Diffusion-weighted magnetic resonance imaging findings of kidneys with obstructive uropathy: differentiation between benign and malign etiology

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Purpose

Diffusion weighted-magnetic resonance imaging (DW-MRI) is used to show Brownian motion of the spins in biologic tissues, can be use to differentiate normal and abnormal structures of tissues. The apparent diffusion coefficient (ADC), as main quantitative parameter used to interpret DW-MRIs, combines the effects of capillary perfusion and water diffusion in the extracellular extravascular space [1]. DW imaging has been extensively used in neuroradiology. The applications of DWI in abdominal disease have lagged behind neurologic applications. Because DW-MRI of abdominal organs is much more difficult to perform as a result of physiologic motion artifacts and heterogeneous composition of the organs [2]. With the advent of echoplanar imaging (EPI) in conjunction with breath-holding, DWI of the abdomen has become possible with fast imaging times minimizing the effect of gross physiologic motion from respiration and cardiac movement. The kidney is an interesting organ in which to measure ADC values, because of its high blood flow and water transport functions. With its complex anatomic structure and physiology, kidney is extremely challenging for DW-MRI. [3, 4]. Obstructive uropathy is a structural or functional hindrance of normal urine flow that causing hydrenephrosis. It can occur due to some benign and malign conditions. To date, no papers have been published on MR diffusion imaging in patients of obstructive uropathy for discrimination benign and malignant etiology. The purpose of this study was to evaluate the capability and reliability of DW- MRI in differentiation between benign and malignant causes in obstructive uropathy.
Methods and Materials

Forty-one patients with hydronephrotic kidneys, 26 patients (20 male and 6 female; mean age, 58; age range, 24-90 years old) with benign etiology and 15 patient (10 male and 5 female; mean age, 62; age range 21-80 years old) with malign etiology and 26 healthy volunteers (8 male and 21 female; mean age 49; age range, 27-65 years old) who had no history of renal disease and had normal creatine level (0.7±0.12) were included in this study. Seven of 26 patients with benign etiology and seven of 15 patients with malignancy, had bilateral hydronephrosis. Therefore fifty-five kidneys of 41 patients and fifty-two kidneys of 26 healthy volunteers underwent MRI. Thirty-three kidneys of obstructive uropathy with benign etiology were consist of benign prostatic hyperplasia (n=10); ureter stone (n=5); narrowness of ureter (n=8); nephrolithiasis (n=8); retroperitoneal fibrosis (n=2). The twenty-two kidneys of obstructive uropathy with malignant etiology were consist of bladder cancers (n=9); colon cancers (n=2); cervical cancers (n=3); uterine cancers (n=1); prostate cancers (n=1); retroperitoneal tumors (n=2) and pelvic tumors (n=4). All volunteers were consist of hepatic hemangioma patients with upper abdominal MRI study. Serum creatinine values were obtained from all patients on the day of the MR examination. The local ethics committee approved the study protocol, and informed consent was obtained from all volunteers and patients.

MR imaging was performed using with a 1.5T whole-body superconducting MR scanner (General Electric signa hi-speed scanner, Milwaukee, WI, USA) equipment with hi-speed gradients. Body coil was used for all images. Axial T2-weighted fat saturation spin-echo images (TE:90, TR:5700, slice thickness 8 mm, intersection gap 1.5, number of excitation 4, matrix size, 512 x 512) were obtained in all patients for demonstration of pelvicalyceal system. DWIs (TE:72, TR:8000, FOV:30x30, slice thickness:5 mm, intersection gap:0, number of excitation:1, matrix size:128 x 128) were obtained using single-shot spin-echo, echo-planar imaging (EPI) sequences with the following diffusion gradient b values: 100, 600, 1000 s/mm². Obtained maximum slice 26-40, examination time 30 s, direction of diffusion all. All images were obtained without breath-holding.

The DWI data were transferred to workstation (Advantege Windows, software version 2.0, GE Medical systems). A large circular region of interests (ROI) were placed in the corticomedullar junction for the measurement of ADC values normal and obstructed kidneys (Fig. 1). For each kidney, three ROIs were placed middle portion of the kidneys and mean ADC values with standard deviations were calculated. ADC maps were calculated automatically with the MR system.

Statistical analysis was performed with the SPSS 12.0 software packages program. The ADC values of the volunteers and patients with obstructed uropathy are reported as the mean ± standard deviation. Independent samples t test was used for the comparison of
paranchymal ADC values of the normal kidneys and the obstructed kidneys which had benign and malign ethiology. A $p$ value of less than .05 was considered to indicate a statistically significant difference.
Fig. 1: Axial apparent diffusion coefficient (ADC) map calculated from echo-planar diffusion weighted images of healthy and hydronephrotic kidneys with high b value at the central portion of normal healthy kidneys (a,b) and hydronephrotic kidneys (c,d). A large circular region of interests (ROIs) were placed in the corticomedullar junction for the measurement of ADC values normal and obstructed kidneys.

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Results

The significant declines were observed in renal signals with an increasing in the value of $b$, in the healthy and obstructed kidneys. The color change was observed on ADC maps, which were created from DW echo-planar images, depending on increasing $b$ value and decreasing ADC coefficients, The coloration was observed much more in hydronephrotic kidneys than normal kidneys, compatible with lower ADC values (Fig. 2). While some hydronephrotic kidneys were large size, other part of them were in normal size.

The mean renal ADC values in patients of hydronephrosis with benign etiology were $3.12\pm 0.61 \times 10^{-3}$, $2.38\pm 0.45 \times 10^{-3}$, $1.93\pm 0.33 \times 10^{-3} \text{mm}^2/\text{sn}$ and patients of hydronephrosis with malign etiology were $3.28\pm 0.44 \times 10^{-3}$, $2.57\pm 0.68 \times 10^{-3}$, $1.83\pm 0.17 \times 10^{-3} \text{mm}^2/\text{sn}$; whereas mean renal ADC values in healthy volunteers of control group were $3.55\pm 0.29 \times 10^{-3}$, $2.67\pm 0.49 \times 10^{-3}$, $2.09\pm 0.19 \times 10^{-3} \text{mm}^2/\text{sn}$ for b100, b600 and b1000 values, respectively. ADC measurements of renal parenchyma in all hydronephrotic kidneys with benign and malign etiology were found to be extremely low compared to normal kidneys ($p<0.05$) (Table 1).

There was statistically significant difference between ADC values of hydronephrotic kidneys with benign causes and normal kidneys. Mean ADC values of hydronephrotic kidneys with benign etiology were statistically significant lower than mean ADC values of normal kidneys for each b100, b600 and b1000 ($p<0.05$). Mean ADC values of hydronephrotic kidneys with malign causes were found lower than mean ADC values of normal kidneys, for each b100, b600 and b1000.

In the obstructed kidneys with benign etiology, minimum and maximum values of ADC were ranging from (1.45 to 4.10) x $10^{-3}$. In the obstructed kidneys with malign etiology, minimum and maximum values of ADC were ranging from (1.49 to 4.02) x $10^{-3}$. Obstructed kidneys with malign etiology had lower ADC values for b1000 compared to obstructed kidneys with benign etiology but these alterations were statistically insignificant.
Fig. 1: Axial apparent diffusion coefficient (ADC) map calculated from echo-planar diffusion weighted images of healthy and hydronephrotic kidneys with high b value at the central portion of normal healthy kidneys (a,b) and hydronephrotic kidneys (c,d). A large circular region of interests (ROIs) were placed in the corticomedullar junction for the measurement of ADC values normal and obstructed kidneys.

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Fig. 2: Axial ADC map calculated from echo-planar DWI of hydronephrotic kidneys with high b value. The coloration of yellow-green was observed significantly in right hydronephrotic kidney compatible with lower ADC values. The ROIs are placed at three locations: anterior labrum, intermediate site and posterior labrum.

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Fig. 3: Comparison of parenchymal ADC values of obstructed kidneys with benign-malign etiology and normal kidneys, for b100, b600 and b1000 (mm²/sn)

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Conclusion

Hydronephrosis is a common disease of urological clinical practice, which is one of the major causes of renal insufficiency and renal failure. Dilatation of the renal pelvis and calyceal system can occur even in the absence of urinary obstruction; therefore, hydronephrosis and obstructive uropathy are not interchangeable or synonymous terms [5]. Obstructive uropathy is a structural or functional hindrance of normal urine flow and it can occur due to some benign and malignant causes. Common causes include bladder stones, kidney stones, benign prostatic hyperplasia, bladder or ureteral cancer, colon cancer, cervical cancer, uterine cancer, scar tissue that occurs inside the ureters and problems with the nerves of bladder [5,6]. Up to now, there are various approaches for trying to define what obstruction really means, including ultrasonography (US), intravenous urography (IVU), diuretic renal scintigraphy (DRS), computed tomography imaging and MRI. MRI can correctly identify the point of obstruction and the non-calculous causes of obstruction. MR excretory urography is a promising technique which affords equivalent functional and additional anatomical information to isotope renography [5].

DW-MRI allows non invasive measurement of ADC values and, in a clinical setting, provides simultaneous information on diffusion and perfusion of kidneys. When applying high b-values, the influence of perfusion is largely cancelled-out, and the ADC value approximates diffusion, and low b-values are influenced by both perfusion and diffusion [7]. DWI can also potentially provide split renal function without the use of exogenous contrast agent. The technique can be implemented in routine practice without a significant time penalty. The lack of consensus regarding the selection of b values makes it difficult to compare results from different investigators and to generate standardised ADC values in disease and health. It is also important to choose ROIs in the proper portion of the kidney. Some authors [8,9] have reported higher values in the medulla as compared with the renal cortex. In our study, we did not try to evaluate ADC values in the cortex and in the medulla separately because it may be difficult and inaccurate to position the ROI cursor on the renal cortex and medulla of the kidney separately, as already pointed out by Fukuda et al [10]. Evaluation of ADC values in the middle portion of the kidneys is suggested to be less influenced by the perfusion effect. In our study the ROI cursors were placed at the approximate level of the corticomedullary junction. In the mesorenal area we preferred the evaluation recommended by Fukuda et al [10].

Several studies have investigated the use of DWI for hyronephrotic kidney. In a study by Bozgeyik et al.[11] demonstrated that an early-phase obstructed non-functioning kidney has statistically insignificant lower ADCs value, compared to the contralateral normal functioning kidney. Similarly, in the evaluation of patients with hydronephrosis, Toyoshima et al. showed that hydronephrotic kidneys with moderate and severe decreases in renal function as assessed with renal scintigraphy had significantly lower
mean ADC values than hydronephrotic kidneys with maintained renal function [12]. Thoeny et al.[3] have reported DW-MRI of the kidneys in healthy volunteers and patients with various renal abnormalities. In their study, the patients with acute ureteral obstruction DW-MRI did not reveal any significant difference between obstructed and contralateral nonobstructed kidney. They also demonstrated that all ADC values of the kidneys in the patients with pyelonephritis were substantially lower compared with the opposite site. In addition to this, they showed that the patients with renal failure had significantly lower ADC of the cortex and medulla than did volunteers. Verswijvel et al.[9] reported lower ADC values in affected parenchymal areas in three patients with acute pyelonephritis, in one case of pyogenic abscess and in one patient with xanthogranulomatous pyelonephritis, compared with the normal renal parenchyma. Chan et al.[13] reported in a series of 12 patients, the authors showed that the pelvicalyceal system of the hydronephrotic kidneys ($n=8$) was hypointense on DW images while the pelvicalyceal system of the pyonephrotic kidneys ($n=4$) was markedly hyperintense compatible with restricted diffusion. These studies highlight the potential role of renal ADC values in the evaluation of hydronephrotic kidneys.

We concluded many pathological renal conditions, such as chronic renal failure, pyelonephritis, or obstructive disorders, decrease the ADC values of kidneys. Yet, to the best of our knowledge, the effect of obstructive uropathy with benign versus malignant etiology on the ADC values of kidneys has not been reported. In the present study there was statistically significant difference between the ADC values of patients with obstructive uropathy and normal healthy volunteer, with lower ADC values of hydronephrotic kidney compatible the previous studies in the literature. But we did not find statistically significant difference between the ADC values of patients of obstructive uropathy with benign versus malignant etiology.

In conclusion DW MRI seems to be a feasible and reliable method to differentiate normal healthy kidney and hydronephrotic kidney. On the basis of this study, this technique could be applied in the clinical area as a rapid addition to existing kidney MRI protocols and thus provide DW images of diagnostic quality as well as quantitative data regarding diffusivity. The present study is our initial experience about DW-MRI of the kidneys in patients of obstructive uropathy with benign and malignant etiology and further studies with using ROIs in different localisation (for example renal pelvis) and with larger series of obstructive uropathy patients are warranted to assess the efficacy of DW-MRI for the discrimination etiology.
References


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