

Diffusion Tensor Imaging (DTI) and tractography for assessment of renal allograft dysfunction

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Introduction: Early detection of functional and structural changes of renal allografts is of great importance in order to initiate the appropriate therapy and to ensure long term allograft survival. The kidney is well defined in cortex and medulla, and nephrons and vessels run radially to the renal pelvis, so that in healthy kidneys a directed diffusion along those structures is expected. Diffusion Tensor Imaging (DTI) measures the diffusion properties including the diffusion direction. The aim of this study is to investigate whether DTI allows for quantification and visualization of diffusion properties in transplanted kidneys and whether allograft dysfunction can be detected by DTI.

Methods: 15 transplanted patients with different degrees of allograft dysfunction (estimated GFR = 0-80 ml/min) and 13 healthy volunteers were examined using a coronal fat-saturated echo-planar DTI-sequence (1.5 T MAGNETOM Avanto, 6 diffusion directions, b-values 0 and 600 s/mm², TR / TE = 5600 ms / 98 ms, matrix = 128x128, 9 averages, no respiratory triggering). Data were analyzed using the Neuro 3D Task Card Software (Syngo, Siemens). Six ROIs were placed in the renal cortex and six ROIs in the renal medulla. Mean Apparent Diffusion Coefficient (ADC) and Fractional Anisotropy (FA) were calculated and compared between healthy volunteers and transplanted patients. Furthermore, the correlation between FA and eGFR was analyzed with the Pearson test. For visualization of diffusion properties tractography was performed. Tractography parameters were minimum FA = 0.200 and maximum angle = 30°. An additional illustration with a minimum FA of 0.100 was created for transplanted kidneys.

Results: ADC was significantly reduced in the cortex and in the medulla of transplanted kidneys compared to healthy kidneys ($p < 0.01$ and $p < 0.05$). FA in the cortex of renal allografts was 0.119 ± 0.017 and it was significantly lower than in healthy kidneys as well ($p < 0.001$). In the medulla differences were even more pronounced: In healthy volunteers FA was 0.416 ± 0.047 , whereas in transplanted patients FA was significantly reduced to 0.278 ± 0.061 ($p < 0.001$) (see Figure 1A). Comparing FA-values of the medulla with the estimated GFR a correlation between both parameters was observed ($r = 0.66$; $p < 0.01$) which is depicted in Figure 1B. Tractography was able to visualize differences in diffusion properties and differences in microstructure and architecture between transplanted patients with impaired allograft function and healthy volunteers (see Figure 2).

Discussion: The feasibility of DTI and tractography in healthy and in transplanted kidneys was demonstrated and initial results indicate that changes in allograft function and microstructure may be detected. In order to investigate the value of DTI for early detection of acute and chronic allograft dysfunction further investigations and especially correlation with biopsy results are important.

Figure 1: (A) Depicted is the Fractional Anisotropy in the medulla of healthy and of transplanted kidneys. *** $p < 0.001$. (B) Correlation between Fractional Anisotropy in the renal medulla and the estimated GFR (eGFR). $r = 0.66$, $p < 0.01$.

Figure 2: Tractography of both kidneys of a healthy volunteer (A) and a transplanted patient with impaired allograft function (B and C).

In healthy kidneys tractography illustrates the preferred diffusion direction along the tubules radially to the renal pelvis (A). Using the same tractography parameters (minimum FA = 0.200, maximum angle = 30°) in a patient with impaired allograft function, the number of tracts is reduced, demonstrating the reduced directed diffusion and the reduced FA (B). (C) shows the tractography of the same patient after changing tractography parameters (minimum FA is reduced to 0.100).

