DTI of the kidney at 3T - protocol evaluation, reproducibility and comparison to 1.5T

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Introduction: Diffusion anisotropy of the kidney can be assessed using Diffusion Tensor Imaging (DTI). Previous studies at a field strength of 1.5T have shown that diffusion anisotropy in the medulla is considerably higher than in the cortex[1]. The purpose of this study was to assess the feasibility of DTI of the kidney at a field strength of 3T. In detail we assess fractional anisotropy (FA) and apparent diffusion coefficients (ADC) of various acquisition protocols and compare these values and signal-to-noise (SNR) and contrast-to-noise-ratios (CNR) to those acquired at 1.5T. Furthermore, we evaluate intrareader-correlation and reproducibility of the method.

Material and Methods: Ten healthy volunteers were examined with a respiratory triggered echo planar imaging (EPI) sequence on a 3T-scanner (Magnetom Verio) and on a 1.5T-scanner (Magnetom Avanto). Sequence parameters and b-values are provided in **Table 1**. Postprocessing was performed with the Syngo©Neuro3D-software and included assessment of cortical and medullary FA and ADC. SNR-measurements were performed for b=0 images in one direction with the subtraction method for images acquired with parallel imaging[2]. Statistical analysis was performed with paired t-tests. 3T-measurements with 2b-values and 6 diffusion directions (2b6d 3T) were tested for intraindividual correlation and reproducibility with weighted-κ-coefficients and the root-mean-square-average (RMSA) method.

Sequence	Field strength	TR	TE	Parallel imaging	Acquired signals	b-values	Diffusion directions	Acquisition time
2b6d 3T	3T	2000ms	73ms	GRAPPA r =2	n = 6	0 300	6	86 sec
3b6d 3T						0 50 300	6	146 sec
2b12d 3T						0 300	12	146 sec
2b6d 1.5T	1.5T					0 300	6	86 sec

Table 1: Sequence and diffusion parameters used in this study. Provided is the "pure" acquisition time. Due to the individual respiratory cycle, "true" acquisition time varies and is approximately four times longer.

Results: At a field strength of 3T, SNR for the cortex was significantly higher than at 1.5T (38.0 ± 8.1 vs. 23.6 ± 7.5; p<0.01; **Figure 1**). SNR for the medulla did not differ significantly (22.0 ± 8.0 vs. 21.9 ± 7.1). CNR for cortex/medulla was significantly higher at 3T (16.0±17.0 vs. 4.8 ± 4.1; p<0.01). FA of the medulla was significantly higher than of the cortex in all measurements (p<0.05, **Table 2, Figure 2**). Tractography visualized a typical radial diffusion direction in the medulla (**Figure 3**). No significant FA-differences could be found between 1.5T and 3T-measurements and between the different protocols (**Table 2**). ADC of the cortex was significantly lower in 3T-measurements with 3 integrated b-values and at measurements at 1.5T (**Table 3**). In all 3T-measurements cortical ADC was higher than in the medulla, though not so for the 1.5T-measurements. Intrareader-correlation was excellent with κ-values ranging from 0.82 to 0.94. RMSA for 2b6d 3T-measurements provided reproducibility coefficients of 12.6% (ADC cortex), 22.0% (ADC medulla), 23.6% (FA cortex) and 54% (FA medulla).

Fractional Anisotropy (FA)		
Sequence	**Cortex**	**Medulla**
2b6d 3T	0.24 ± 0.06	0.37 ± 0.06
2b6d repro 3T	0.24 ± 0.04	0.37 ± 0.08
2b12d 3T	0.22 ± 0.04	0.34 ± 0.06
3b6d 3T	0.25 ± 0.05	0.35 ± 0.06
2b6d 1.5T	0.27 ± 0.03	0.37 ± 0.05

Table 2: Mean FA-values did not differ significantly between 1.5T and 3T and the different applied protocols.

Apparent Diffusion Coefficient (ADC)		
Sequence	**Cortex**	**Medulla**
2b6d 3T	2.83 ± 0.27	2.64 ± 0.20
2b6d repro 3T	2.80 ± 0.27	2.58 ± 0.42
2b12d 3T	2.86 ± 0.25	2.80 ± 0.37
3b6d 3T	2.64 ± 0.25	2.44 ± 0.26
2b6d 1.5T	2.57 ± 0.19	2.61 ± 0.30

Table 3: Mean ADC-values for the cortex were significantly lower at 1.5T and for 3 b-values. The differences were not significant for the medulla.

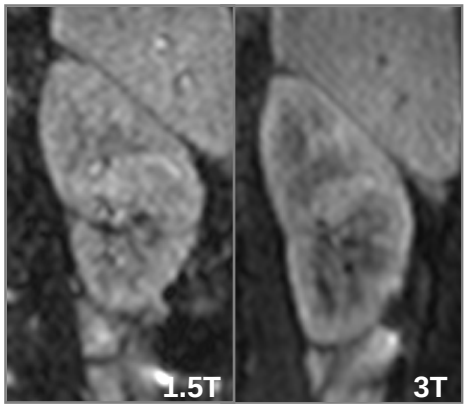

Figure 1: Compared to 1.5T, cortical SNR is significantly higher at 3T. Higher corticomedullary CNR leads to improved discrimination of cortex and medulla. (b=0 image in 1 diffusion direction)

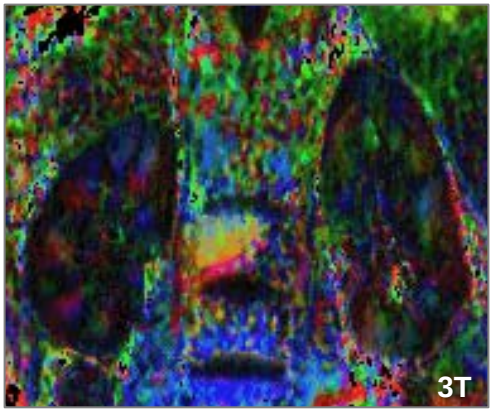

Figure 2: Color coded FA-map with 2 b-values and 6 diffusion directions at 3T (2b6d 3T). FA in the medulla is significantly higher than in the almost isotropic cortex.

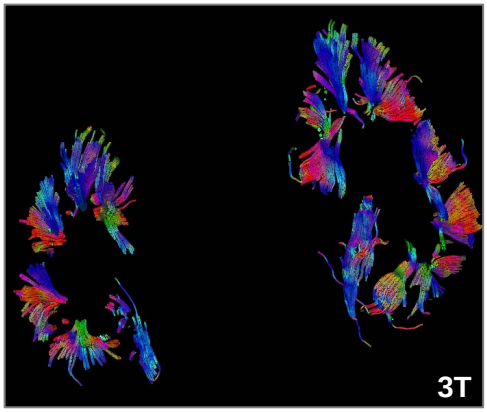

Figure 3: Tractography reveals a radially oriented diffusion direction in the medulla (2b6d 3T).

Conclusion: DTI of the kidney at 3T is feasible with mean FA-values not significantly different to 1.5T measurements at a significantly higher SNR and CNR for cortex and medulla and thus improved corticomedullary discrimination. However, medullary FA is less reproducible than FA of the cortex and 1.5T-measurements provide slightly lower ADC-values. Measurements with 3 b-values provide lower ADC-values than measurements with 2 b-values due to the reduction of perfusion influences. For calculation of FA, acquisition of 2 b-values and 6 diffusion directions appears sufficient. DTI of the kidney may become a valuable tool for studying renal microarchitecture and medullary flow, however a certain variability due to the applied field strength and a varying reproducibility should be considered.

References: [1]Notohamiprodjo M, et al. Diffusion tensor imaging of the kidney with parallel imaging: initial clinical experience; Invest Radiol. 2008 Oct;43(10):677-85.
[2]Dietrich O, et al. Measurement of SNR in MR images: influence of multichannel coils, parallel imaging, and reconstruction filters. JMRI. 2007 Aug;26(2):375-85