ISMRM 2008

Diffusion-weighted MRI of the kidneys: beyond morphology?

Harriet C. Thoeny

Functional magnetic resonance imaging appears to hold promise as noninvasive imaging modality in the detection of early structural and functional changes of different organs. Diffusion-weighted MRI (DW-MRI) is a MR imaging technique based on the Brownian motion of the spins in biologic tissues. The apparent diffusion coefficient (ADC) as a quantitative parameter calculated from the DW-MR images reflects the microenvironment of diffusing water molecules. In addition to diffusion, the ADC simultaneously provides information on microcirculation-including capillary perfusion - provided that these entities can be separated. Since the main kidney functions are related to transportation of water (glomerular filtration, active and passive tubular reabsorption, and secretion), diffusion characteristics may provide insight into structural and functional consequences of different renal diseases.

In contrast to neuroradiology, where DW-MRI is the gold standard in the detection of an acute stroke, its application in abdominal organs is somewhat delayed due to technical challenges, in particular respiration, cardiac motion, and peristalsis.

Several articles dealing with DW-MRI of the kidneys have been published. However, most of these have been preliminary and performed in healthy volunteers investigating the feasibility of DW-MRI and addressing technical aspects. Recently, DW-MRI has shown decreasing ADC values in foetuses during the first gestational weeks (up to 28 weeks) with no significant change thereafter. DW-MRI has been shown to be able to detect various renal pathologies of fetal kidneys. In children, an age-dependence of the ADC could be observed with the greatest changes during the first years of life. In healthy volunteers there has been an ongoing controversy about whether the ADC values are greater in the cortex or the medulla. Furthermore, the reported ADC values of healthy native kidneys show large variations. These differences are primarily due to the selected b-value ranges and hamper comparison between studies.

In experimental settings, DW-MRI has been applied in the evaluation of renal artery stenoses and ureteral obstruction in pigs showing a decrease in ADC in both pathologies. In another study on pigs, DW-MRI was able to differentiate acute and chronic ureteral obstruction. Diabetic rats with cellular edema showed significantly lower ADC values in the kidneys compared to the control group; these results correlated with histopathological findings. A decrease of the ADC has been described in dog kidneys following ischemia induced by renal artery ligation.

In patients with acute and chronic renal failure, ADC values in cortex and medulla were significantly lower than those of normal kidneys. Also in patients with renal artery stenoses the ADC values in the cortex, but not in the medulla, where significantly lower than those of normal and contralateral kidneys. Furthermore, a relationship between renal ADC values and glomerular filtration rate has been reported. DW-MRI may also be applied to differentiate pyonephrosis from hydronephrosis. In renal tumors different ADC values were observed compared to the normal renal parenchyma.

DW-MRI has been applied in an experimental rejection model of transplanted kidneys, where ADC values in the cortex and medulla decreased significantly, suggesting the potential of this method for monitoring early graft rejection. Recently, DW-MRI has also been applied in human renal allografts and demonstrated its reproducibility and differences compared to native kidneys.

Since the detection of nephrogenic system fibrosis noninvasive imaging without any contrast medium administration gained importance for the accurate, safe and early detection of renal pathologies in native kidneys and allograft dysfunction after kidney transplantation.

DW-MRI has a great impact on the management of various renal diseases in native and transplanted kidneys. However, a strong collaboration between physicists, radiologists and clinicians is the prerequisite for the successful realisation of this challenging and promising technique.