Diffusion Imaging of Focal and Diffuse Renal Diseases

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In recent years diffusion-weighted MRI (DW-MRI) gained increasing importance in applications outside the brain. The main applications of this noninvasive technique in the body focus on tissue characterization, functional evaluation and predicting and monitoring treatment response in a broad spectrum of lesions and organs (1). The kidney is a particularly interesting organ to analyze by DW-MRI because of its high blood flow and water transport functions. DW-MRI has already been successfully applied in fetal imaging and in children providing information on normal renal development (2,3,4,5,6) with the consequent potential of disease assessment.

In the evaluation of focal renal lesions DW-MRI is helpful to differentiate solid from cystic lesions in patients at risk for NSF where no contrast medium should be administered. The characterization of renal masses (ie, viable solid tumors, necrotic or cystic tumor areas, and benign cysts) based on the underlying ADC and the T1 signal characteristics was assessed on 26 focal renal lesions (median size was 8.2 cm; range: 1.7-18.5 cm) in 25 patients (7). Renal tumors had significantly lower ADCs compared with benign cysts ($P<.001$). In solid enhancing tumors significantly lower ADCs compared with nonenhancing necrotic or cystic regions ($P=.007$) were reported. Furthermore, T1 hyperintense lesions had lower ADC values compared with their hypointense counterparts (7). Interestingly, necrotic and cystic tumor areas had significantly lower ADC values compared with simple cysts. Furthermore, DW-MRI might be useful to differentiate renal cell carcinomas (RCCs) from oncocytomas and to distinguish papillary from nonpapillary tumors based on their underlying ADC values as shown in a single center study and a relatively small number of lesions (8).

In diffuse renal disease however diagnosis based on morphology arrives usually late in the time course of the disease process and adequate treatment is therefore often delayed. DW-MRI has shown promising results for the evaluation of acute and chronic renal failure with decreased ADC values reported in this group of patients (9,10,11,12,13) compared to healthy volunteers. These promising results were confirmed by a study investigating the relationship between ADC values and the split glomerular filtration rate (GFR) measured by 99Tcm-DTPA scintigraphy (11). There

was a statistically significant difference in renal ADCs among the four groups with different degrees of renal impairment ($P<0.001$).

In patients with acute ureteral obstruction DW-MRI using a biexponential fitting approach for image analysis allowed to detect changes in perfusion and diffusion, whereas the ADC value calculated by monoexponential fitting did not reveal any significant difference between obstructed and contralateral nonobstructed kidney (10). The differentiation between hydronephrosis and pyonephrosis is another important clinical challenge where lower ADC values could be observed in patients with pyonephrosis compared to those with hydronephrosis (14,15). DW-MRI for the assessment of kidneys with renal artery stenosis in humans showed that ADC values in the cortex were significantly lower in the affected kidney than those of the normal and contralateral kidneys ($P<0.001$) (9). In the medulla the noted difference was not significant. An animal study performed on dogs with induced renal ischemia corroborated the findings published in humans showing deceased ADC values in all layers of the kidney following ligation and remained lower compared to the contralateral kidney even after release of the ligation (16). DW-MRI providing information on structural changes is an ideal method to overcome the drawbacks of radiation exposure and contrast medium administration in patients with pyelonephritis although up to date only reports on single cases were published (10,15,17,).

Although MRI and CT are excellent imaging modalities in the diagnostic work-up of a vast variety of renal pathologies, DWI showed already promising results as noninvasive and sensitive technique to provide information one step beyond morphology.

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