Functional MRI of Transplanted Human Kidneys evaluated by Diffusion-Weighted MRI - Initial Experience

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Introduction: Early and specific detection of dysfunction and complications in the renal allograft are fundamental to initiate appropriate treatment. Determination of renal function may also reveal physiological mechanisms that may prove useful for future therapeutic procedures. Currently used methods to assess renal function like ultrasound, radionuclide imaging, and laboratory methods have several disadvantages, as they are nonspecific, require radioactive contrast agents or are limited in spatial information. Recently, few studies have used diffusion-weighted MRI to assess renal function. Very different ADC values were reported for the kidney, which is most likely due to the choice of b-factor ranges, resulting in varying contributions of micro-perfusion to the signal decay [1]. To our knowledge only one study analyzed DW-MRI in transplanted kidneys in an experimental setting [2].

In this study we evaluated if diffusion-weighted imaging of the human transplanted kidney 1) provides reliable results and 2) provides non invasive information on the functional kidney status.

Methods:

Study Population: Eleven patients (8 men, 3 women; mean age: 48±15), who underwent kidney transplantation 10±4 months (range: 5-19) prior to the MR examination and who had no clinical or laboratory signs of kidney dysfunction were included in our study. Laboratory parameters including serum creatinine were obtained from all patients immediately after the MR examination. All patients received Cyclosporin A based immunosuppression.

MR Imaging: MR imaging was performed on a 1.5T MR scanner (SONATA, Siemens) with a 40mT/m maximum gradient capability using a 6-channel body coil. After conventional imaging for morphological evaluation, coronal diffusion–weighted multisection single shot echo-planar imaging (DW-MRI) was performed for functional evaluation, applying parallel imaging (SENSE, acceleration factor of 2) with following diffusion gradient b-values: b=0, 10, 20, 40, 60, 150, 300, 500, 700 and 900 sec/mm^2. Gradients were applied in three orthogonal directions and subsequently averaged. Six averages were acquired using respiratory triggering. The following parameters were used: TR_{min}=2500msec, TE=71msec, 21 slices, slice thickness of 5mm, intersection gap 1mm, matrix size = 128x128, field of view = 400x400mm^2, with an min. acquisition time of 7:18min.

DWI Processing: Processing of the data was performed by I) monoexponential fitting employing a) the 4 lowest b-values, yielding ADC_{low}, b) the 6 highest b-values, yielding ADC_{high}, c) all b-values, yielding ADC_{tot}, and II) by biexponential fitting of all b-values, yielding in addition the contribution of the fast decaying component to the diffusion ("perfusion fraction", PF). Three ROIs were selected in both, cortex and medulla at the upper and lower pole as well as at the mid-level for a number of slices covering large parts of the kidney, using morphological images as anatomical guidance and for detection of any movement or geometric image distortions.

Results: The DW images of the transplanted kidneys showed much less motion induced blurring than is known for native kidneys, due to their less motion sensitive location (see Fig. 1). Slight misregistrations of up to 0.5–1 cm were noted due to geometric distortions and movement. While for higher b-values (> 100 sec/mm^2) a good linear correlation was observed ($\log_e$(Intensity) vs. b-values), the signal intensity for low b-values was less stable, which is probably due to blood flow, and suggests using cardiac triggering for future studies. Perfusion influenced ADC_{low}-values were much higher than ADC_{high}, which resemble more pure diffusion. Despite the high signal variance for low b-values, ADC values (especially ADC_{high} and ADC_{tot}) showed only very small standard deviations (Table). The ADC values are similar to recently obtained values in native kidneys of volunteers [3], however, slightly different b-values were used in this study. All ADC values and PF were almost identical between cortex and medulla. Despite the fact that we selected kidneys with a stable function, we found a significant inverse correlation between s-creatinine and PF in cortex and medulla (R=-0.82 and R=-0.63, respectively, Fig. 2), indicating that reduced kidney function leads to reduced micro-perfusion. In addition, the ADC values were found to be generally lower with increasing serum creatinine levels (Fig. 3).

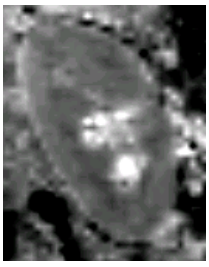

Fig. 1: ADC map of a renal allograft

	Medulla	Cortex
ADC_{high}	201±9	198±13
ADC_{low}	371±75	368±78
ADC_{tot}	216±11	216±15
PF	0.17±0.05	0.18±0.05

Table: ADC values in renal transplants with stable function

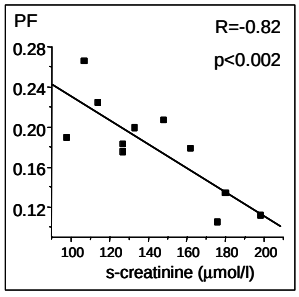

Fig. 2: Correlation between PF in cortex and s-creatinine

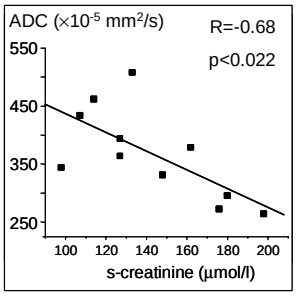

Fig. 3: Correlation between ADC_{low} in cortex and s-creatinine

Discussion: These preliminary results clearly demonstrate that DWI measurements in human transplanted kidneys are feasible and they demonstrate the potential of the method. Low variability was observed for diffusion parameters within the relatively homogeneous subject group and the ADC values are comparable to those in healthy volunteers. A good correlation with s-creatinine as an indicator for the functional status of the kidneys was found. Especially the perfusion fraction appears very promising to assess renal function. The combination of DWI and other functional MRI methods with morphological MRI may lead to a 'one-stop-shop'-method, for a comprehensive characterization of the kidney.

References

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