sequence was applied with ten different b-values ($b \in \{0, 10, 20, 50, 100, 180, 300, 420, 550, 700 s/mm^2\}$) in 6 non-collinear directions. As motion-probing gradient scheme the double inversion method was employed [6]. Further parameters were: Seven coronal slices, field of view=30×30cm^2, slice thickness=5mm, intersection gap=2mm, number of acquisitions=2, parallel imaging (GRAPPA factor=3), bandwidth per pixel=2298Hz/px, image matrix=128×128, respiratory triggering, TR_{min}=3300ms, TE=66ms resulting in a minimal acquisition time of TA_{min}≈6min. The data postprocessing included a) monoexponential fitting, yielding ADC_{tot}, b) biexponential fitting, yielding ADC_D and F_P and calculation of FA. Six regions of interest (ROI) per patient were placed in both medulla and cortex, and merged separately.

Results: Fig. 1 depicts the renal anatomy, a diffusion-weighted image and the maps of ADC_{tot}, ADC_D, F_P and FA, demonstrating the quality of the acquired data. In the FA map medullary tissue appears brighter, i.e. more anisotropic, compared to cortex, in accordance with the literature. In Fig. 2 the high coincidence between the structure of the anisotropic medullary regions in the FA map, a schematic drawing and a photograph of human kidney is shown. FA values were similar for all subjects (Tab. 1) with very low standard deviation. Low standard deviation was also obtained for ADC_{tot} and ADC_D, but was slightly higher for F_P. FA values for both medulla and cortex agree with literature [2]. ADC_{tot}, ADC_D, and F_P determined by DTI are in the same range as those determined by DWI [5].

Discussion & Conclusions: Renal DTI can be performed within acceptable scan times and provides comprehensive information including ADCs, perfusion fraction and anisotropy indices with low standard deviations. However, the reliable simultaneous determination of all these parameters prevents the acquisitions to be performed in a breath-hold condition. A minor disadvantage of DTI compared to DWI is a slightly prolonged minimal TE for equivalent diffusion weighting. Nevertheless the current study suggests the applicability of DTI in human kidney in daily clinical practice.

References: 1. Michaely et al. Abdom. Imaging **32**: 1 (2007)
2. Ries et al. J. Magn. Reson. Imaging **14**: 42 (2001)
3. Chandarana et al. Proc. Intl. Soc. Magn. Reson. Med. **16**: 494 (2008)
4. Le Bihan et al. Radiology **168**: 497 (1988)
5. Thoeny et al. Radiology **241**: 812 (2006)
6. Heid Proc. Intl. Soc. Magn. Reson. Med. **8**: 799 (2000)

Acknowledgment: Supported by SNF 320000-111959 and 320000-113512.