Multiparametric functional MRI for assessment of delayed renal allograft function

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Target audience: Radiologists, nephrologist and physicist with an interest in functional MRI of transplanted kidneys.

Purpose: Delayed renal allograft function (DGF) is clinically defined as failure of serum creatinine to adequately decrease or need for dialysis during the first week after transplantation. DGF is associated with an increased risk of acute rejection, impaired long-term allograft function and graft loss. In this study, we investigate whether multiparametric functional MRI including arterial spin labeling (ASL), diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) allows diagnosis of DGF.

Methods: Forty patients were examined between day 4-10 after kidney transplantation using a 1.5 T magnet (Magnetom Avanto, Siemens Healthcare). Flow alternating inversion recovery (FAIR) trueFISP ASL (inversion time = 1200 ms), fat-saturated echoplanar DWI (10 b-values = 0-1000 s/mm^2) and fat-saturated echoplanar DTI sequences (b-values = 0,600 s/mm^2, 20 diffusion directions) were acquired. All images were co-registered using non-rigid registration and the software Elastix (open source: http://elastix.isi.uu.nl/) in order to correct for motion. Parameter maps of renal perfusion and fractional anisotropy (FA) were calculated. Maps of apparent diffusion coefficients (ADC) were obtained using a mono-exponential fit. In addition, pure diffusion (ADC$_{Diff}$) and the perfusion fraction of diffusion (Fp) were determined using a bi-exponential model. Serum creatinine was examined daily during the first 10 days after transplantation as well as three months afterwards. Based on these parameters DGF was diagnosed by a nephrologist and was defined as failure of serum creatinine to decrease by at least 10% daily on 3 successive days or need for dialysis during the first week after transplantation. Renal biopsy was available in 16/40 patients. Statistical analysis comprised unpaired t-tests for comparison of functional MRI parameters between patients with normal initial graft function and DGF and correlation analysis between MRI parameters and serum creatinine. Values are given as mean±SEM.

Results: DGF was diagnosed in 19/40 patients. Patients with DGF were significantly older (59.7±2.6 years vs. 47.8±3.5 years; p<0.05), received more often transplants form cadaveric donors (not significant), donor serum creatinine was higher (132±25 **µ**mol/L vs. 66±4 **µ**mol/L; p<0.05) and cold ischemia time was longer (12±2 h vs. 8±1 h; p<0.05). 8/9 patients with acute rejection at histology met DGF criteria. Renal perfusion was significantly decreased in patients with DGF compared to patients with normal initial graft function (213±79 vs. 329±70 ml/(min*100g), p<0.001). Furthermore, in DGF patients mono-exponential ADC (1.73±0.03 vs. 1.94±0.03*10^{-3} mm^2/s, p<0.001) as well as ADC$_{Diff}$ (1.31±0.03 vs. 1.40±0.03*10^{-3} mm^2/s, p<0.05) and the perfusion fraction of diffusion (0.25±0.01 vs. 0.30±0.02*10^{-3} mm^2/s, p<0.01) were significantly lower than in patients with normal initial graft function. Also, diffusion anisotropy (FA) in the renal medulla was impaired in patients with DGF (0.230±0.067 vs. 0.302±0.067; p<0.01). Examples of MRI parameter maps are shown in Figure 1. Renal perfusion and FA were inversely correlated with serum creatinine at the day of MRI (r=-0.73 and r=-0.65, respectively; p<0.001) as well as at 3-months follow-up (r=-0.41 and r=-0.42, respectively; p<0.05). Mono-exponential ADC only correlated with serum creatinine at the day of MRI (r=-0.59, p<0.001).
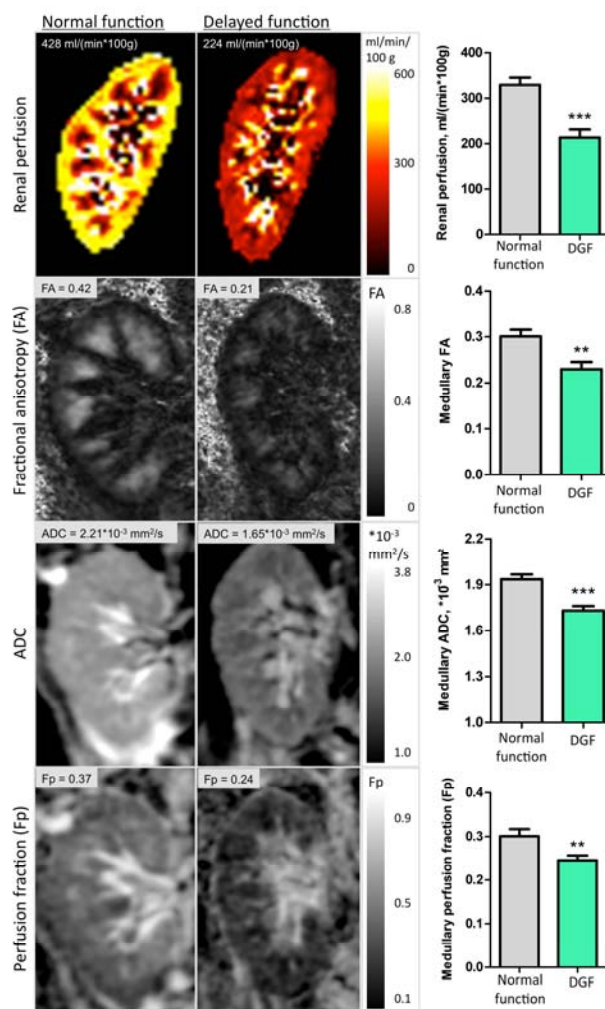

Figure 1: Examples of MRI parameter maps of one patient with normal initial graft function (left) and one with DGF (right) are shown. Furthermore, mean±SEM of the parameters are given and significant differences are indicated. **p<0.01, ***p<0.001.

Discussion: Multiparametric functional MRI by assessment of renal perfusion, tissue diffusion and renal microstructure enables detection of DGF and significantly correlates with renal allograft function. Thus, functional MRI techniques may be useful for risk stratification during the early post-transplantation period and may provide additional information to kidney biopsy.