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ORIGINAL PAPER

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Contribution of diffusion weighted MRI to the differential diagnosis of renal masses

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ABSTRACT

Introduction and aim. We aimed to assess the usefulness of diffusion weighted imaging (DWI) and apparent diffusion coefficients (ADCs) for characterizing renal masses.

Material and method. In this retrospective study we measured the ADC values of renal masses at b=0, b=500 and b=1000. Measurements were made by placing a circular region of interest with a diameter of 1 cm.ADC values from normal renal parenchyma were taken to define the ADC and to compare with the ADC values of the lesions.

Results. A total of 72 lesions of 54 patients were included.40 of the masses were benign and 32 were malignant. The ADC values of benign lesions at both b values were significantly higher than malignant lesions. We found the lowest values in angiomyolipomas (AMLs) and oncocytomas and the highest values in Bosniac type I cysts. Similarities was found between the ADC values of some AMLs and the RCCs. In terms of statistical results, the inclusion of AMLs in the analysis did not significantly affect the difference between malignant and benign lesions.

Conclusion. In our study, the ADC values of benign renal masses were higher than those of normal renal parenchyme, which is higher than those of malignant renal masses.The lowest ADC values were observed in AMLs and oncocytomas.

Keywords. apparent diffusion coefficient, diffusion weighted imaging, renal neoplasms

Introduction

Benign and malignant kidney lesions can originate from different tissues. Characterization of renal masses is needed in the treatment planning. Renal cell carcinoma (RCC) is the most common malignant kidney tumor in adults.[1] There are three major subtypes of RCC: clear cell RCC, papillary RCC and chromophobe RCC. Since these subtypes have different prognoses and responses to molecular therapy, subtyping is important and cross-sectional imaging is essential for the detection and characterization.[2-4] Magnetic resonance imaging (MRI) has many advantages including high contrast resolution, absence of ionizing radiation, less toxicity of its contrast agents compared to iodinated contrast agents. Diffusion

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weighted imaging (DWI) is a method that enables the characterization of biological tissues based on the diffusion properties of water molecules. However, since this method is sensitive to cardiac, respiratory and peristaltic movements, its use in the early days was limited in brain examination. Nowadays, with the development of fast MRI sequences such as echo-planar imaging (EPI), it has started to be used in other body areas effectivelly. Since the sequences used in DWI is also T2 weighted, "apparent diffusion coefficient" (ADC) maps with only diffusion effect are created to erase the T2 effect.[5]

Aim

The main purpose of our study is to determine DWI findings of various renal masses and to investigate their contribution to the diagnosis regarding benign and malignant differentiation by presenting the characteristic features and calculating the ADC values that may be useful in differential diagnosis.

Material and methods

In this retrospective study we measured the ADC values of renal masses of 54 cases at b=0, b=500 and b=1000. Measurements were made by placing a circular region of interest (ROI) with a diameter of 1 cm on the lesions. In the relatively homogeneous lesions larger than 2 cm, the average of 3 separate ROI measurements in the same slice was calculated. On the other hand, for the lesions with heterogeneous internal structure, the measurements were made from the solid parts that enhances on postcontrast images and shines most on DWI. The ADC value of the lesions with a diameter of 1 cm was made by using a single ROI. In addition, the average of 3 different ADC values from normal renal parenchyma were taken to define the ADC and to compare with the ADC values of the lesions.

Statistical analysis

Data were analyzed using the IBM SPSS Statistics 22 (IBM SPSS, Turkey). The conformity of normal distribution of data was evaluated by Shapiro-Wilk test. In addition to descriptive statistical methods (mean, standad deviation), in the comparison of parametes in two goups student t test was used. ROC curve analysis was used to establish a cut-off point and the significance level for the study was set as $p<0.05$.

Results

A total of 72 lesions of 54 patients (35 males and 19 females), aged between 26 and 86 (mean 59.5±15.7 years) were included in this study. 40 of the masses were benign (19 Bosniac type 1 cysts, 12 Bosniac type 2 cysts, 3 oncocytomas and 6 angiomyolipomas) and 32 were malignant (31 RCC and 1 transitional cell carcinoma).

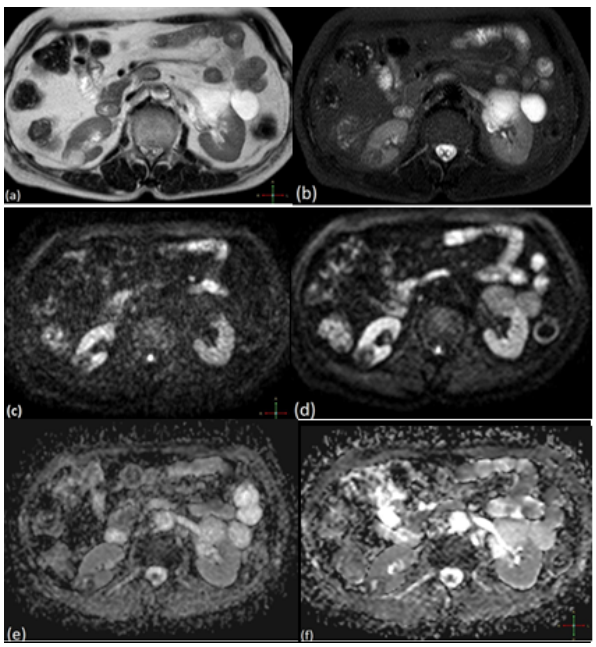

Fig. 1. a-e) Angiomyolipoma of the right kidney in a 78-year-old female patient, which is hyperintense on T 2-w image (a); losing signal in the fat suppressed sequence (b); showing locally restricted diffusion on DWI (c-e); with ADC values measured as $1.21x10^{-3}$ mm^2/s at b=1000 (d) and $1.67x10^{-3}$ mm^2/s at b=500 (e)

The average ADC values of all masses without distinguishing between malignant and benign masses were

Table 1. ADC values of benign-malignant lesions

	Malignant (n=32) (31 RCC and 1 transitional cell carcinoma)		**Benign (n=40)** (19 Bosniac type 1 cysts, 12 Bosniac type 2 cysts, 3 oncocytomas and 6 AMLs)		**p**
	mean $x10^{-3}$ mm^2/s	**SD**	**mean** $x10^{-3}mm^2/s$	**SD**	
ADC value of the lesion at b=1000	1.206**	0.386	2.328	0.713	<0.0001
ADC value of the lesion at b=500	1.413**	0.441	2.524	0.782	<0.0001
ADC value of the normal parenchyma at b=1000	1.920	0.180	1.939	0.164	0.653
ADC value of the normal parenchyma at b=500	2.227	0.252	2.230	0.274	0.954

** $p < 0.01$

found to be 1.72±0.81x10^{-3} mm^2/s at b=1000 and was 1.95±0.82x10^{-3} mm^2/s at b=500 .The average ADC values of 32 malignant masses (1.2x10^{-3} mm^2/s at b=1000 and 1.41x10^{-3} mm^2/s at b=500) were significantly lower than the ADC values of the normal renal parenchyma which was statistically significant (p<0.01). The average ADC values of benign masses were higher than the ADC values of normal renal parenchyma (1.92x10^{-3} mm^2/s at b=1000 and 2.23x10^{-3} mm^2/s at b=500) and it was statistically significant.The ADC values of benign lesions at both b=1000 and at b=500 were significantly higher than the ADC values of malignant lesions (p<0.01). These differences between benign-malignant lesions did not differ significantly between images obtained at b=500 and b=1000 images (Table 1).

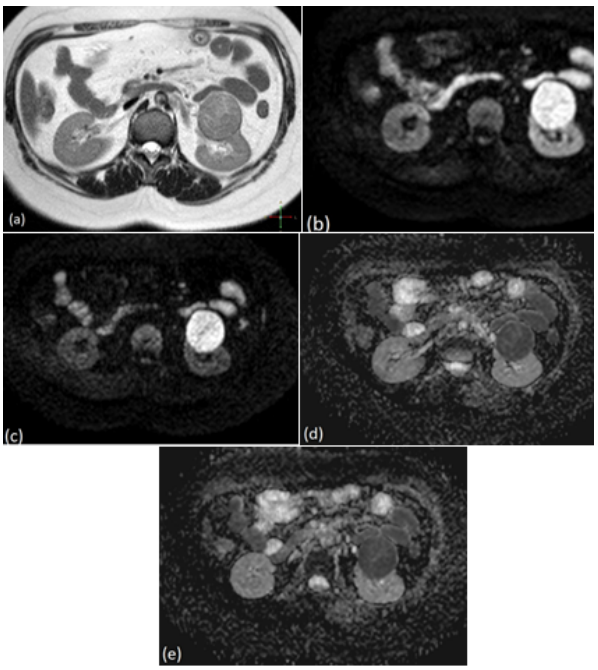

Fig. 2. a-e) Oncocytoma in a 26-year-old female patient. T2-w image shows a hypointense lesion with central linear hyperintity and smooth contours (a); significant restriction on diffusion-weighted images is shown (b-d); with ADC values measured as 0.9x10^{-3} mm^2/s at b=1000 (c) and 1.11x10^{-3} mm^2/s at b=500 (d)

Table 2. ADC values of the AMLs and oncocytomas

	ADC (mean, x10^{-3} mm^2/s)	SD
ADC value of the AMLs at b=1000 (n=6)	1.048	0.510
ADC value of the AMLs at b=500 (n=6)	1.486	0.195
ADC value of the oncocytomas at b=1000, (n=3)	1.286	0.362
ADC value of the oncocytomas at b=500 (n=3)	1.450	0.310

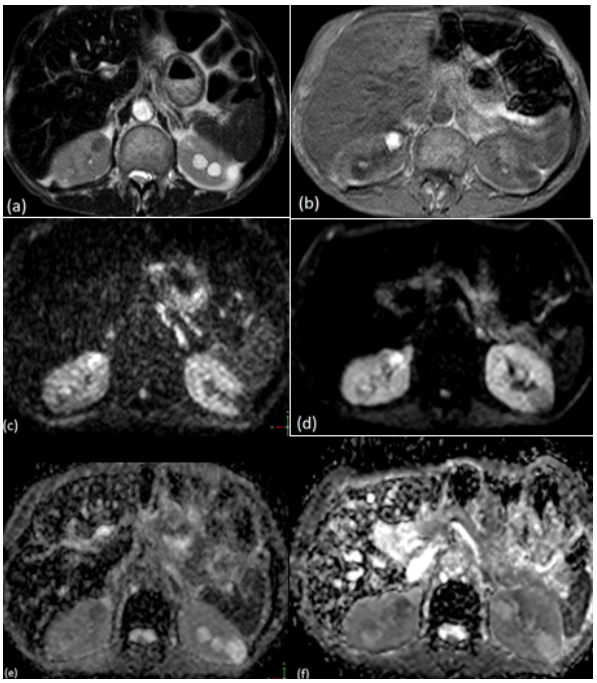

Fig. 3. a-e). Hemorrhagic cyst in the right kidney and simple cysts in the left kidney in a 69-year-old male patient. On T2w images, one hypointense lesion in the right kidney and a few hyperintense lesions in the left kidney are shown (a); On T1w images, the lesion on the right is hyperintense, and the lesions on the left are hypointense (b); While restricted diffusion was observed in the right lesion, it was not observed in the left lesions on DWI (c-f); The ADC value of the right lesion was measured as 1.57x10^{-3} mm^2/s at b=1000 (e) and 1.58x10^{-3} mm^2/s at b=500 (f). The ADC value of the largest left lesion was measured as 3.09x10^{-3} mm^2/sn at b=1000 (e) and 3,50x10^{-3} mm^2/s at b=500 (f)

Among benign masses, we found the lowest values in angiomyolipoma (Fig. 1) and oncocytomas (Fig. 2), and the highest values in Bosniac type I cysts (Fig. 3), (Table 2). It was found similarities between the ADC values of some angiomyolipomas and the ADC values of RCCs (Fig. 4). In terms of sensitivity in distinguishing benign-malignant lesions, AML was first excluded from the analysis. It was then analyzed again by adding AMLs. In terms of statistical results, it was revealed that the inclusion of AMLs in the analysis did not significantly affect the difference between malignant and benign lesions.

Discussion

Randomized movements of molecules depending on their kinetic energies are called as diffusion. Diffusion-weighted MRI is an MRI technique used to show molecular diffusion which is Brownian motions of spins in biological tissues. In conventional MRI, the molecular motion of water contributes a very small amount to the image. With the use of strong gradients, the tissues become sensitive to diffusion of water and DWI can be

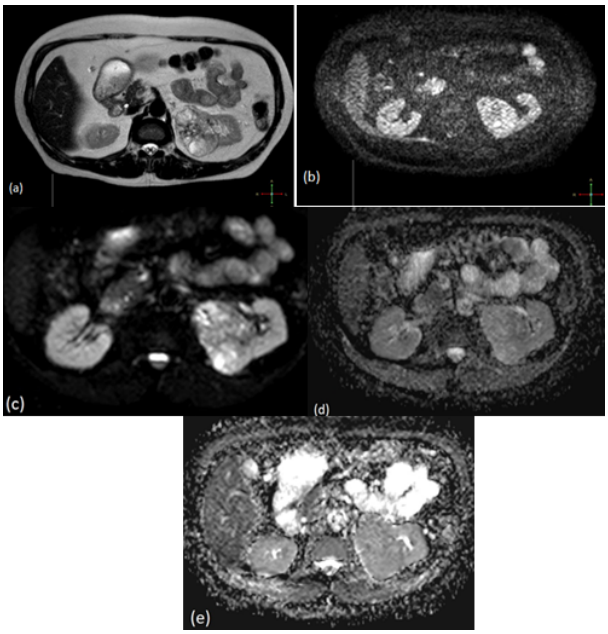

Fig. 4. a-e). Clear cell RCC in a 56-year-old male patient. Heterogeneous hyperintense lesion containing areas of cystic necrosis in the left kidney on T2W images (a); showing restriction on DWI (b-e); the ADC values were measured as 1.68x10^{-3} mm^2/s at b=1000 (d) and 2.05x10^{-3} mm^2/s at b=500 (e)

performed. The kidneys are very suitable for diffusion studies with its high blood flow and its basic function in fluid transport.[6,7] Because of their complex anatomical and physiological structures, kidneys attract a great attention for DWI.[8,9] In a cross-sectional study conducted on 30 patients having renal masses a statistically significant difference was found in mean of ADC values in relation to different types of malignant RCCs, while no statistically significant difference in relation to different types of benign renal masses was found.[10] Although there is no clear consensus on which b value to use in the evaluation of the renal lesions, the recommended b value is between 600 and 1000 s/mm^2.[11] We measured all the ADC values in our study at b value of both 500 s/mm^2 and 1000 s/mm^2. In the study conducted by Cova et al. with 39 cases, ADC values were measured from normal renal parenchyma, areas of the lesion and dilated collecting system. The study found the followings; higher ADC values in simple renal cysts and renal pelvis of hydronephrotic kidneys compared to normal renal parenchyma, lower ADC values in solid kidney tumors and the lowest ADC values in the renal pelvis of pyonephrotic kidneys. [12] Similarly, in our study, the highest ADC values measured at both b values were belonged to simple renal cysts. In a retrospective study including 66 renal tumors of which 33 were clear cell RCC, 9 were papillary RCC, 4 were chromophobe RCC, 11 were oncocytoma and 9 were AML, oncocytomas were found to have the highest ADC values, significantly higher than AMLs and all RCC subtypes.[13] In the study of Taouli et al., ADC measurements of 109 kidney masses at b=400 and b=800 values, 81 of which were benign and 28 of which were malignant were analyzed.[14] They found the average ADC values of AMLs (n=10) lower than RCCs. In the study of Zhang et al., 1 AML case had an ADC value of 1.23x10-3 ^{3} mm^2/s. In the same study, the average ADC value of RCCs was 2.03x10-3 mm^2/s.[15] Doğanay et al. analyzed ADC values by adding and subtracting AML in their study and found a lower average ADC value in AMLs.[16] Kılıçkesmez et al. found that ADC values of AMLs were higher than RCCs and they reported that as the fat content of AMLs increased, ADC values decreased. [17] In our study, ADC values of AMLs were found also to be higher than malignant lesions with no significant difference in terms of statistical results and as the fat content of the AMLs increased, the ADC values decreased in our AML cases. All measurements in our study performed at 2 different b values made from solid parts of malignant tumors and were found to be lower than simple cysts. On the other hand, in some studies in the literature, ADC values of cystic parts of malignant lesions and ADC values of benign cystic lesions were also compared.[14-18] Among these studies, except for those of Taouli et al. [14] ADC values of cystic parts of malignant lesions were lower than ADC values of benign cystic lesions. Zhang et al. reported that although benign cysts and cystic/necrotic renal tumors may look similar in conventional MRI, there is a significant difference in ADC values.[15] There are some limitations of our study including the limited number of the lesions and the limited pathologies (e.g. absence of metastases).In addition, for the malignant lesions the ADC measurements were made from the solid parts and the ADC values of the cystic/necrotic components of the malignant lesions could not be compared.

Conclusion

DWI is useful in differentiating benign and malignant renal masses.In our study, the ADC values of benign renal masses were higher than those of normal renal parenchyma, which is higher than those of malignant renal masses. Among the benign lesions the lowest ADC values were observed in AMLs and oncocytomas. The ADC values of AMLs were higher than those of RCCs.

Declarations

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Author contributions

Conceptualization, N.K. and B.E.; Methodology, N.K. and Z.G.K.; Validation, N.K., B.E., and H.G.D., Formal Analysis, N.K., B.E. and Z.G.K.; Investigation, N.K., B.E. and M.O.A.; Data Curation, N.K., B.E., M.O.A. and

H.G.D.; Writing – Original Draft Preparation, N.K. and B.E.; Writing – Review & Editing, N.K., B.E. and Z.G.K., Supervision, N.K. and Z.G.K.

Conflicts of interest

The authors declare no conflict of interest.

Data availability

The data sets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Ethics approval

Ethics approval was obtained from the Hospital's Ethical Committee.

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