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Diffusion weighted MRI in evaluation of transplanted kidney: Preliminary clinical experience

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Abstract

Purpose: To evaluate the diagnostic performance of Diffusion Weighted (DW) magnetic resonance (MR) imaging in evaluation of transplanted kidneys.

Patients and methods: One hundred twelve patients with transplanted kidney from live kidney donors were evaluated with coronal T2w and DW MRI of the kidney. There was 86 males and 26 females and the mean age was 26.9 ± 11.5ys (range10-55). Apparent diffusion coefficient (ADC) was calculated and the kidneys studied for any areas diffusion restriction. Our patients classified into 2 groups: Group 1 included 81 patients with stable kidney function and normal serum creatinine and the second group included 31 patients with altered kidney function, it includes 18 patients with chronic nephropathies and 13 patients with acute cellular rejection.

Results: The mean ADC values for group 1 was 2.7 ± 0.26 x 10^{-3} mm^2 /sec (range 1.93-3.6). In cases of chronic nephropathies, the mean ADC values was 2.3 ± 0.22mm^2/sec (range 2.05-2.77) while in cases of acute cellular rejection it was 1.8 ± 0.2mm^2/sec (range 1.7-2.2). When we use the 2.4mm^2/sec as a low cutoff ADC value for diagnosis of normal kidney function, the sensitivity, specificity and overall accuracy for DWI MRI was 80%, 96% and 93.5% respectively.

When we used the ADC value of 2mm^2/sec as a cutoff value between acute cellular rejection and chronic nephropathies, the sensitivity, specificity and overall accuracy of DWI MRI was 90%, 98% and 90% respectively.

Conclusion: In this relatively large study including stable and abnormal function in transplanted kidneys, we can conclude that DW MRI is relatively a new technique that allows diagnosis of transplanted kidney with normal and altered function.

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Introduction

Renal transplantation is the preferred mode of renal replacement therapy in end stage renal disease [1]. Accurate, safe, and early detection of allograft dysfunction after kidney transplantation remains a major challenge. Functional magnetic resonance (MR) imaging appears to hold promise as a noninvasive novel approach to aid in the detection of early functional changes [2-5].

Diffusion-weighted imaging (DWI) provides quantification of Brownian motion of water protons by calculating the apparent diffusion coefficient (ADC), and can be used for in vivo quantification of the combined effects of capillary perfusion and diffusion [6].

Since the main kidney functions are related to transportation of water (glomerular filtration, active and passive tubular reabsorption, and secretion), diffusion characteristics may provide useful insight into the functional consequences of different renal

diseases. DW MR imaging has been used to examine transplanted kidneys in an animal study [7]. In the experimental transplant rejection model, ADC values in the cortex and medulla decreased significantly, suggesting the potential of this method in monitoring early graft rejection [8].

The aim of our study is the evaluation of the diagnostic performance of Diffusion Weighted (DW) magnetic resonance (MR) imaging in evaluation of transplanted kidneys from the live kidney donors in both normal and impaired kidney functions.

Material and methods

The local ethics committee of our hospital approved the study, and consent was taken from all of our patients.

The study included 112 patients who underwent kidney transplantation at our center from live donors. The patients who were included in the study; were 86 males and 26 females, their mean age was 26.9 ± 11.5ys (range 10-55). We divided our patients into 2 main groups; first group included patients with stable graft function and normal serum creatinine (≤ 1.3 mg/dl) and all the patients in this group were studied at the day 14th after transplantation as a basal study. The second group included patients with impaired kidney function and high serum creatinine, their mean serum creatinine 3.3 ± 1mg/dl (range 1.8-7) and the mean interval between transplantation and MR study was 8.6 ± 6 ys (range 10 days-18ys).

MR Imaging protocol: MRI study was performed with a 1.5T imager (Signa-Horizon, GE medical system, Milwuakee; Wis). For morphological evaluation and accurate anatomical localization of the transplanted kidney we initially acquired coronal T2w images for the kidney with the following parameters [Time of repetition (TR), 10000-14000 msec; (Time to echo (TE), 80-90msec; section thickness 4mm; intersection gap 1mm; Matrix, 256x192; Number of excitation (NEX),2; Field of view (FOV), 36cm] we acquired 24 images for the kidney. Then, with the patient free breathing, DW images were obtained in the coronal plane by using a body coil and a monodirectional gradient multisection fast spin-echo echoplanar sequence (TR/TE 8000/61.2; bandwidth, 142 kHz; matrix, 128 x128; section thickness, 4 mm; intersection gap,0 mm; FOV, 36 cm; signals acquired, seven; water signals acquired with *b* values of 0 and 400 sec/mm2). Forty to 54 sections were obtained in 60–120 seconds to cover the pelvis.

Image analysis: We started image analysis by morphological evaluation of the kidney at the coronal T2w for the kidney size and to detect if there is any abnormal signal intensity (SI) or hydronephrotic changes. DW images were analyzed by using software (FuncTool; GE Medical Systems), they analyzed it for any areas of high SI and then regions of interest (ROI) were placed at the midline including all the renal parenchyma but excluding renal sinus and any areas of abnormal high SI. In cases of abnormal focal areas of high SI we took a ROI for it separately. The diffusion weighted values were calculated on a pixel-by-pixel basis to obtain the ADC values.

Ultrasound guided (US) needle biopsy were done for the second group of patients with abnormal graft function to get the histopathology which is the gold standard and we correlated the histopathology with the ADC values. So we can achieve better understanding of the clinical situation through correlation with the radiological and pathological work up.

For statistical analysis the data were processed by using software (SPSS, version 10; SPSS, Chicago, Ill), with stable kidney function or the final histopathologic report as the reference standard. We evaluated the sensitivity, specificity, positive predictive value (PPV), and accuracy of DW and T2-weighted MR images as aids in the identification of abnormal transplanted kidney.

Results

The final histopathological diagnosis of the second group in our study with altered kidney function was; 18 chronic graft nephropathies and 13 acute cellular rejection.

The mean ADC values for the first group that included 81 patients with normal kidney function was 2.7 ± 0.26 x 10^{-3} mm^2 /sec (range 1.93-3.6). In cases of chronic nephropathies, the mean ADC values was 2.3 ± 0.22mm^2/sec (range 2.05-2.77) while in cases of acute cellular rejection it was 1.8 ± 0.2mm^2/sec (range 1.7-2.2).

In cases with normal kidney function the ADC values were higher than in cases with abnormal kidney function, the ADC is more than 2.4mm^2/sec in most of the cases while most cases of acute rejection the ADC value was below 2mm^2/sec. While in cases with chronic nephropathies the ADC values were between 2-2.4mm^2/sec. When we used the 2.4mm^2/sec as a low cutoff ADC value for diagnosis of normal kidney function, the sensitivity, specificity and overall accuracy for DWI MRI was 80%, 96% and 93.5% respectively. When we used

the ADC value of 2mm^2/sec as a cutoff value between acute cellular rejection and chronic nephropathies, the sensitivity, specificity and overall accuracy of DWI MRI was 90%, 98% and 90% respectively (table1).

Morphological analysis of DWI MRI could identify focal areas of restricted diffusion in 7 cases, the appeared a high SI areas at DWI with their mean ADC value was 1.68mm^2/sec (range 1.38-1.8). Two of these cases were acute focal pyelonephritis that were diagnosed at DWI by detecting the extrarenal inflammatory extension with perinephric fat distortion and confirmed contrast enhanced MRI and follow up after medical treatment. The remaining 5 cases had ischemic changes with wedge shape areas of high SI at DWI, the diagnosis was confirmed by contrast enhanced MRI that showed hypoperfusion at the affected areas.

Table 1. ADC values in transplanted kidneys with stable & Abnormal function

	ADC Values	
	Mean±SD	Range
Normal kidney	2.7±0.26 x 10^{-3} mm^2/sec	1.93-3.6
Chronic nephropathy	2.3±0.22x 10^{-3} mm^2/sec	2.05-2.77
Acute cellular rejection	1.8±0.2 x 10^{-3} mm^2/sec	1.7-2.2
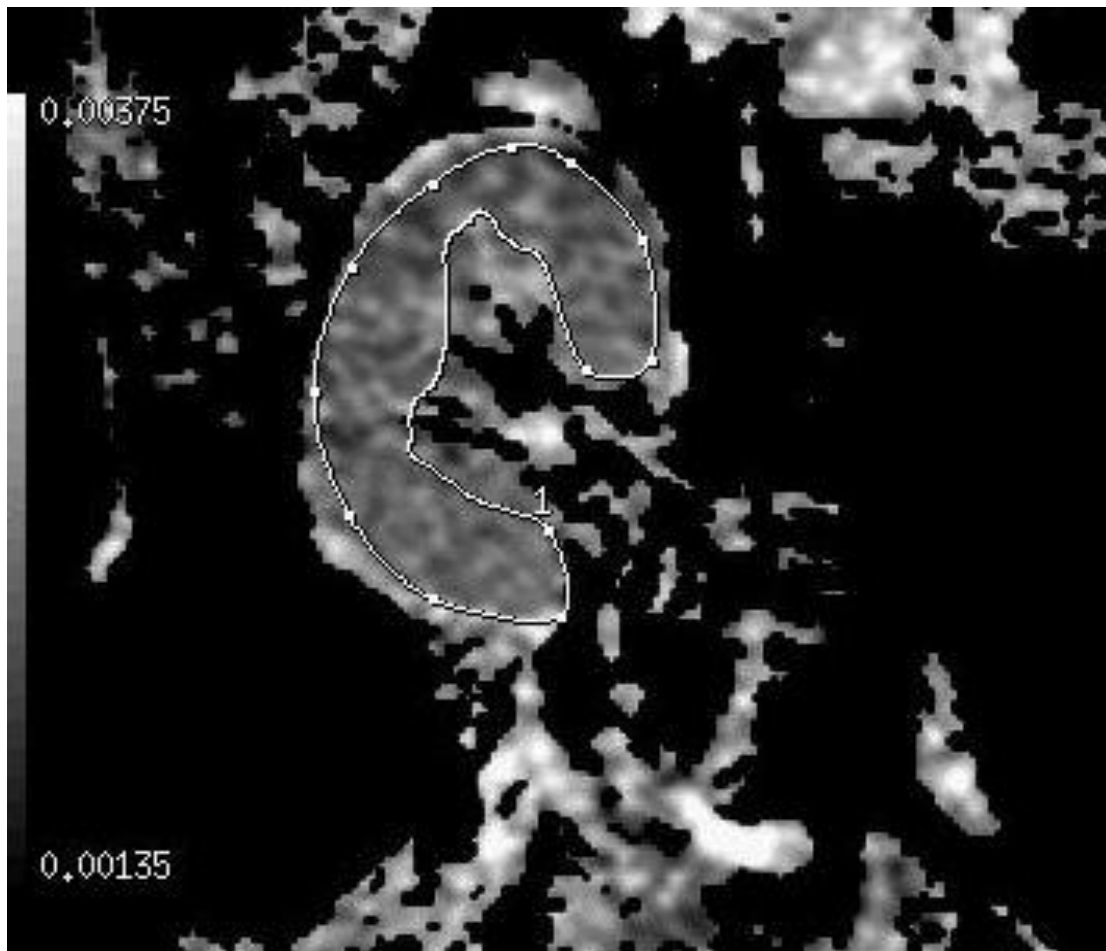
Fig. 1. The ADC map for a case of kidney transplant with stable kidney function, it shows the ROI outline the renal parenchyma.
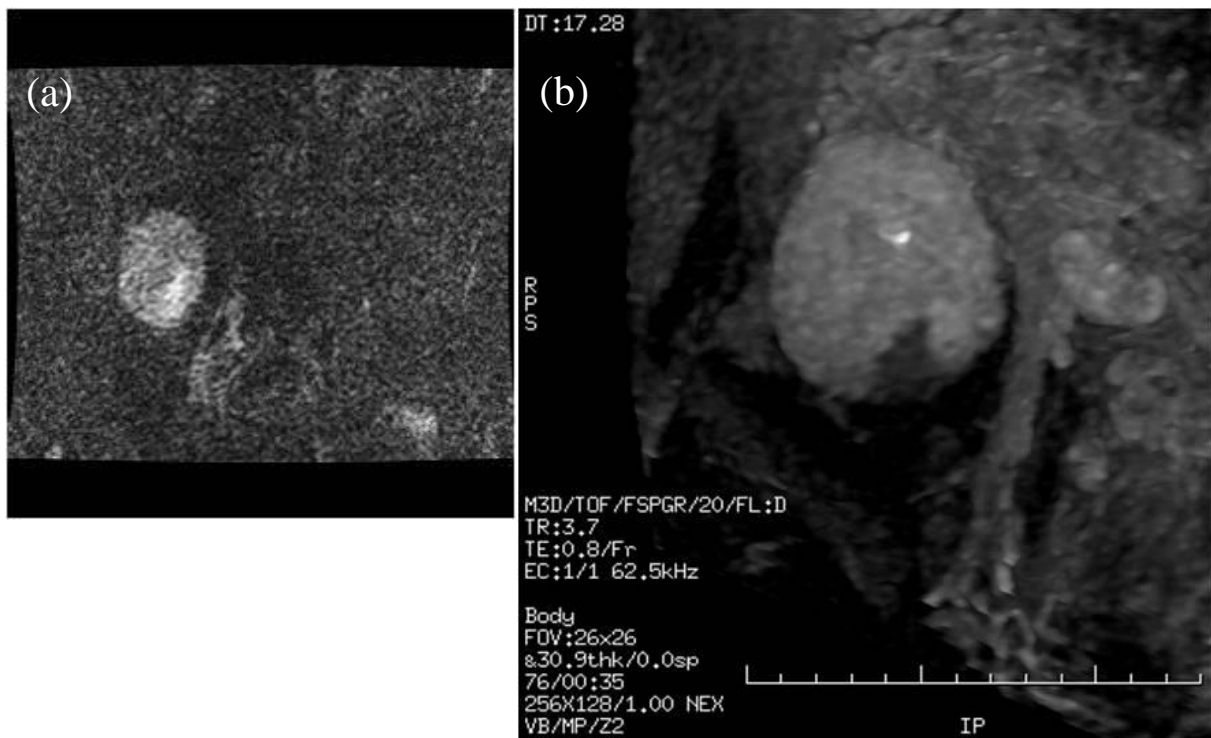
Fig. 2. A case of basal study for transplanted kidney with lower polar infarction (a) DW MRI shows a wedge shaped area of restricted diffusion displaying high SI relative to normal renal parenchyma and it corresponds to a wedge shaped area of hypoperfusion at post contrast MRI(b)

Discussion

Molecular diffusion is a physical process, which is used to describe the Brownian motion of water molecules [8]. The ADC is used as a measure of diffusion in biologic systems, because the measured diffusion coefficient may depend on factors other than Brownian motion, such as perfusion [9]. The kidney is well suited for diffusion studies because of its high blood flow and its fluid transport function [10].

To our knowledge, ADC values in patients with transplanted kidneys and altered kidney function have not been reported previously and this is the first large series including normal and abnormal graft. In a study done by Thoeny etal; they reported the findings in native kidneys, and they reported that the ADC values were virtually identical in the cortex and the medulla of transplanted kidneys [11]. Yang et al [7] used DW MR imaging to assess transplanted kidneys in rats. In agreement with Thoeny etal [11] findings in human kidneys, the ADC values in the native rat kidneys were higher in the cortex than in the medulla, and these corticomedullary differences were smaller in transplanted rat kidneys. In contrast to Thoeny etal

[11] findings, the ADC values in the rats with renal allografts were lower than the ADC values in the rats with native kidneys. Renal allografts in the rats were investigated during the first 4 days after transplantation, whereas our measurements were obtained more than 100 days after transplantation; thus, a direct comparison of the study findings was impossible [11].

Our study included 2 groups of patients; one group with stable kidney function and they were studied at the early post transplantation while the other group with altered kidney function and this group was studied at a different interval post transplantation. We found in our study that the ADC values in patients with stable kidney function were higher than in patients with altered kidney function. As the DW MRI simultaneously provides information on diffusion and microcirculation or perfusion [12]. The perfusion reflects microcirculation of blood and movement in predefined structures, such as tubular flow and glomerular filtration in the kidneys [11]. So; we suggest that in chronic kidney nephropathies there is affection of cellular diffusion while in acute rejection there is affection of kidney perfusion as well as the cellular diffusion and for this reason the ADC values in acute rejection is lower than that in

chronic nephropathy as the mean ADC value in acute rejection in our study was 1.8 ± 0.2mm^2/sec while in chronic nephropathies it was 2.3 ± 0.22mm^2/sec.

In our study the DW MRI have another advantage other than the diagnosis of graft impairment as it can diagnose the ischemic changes in the kidney as well as the focal pyelonephritis with high accuracy without using the gadolinium based MR contrast agents that carry the risk of nephrogenic systemic fibrosis in patients with impaired kidney function.

Conclusion

In this large study including stable and abnormal function in transplanted kidneys, we can conclude that DW MRI is relatively a novel technique that allows detection of restricted cellular fluid in the affected kidneys and it can diagnose the impaired graft function with relatively high specificity and this will allows us in the future to reduce the need for the invasive US guided biopsies with its high associated risk of complications and it also allows the diagnosis of ischemic changes and infection without using contrast media.

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