Diffusion-Weighted Imaging during Acute Unilateral Ureteral Obstruction - Demonstration of the necessity to separate diffusion and microperfusion contributions

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Introduction: Diffusion-weighted imaging (DWI) is a promising functional MR-method for the diagnostic work-up of the kidney. DW-MRI yields the apparent diffusion coefficient (ADC) as a quantitative parameter. In addition to diffusion, microcirculation including capillary perfusion may be quantitated from DW-MRI [1]. However, the value of this separation between diffusion and microcirculation has been discussed [1-3] and there have been only few reports in the kidney to distinguish diffusion and perfusion. In this study we performed DWI in patients with acute ureteral obstruction to determine possible changes in both, diffusion and microperfusion. Besides its possible clinical impact in helping determining the time point of therapeutic intervention we hypothesized that the known reduction in perfusion during ureteral obstruction will be detectable in DWI via the separation of diffusion and perfusion contributions. This would emphasize the usefulness of the disputed separation.

Methods: Ten patients (1 female, 9 male, mean age=43.5y±12.2y, range=25y-66y) with acute ureteral obstruction due to a distal calculus were examined on a 1.5T MR whole-body scanner (Sonata, Siemens, Erlangen, Germany) using two 6-channel body coils. Anatomical imaging was followed by a DW single shot echo-planar imaging sequence. Thirteen coronal slices (5mm thickness, 1mm intersection gap) were acquired with 6 averages applying parallel imaging (GRAPPA, acceleration factor of 2). Respiratory triggering was performed whenever possible. Ten b-values were applied ($b \in \{0, 10, 20, 40, 60, 150, 300, 500, 700, 900 s/mm^2\}$) in 3 orthogonal directions. Further parameters were TR_{min}/TE=2500ms/71ms, FOV=400mm, matrix size=128x128, min. acquisition time ~7min. Processing of the data was performed I) by monoexponential fitting employing a) all b-values, yielding ADC_{tot}, b) the 5 lowest b-values, yielding ADC_{low}, c) the 5 highest b-values, yielding ADC_{high}, and II) separating diffusion and perfusion contributions by biexponential fitting of all b-values, yielding ADC_D (mostly determined by diffusion) and the apparent contribution of the fast decaying component ("perfusion fraction", F_P). About 60 regions of interest (ROIs) per patient were placed in cortex and medulla of the obstructed and contralateral nonobstructed kidney and were thereafter merged separately for cortex and medulla for each.

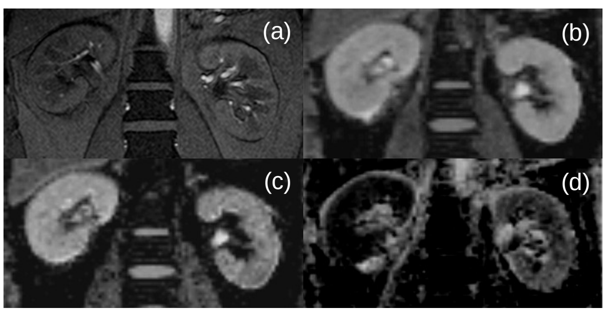

Fig. 1: Morphological MRI (a) and maps for ADC_{tot} (b), ADC_D (c), and F_P (d). The right kidney was obstructed.

	Medulla			Cortex		
	Obstr.	**Nonobstr.**	**t-test**	**Obstr.**	**Nonobstr.**	**t-test**
F_P	17.7±6.8	23.6±7.7	p=0.029	19.9±5.6	26.4±6.5	p=0.008
ADC_D	194±15	183±19	p=0.019	205±19	200±16	p=ns
ADC_{tot}	214±13	209±13	p=ns	226±15	230±12	p=ns
ADC_{high}	196±14	186±17	p=0.015	207±16	203±13	p=ns
ADC_{low}	331±106	407±54	p=0.017	375±79	427±53	p=0.026

Tab. 1: Mean values (± sd) for the perfusion fraction F_P [%] and the ADC values [$10^{-5} mm^2/s$]. T-tests compare obstructed with nonobstructed kidneys

Results: In Fig. 1 are shown maps for ADC_{tot}, ADC_D and F_P, demonstrating the quality of the data and differences between the obstructed and nonobstructed kidney. F_P in medulla as well as in cortex was significantly lower in the obstructed kidney compared to the nonobstructed contralateral side (Tab. 1). ADC_D was significantly higher in the medulla of the obstructed kidney. No significant difference between normal and obstructed kidney was detected for ADC_{tot}. Interestingly, a significant *increase* of ADC_{high} was found in the medulla of the obstructed kidney compared to the nonobstructed side, while the opposite finding, i.e. a significant *decrease* was obtained for ADC_{low}, which is probably due to changed microperfusion.

Discussion & Conclusions: The presented results suggest that DW-MRI might provide information as to the degree of obstruction and might therefore help in the decision making of the time point of therapeutic intervention. In addition, the results clearly demonstrate the validity and necessity to separate diffusion and microperfusion compartments, first because the significantly reduction of F_P in the obstructed kidney would have remained undetected, and secondly in order to prevent misleading findings and interpretations: Depending on the choice of b-values for the experiment a increase (ADC_{high}), decrease (ADC_{low}) or no change (ADC_{tot}) would be detected.

References:
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