

## Original Research Article

# Role of diffusion: weighted magnetic resonance imaging in evaluation of renal masses

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### ABSTRACT

**Background:** Diffusion-weighted magnetic resonance imaging (DWI) is a valuable tool to narrow down the differential diagnosis of renal masses. Studies have shown that benign renal masses have higher Apparent diffusion coefficient (ADC) value than malignant renal masses. Aim of study was to evaluate the role of diffusion-weighted magnetic resonance imaging in the characterization of renal masses.

**Methods:** The study was conducted in department of Radio diagnosis at ABVIMS and Dr. RML Hospital, New Delhi between June 2017 to March 2019. This was a cross-sectional observational study comprising of 28 patients. Patients found to have renal mass on ultrasound and computed tomography (CT) were evaluated further on 3T siemens Magnetic resonance imaging (MRI) scanner. In addition to routine sequences, DWI using b value of 0,500,1000 s/mm<sup>2</sup> sequence was used to study to differentiate benign and malignant renal masses.

**Results:** Of a total of 28 cases, the most common malignant mass was renal cell carcinoma (RCC). Angiomyolipoma (AML) was the most common benign masses. DWI showed low ADC values in most of the malignant masses and high ADC values in most of the benign masses. The cut-off level of ADC value for differentiation among benign and malignant renal masses was  $1.08 \times 10^{-3}$  mm<sup>2</sup>/s. DWI-MR findings were correlated with histopathological diagnosis.

**Conclusion:** DWI with ADC measurements are a non-invasive, problem solving tool for characterization of renal masses helping to differentiate malignant from benign masses.

**Keywords:** DWI, ADC, Renal mass

### INTRODUCTION

The kidneys are retroperitoneal organs that are generally located on either side of the vertebral column and typically extend from the transverse processes of T12 to L3 vertebrae. Several renal masses are often encountered in clinical practice. Improvement in imaging technology continues to have a significant impact on the diagnosis and treatment of renal masses. Due to the rapid pace in the development of imaging techniques and an increasing number of the investigation being done, several renal masses are discovered incidentally during evaluation of unrelated or non-specific symptoms.

In deciding on a therapeutic approach for different renal masses, it is pivotal to differentiate malignant from benign ones as the choice of treatment varies between reassurance of the patient, radiological follow-up, partial nephrectomy, and radical nephrectomy.<sup>1</sup> Around 16-33% of nephrectomies are performed on benign masses.<sup>2</sup>

A renal mass may be cystic or solid, the most common renal mass being the benign cyst. Most renal cysts are fortuitously found and do not require treatment or additional evaluation. Renal cysts are so common that patients who are over the age of 50 have a 33-50% possibility of having at least one renal cyst.<sup>3</sup>

Benign solid renal masses include angiomyolipoma, oncocytoma, and cystic nephroma. Amongst benign renal masses, angiomyolipoma has the highest prevalence of 7-9%.

The most common malignant renal mass is renal cell carcinoma (RCC), accounting for 2-3% of all renal masses. RCC comprises of  $\geq 80\%$  of renal parenchymal masses. Transitional cell carcinoma forms the majority of renal pelvic tumors.

The subtypes of Renal cell carcinoma (RCC) are:

- Clear cell renal carcinoma (ccRCC), one of the most common types, accounting for 70-80% of cases;
- Papillary renal carcinoma (pRCC), accounting for about 10-15% of cases; and
- Chromophobe renal carcinoma (chRCC), which is the least common, accounting for 5% of all RCCs.

The other solid neoplastic masses encountered in clinical practice are transitional cell carcinoma (TCC), Wilm's tumor, lymphoma, and metastases, squamous cell carcinoma and renal sarcoma.

In the assessment of renal masses, magnetic resonance imaging (MRI) is a useful modality due to multi-planar imaging capabilities, and the possibility of tissue characterization. MRI allows detection and characterization of various renal masses. However, differentiation between cystic masses (Bosniak type 3 and type 4) and cystic RCC, solid masses like oncocytomas and RCCs, as well as different subtypes of RCCs remains challenging.

Diffusion-weighted magnetic resonance imaging (DWI) is a valuable tool to narrow down the differential diagnosis of renal masses further.

Diffusion-weighted magnetic resonance imaging (DWI), which relies on the random motion of free water molecules, can provide information on spatial structure and biophysical characterization of tissues such as cellular density, microstructure, and microcirculation. Neoplastic masses with dense cellularity such as renal cell carcinoma have reduced interstitial spaces and show restricted microscopic mobility of water molecule, within and between intracellular and extracellular spaces, leading to high regional intensity on DWI.

The gradation of water molecules diffusion can be analyzed quantitatively by the apparent diffusion coefficient (ADC) value. The ADC value is inversely proportional to cellular density because increased cellular density restricts water diffusion in the interstitial space. Hence, ADC can act as a predictor in differentiating malignant from benign renal masses and narrow down the differential diagnosis on imaging.

## METHODS

The study was conducted in the department of Radio-diagnosis at ABVIMS and Dr. Ram Manohar Lohia Hospital from November 2017 to March 2019. Informed consent was taken from the patient/attendant/legally acceptable representative for inclusion in the study as per the proforma attached. The patients referred by the clinicians to the Department of Radio-diagnosis for evaluation of renal masses were evaluated by MRI including DWI sequence.

### MRI protocol

MRI was performed with the patient in a supine position using a 3T scanner (siemens magnetom skyra) and a phased array body coil. The following sequences were obtained:

- Coronal T2 weighted half fourier, turbo spin-echo (HASTE).
- Axial T2 weighted half fourier, turbo spin-echo (HASTE).
- Axial T1 fl 2D in-opp phase.
- Axial DWI MR sequence with echo-planar imaging before contrast administration using three b values 0,500, 1000 sec/mm<sup>2</sup> with ADC maps.
- Following DWI, axial fat-suppressed T1W Gradient echo (GRE) sequences volumetric interpolated brain examination (VIBE) before and after administration of an intravenous bolus of 0.1 mmol/kg (2 ml/sec) of gadolinium diethylenetriaminepentacetate (DTPA) followed by 20 ml of saline flush with a power injector at 20, 45, 70, 90, 120 and 180 seconds after the administration of contrast materials.
- Based on diffusion-weighted imaging, the calculated ADC values were used to characterize the mass lesion as benign or malignant.

### Image analysis

The DWI datasets were transferred to an independent work-station for post-processing, and ADC maps were reconstructed. The ADC value was calculated manually by placing a region of interest (ROI) in the tumor. The ROI was chosen to include a solid component of cancer. The necrotic part, which was suggested from T1 and T2 weighted images, was not included in the ROI. The ROI was then copied to the corresponding DW image (b=500, b=1000) and ADC maps. Multiple regions of interest (ROI) for obtaining ADC values were placed within the mass and in contralateral normal renal parenchyma and the average value was taken.

### Statistical analysis

Categorical variables did present in number and percentage (%), and continuous variables were presented as mean $\pm$ standard deviation (SD) and median. The Kolmogorov-Smirnov test was used to check the normality

of data. If the normality did reject, then the nonparametric test was used. Quantitative variables were compared using the independent t-test/Mann-Whitney test (when the data sets did not regularly distribute) between the two groups and ANOVA / Kruskal Wallis test between more than two groups. Paired t-test/Wilcoxon ranked sum test did use for comparison between the ADC value of normal renal parenchyma and masses in benign and malignant. A p value of <0.05 was considered statistically significant. The data did enter in Microsoft excel spreadsheet and analysis was done using Statistical package for social sciences (SPSS) version 21.0.

Each patient's quantitative DWI findings were recorded and subsequently correlated with histopathological results, wherever possible, and ADC values did compare among the disease groups and contralateral normal renal parenchyma.

**RESULTS**

**Table 1: Distribution of cases according to final diagnosis.**

Final diagnosis	No. of cases	% of cases
Renal cell carcinoma	16	57.14
Transitional cell carcinoma	1	3.57
Angiomyolipoma	5	17.85
Oncocytoma	1	3.57
Neuroendocrinal tumor	2	7.14
Rhabdomyosarcoma	1	3.57
Bosniak cyst 1	2	7.14

A total of 28 cases with Computed tomography (CT)/ultrasonography (USG) diagnosis of renal mass underwent MRI examination. Out of 28 patients included in the study, 19 (67.90%) were males, and 9 (32.10%) were females. The cases in our study were in the age range of 20-80 years. Maximum cases were in the age group of 40-50 years (10/28=35.7%). The mean age was 50.21±12.

**ADC values**

In our study, the mean ADC values of Bosniak cyst 1 was highest ( $3.18 \pm 0.05 \times 10^{-3}$  mm<sup>2</sup>/s) among the masses. The mean ADC value for clear cell renal cell carcinoma (ccRCC) was  $0.85 \pm 0.13 \times 10^{-3}$  mm<sup>2</sup>/s,  $1.14 \pm 0 \times 10^{-3}$  mm<sup>2</sup>/s for papillary renal cell carcinoma (pRCC),  $1.06 \pm 0 \times 10^{-3}$  mm<sup>2</sup>/s for transitional cell carcinoma (TCC),  $1.24 \pm 0 \times 10^{-3}$  mm<sup>2</sup>/s for rhabdomyosarcoma (RMS),  $0.58 \pm 0 \times 10^{-3}$  mm<sup>2</sup>/s for neuroendocrine tumor (NET),  $1.31 \pm 0 \times 10^{-3}$  mm<sup>2</sup>/s for oncocytoma,  $1.15 \pm 0.14 \times 10^{-3}$  mm<sup>2</sup>/s for angiomyolipoma (AML).

**Table 2: The mean ADC values for benign and malignant masses.**

ADC Value	Benign	Malignant	P value
Mean ADC±SD	1.73±1	0.89±0.3	0.011
Median	1.28	0.88	
Min-max	0.98-3.22	0.44-1.31	

The mean ADC of normal renal parenchyma ( $1.55 \pm 0.12 \times 10^{-3}$  mm<sup>2</sup>/s) was lower than the benign lesions ( $1.73 \pm 1 \times 10^{-3}$  mm<sup>2</sup>/s, p =0.607) and higher than the malignant masses ( $0.89 \pm 0.3 \times 10^{-3}$  mm<sup>2</sup>/s). In our study, the mean ADC of benign masses was  $1.73 \pm 1 \times 10^{-3}$  mm<sup>2</sup>/s, which was higher than malignant masses. The mean ADC value for malignant masses was  $0.89 \pm 0.3 \times 10^{-3}$  mm<sup>2</sup>/s.

Two subtypes of RCC were found in our study, ccRCC and pRCC. The mean ADC value of pRCC ( $1.14 \pm 0 \times 10^{-3}$  mm<sup>2</sup>/s) was higher than ccRCC  $0.85 \pm 0.29 \times 10^{-3}$  mm<sup>2</sup>/s.

In our study, the mean ADC of ccRCC was lower than TCC and the mean ADC of AML ( $1.15 \pm 0.14 \times 10^{-3}$  mm<sup>2</sup>/s) was higher than RCC ( $0.87 \pm 0.29 \times 10^{-3}$  mm<sup>2</sup>/s).

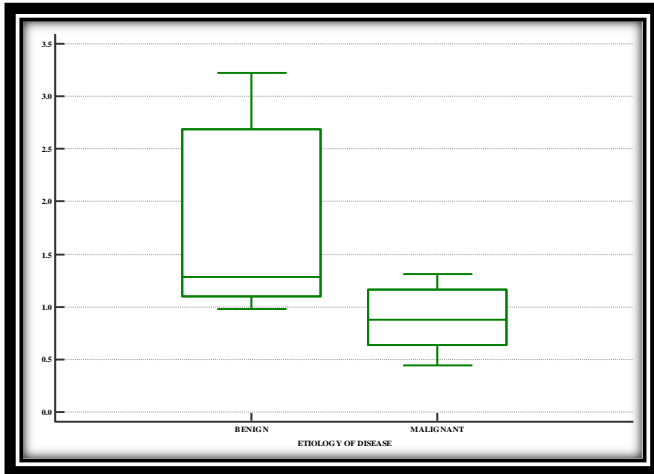
In our study, we found 2 cases of NET and 1 case of RMS on histological follow-up, which are the types of rare renal masses. The mean ADC of RMS ( $1.24 \pm 0 \times 10^{-3}$  mm<sup>2</sup>/s) was higher than RCC ( $0.87 \pm 0.29 \times 10^{-3}$  mm<sup>2</sup>/s), and the mean ADC value in NET cases was  $0.58 \pm 0.08 \times 10^{-3}$  mm<sup>2</sup>/s.

**Table 3: ADC values of the renal masses.**

Lesion	No.	Mean ADC±SD x 10 <sup>-3</sup> mm <sup>2</sup> /s		P value
		Normal renal parenchyma	Lesion	
ccRCC	15	1.55±0.13	0.85±0.13	0.04
pRCC	1	1.4±0	1.14±0	
TCC	1	1.82±0	1.06±0	
Angiomyolipoma	5	1.53±0.08	1.15±0.14	
Oncocytoma	1	1.89±0	1.31±0	
Neuroendocrinal tumor	2	1.57±0	0.58±0.08	
Rhabdomyosarcoma	1	1.45±0	1.24±0	
Bosniak cyst 1	2	1.51±0.16	3.18±0.05	

**Table 4: The mean ADC values for different Histological grades of renal mass.**

ADC Value	Grade 1	Grade 2	Grade 3	P value
<b>Mean ADC±SD</b>	1±0.32	1±0.25	0.66±0.15	0.069
<b>Median</b>	1.06	1.08	0.68	
<b>Min-max</b>	0.57-1.31	0.64-1.24	0.44-0.88	



**Figure 1: The mean ADC Values for benign and malignant masses.**

The cut-off level of ADC for differentiation among benign and malignant renal masses with b value 1000 s/mm<sup>2</sup> derived from the receiver operating characteristic curve (ROC) analysis was 1.08×10<sup>-3</sup> mm<sup>2</sup>/s (p=0.0001). The resulting sensitivity and specificity of DWI were 71.43% and 85.71%, respectively. The area under curve (AUC) was 0.827 (95% Confidence interval (CI)- 0.637 to 0.942).

**DISCUSSION**

Recent studies have shown that DW-MRI may enable characterization of renal masses and in differentiating benign from malignant ones. However, only a few reports are investigating the utilization of DWI and ADC value in the differentiation of renal masses.<sup>4</sup>

DWI protocol adopts DW gradient pulses to produce signals which are susceptible to the localized diffusivity of water molecules and thus can indirectly measure the renal cell density.<sup>5</sup> ADC value of any mass depends on its cellular density. So healthy renal tissue and neoplastic mass show different ADC values on DW imaging, which can be useful for recognizing and characterizing renal masses.<sup>6</sup> Consequently, DWI with ADC values can be effective methods in the diagnosis and quantitative measurement of neoplasms.

The choice of ‘b’ values also affects the calculated ADCs, with the use of higher b value (>500 s/mm<sup>2</sup>) being more accurate for actual diffusion and resulting in lower ADC.<sup>7</sup> In the literature, there is no consensus on the optimal b

value to be used at DWI.<sup>5,8</sup> High b-values increase diffusion weighting and, in theory, tumor detection, especially at 3T. The ADC value is potentially an actual mean, but despite there being no official cut-off for tumors, the value of 1000 mm<sup>2</sup>/s seems a reasonable threshold. It is unclear why there is a discrepancy between the present observations and previous reports. However, if the current findings were to be confirmed in a more extensive series, it could be imperative diagnostically. Given results of Zhang et al, it can be hypothesized that, because the main drawback of DWI is the lack of standardization, the variability of ADC values can probably be explained by differences in b values, coil systems, breath-hold versus free breathing, and field strengths used for MRI.<sup>5</sup>

In our study, we assessed the role of DWI and ADC measurement for the characterization of renal masses and the differentiation between benign and malignant masses.

Solid renal-masses, consist of predominantly enhancing tissue, either be benign or malignant. Solid benign masses encountered in our study include angiomyolipoma (AML), oncocytoma, Bosniak cyst 1, and solid malignant masses were RCC, TCC, NET, RMS.

In our study, RCC was found in 16 patients (57.14%) which was the most common renal mass encountered. It is followed by angiomyolipoma (5, 17.85%). NET and Bosniak cyst 1 were found in 2 patients (7.14%) each. TCC, r, and RMS were found in 1 patient (3.57%) each.

The ADC is a quantitative parameter that detects the extent of diffusion of water molecules. It is computed from DW-MRI. Multiple b values are used in the clinical practice to increase the accuracy of the ADC calculation. Many studies suggested that using b value higher than 400 s/mm<sup>2</sup> for abdominal diffusion MRI scans gives more accurate ADC measurement as it reduces the T2 shine through and intra-voxel perfusion effect.<sup>9,11</sup>

Bozcourt et al found that a b value of 800 s/mm<sup>2</sup> increased specificity with no significant effect on sensitivity and accuracy compared to a b-value of 400 s/mm<sup>2</sup>.<sup>11</sup>

**Normal renal parenchyma**

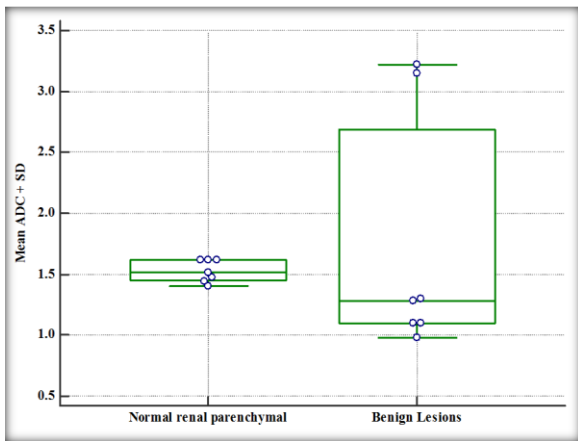
In our study, the mean ADC value of normal renal parenchyma was 1.55±0.12×10<sup>-3</sup> mm<sup>2</sup>/s and the range was 1.34-1.89×10<sup>-3</sup> mm<sup>2</sup>/s, which are within the same scale as found in previous studies, with reported ADC values of 1.58 ×10<sup>-3</sup> mm<sup>2</sup>/s and 1.56 ×10<sup>-3</sup> mm<sup>2</sup>/s.<sup>12,13</sup> However,

higher ADC values were reported in other studies, reaching  $3.36 \pm 0.41 \times 10^{-3} \text{ mm}^2/\text{s}$ ,  $2.1 \pm 0.18 \times 10^{-3} \text{ mm}^2/\text{s}$ , and  $2.88 \pm 0.65 \times 10^{-3} \text{ mm}^2/\text{s}$ , respectively.<sup>4,14,15</sup>

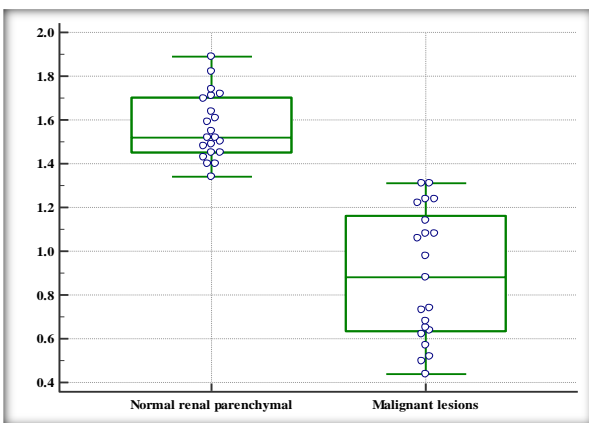
**Benign versus malignant lesions**

In our study, the mean ADC value of benign lesions was higher than the normal renal parenchyma, but malignant lesions show lower values. The mean ADC of benign lesions was  $1.73 \pm 1 \times 10^{-3} \text{ mm}^2/\text{s}$ , which was higher than malignant lesion ( $p=0.011$ ). The mean ADC value for malignant lesions, was  $0.89 \pm 0.3 \times 10^{-3} \text{ mm}^2/\text{s}$ .

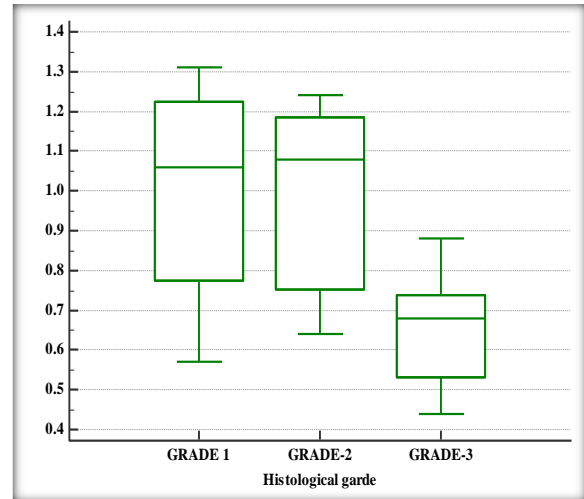
The mean ADC of normal renal parenchyma ( $1.55 \pm 0.12 \times 10^{-3} \text{ mm}^2/\text{s}$ ) was lower than the benign lesions ( $1.73 \pm 1 \times 10^{-3} \text{ mm}^2/\text{s}$ ,  $p=0.607$ ) but higher than malignant lesions ( $0.89 \pm 0.3 \times 10^{-3} \text{ mm}^2/\text{s}$ ,  $p=0.0001$ ).



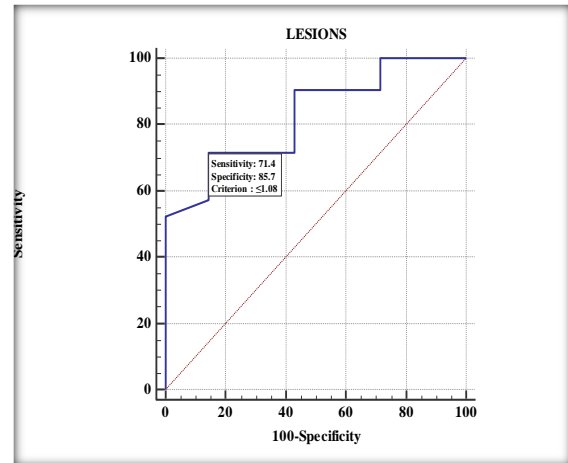
**Figure 2: Mean ADC value comparison of normal renal parenchyma with benign masses.**



**Figure 3: Mean ADC value comparison of normal renal parenchyma with malignant masses.**



**Figure 4: The mean ADC values for different Histological grades of renal masses.**

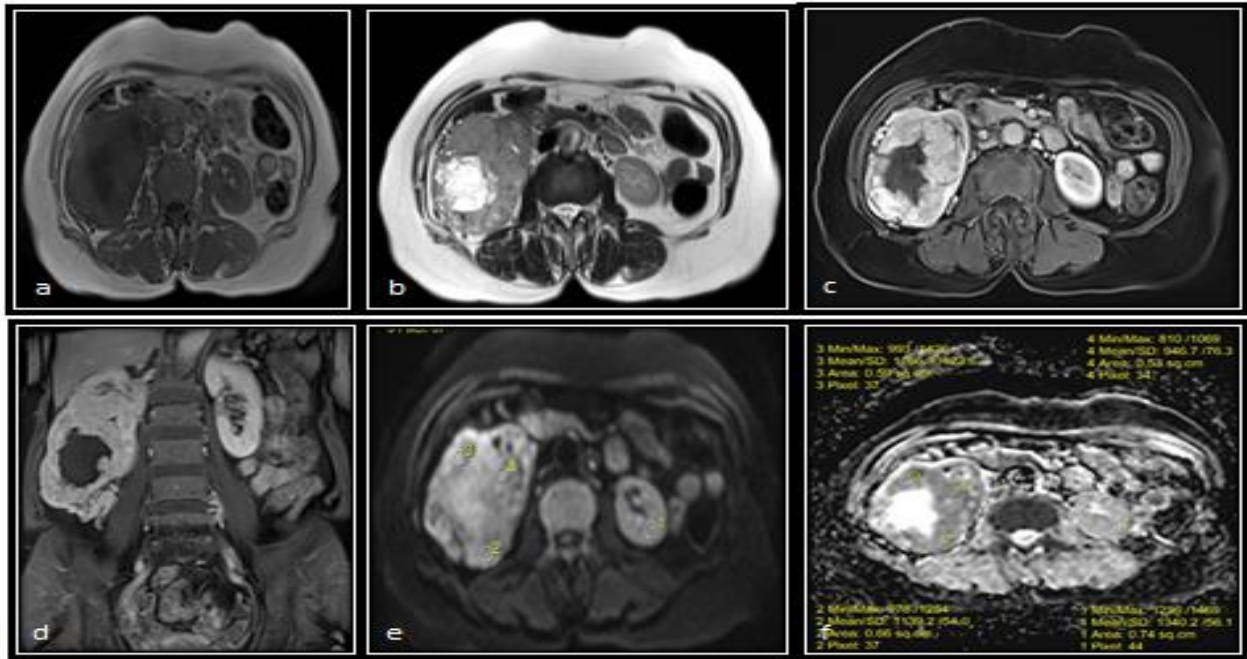


**Figure 5: Receiver operating characteristic (ROC) Curve.**

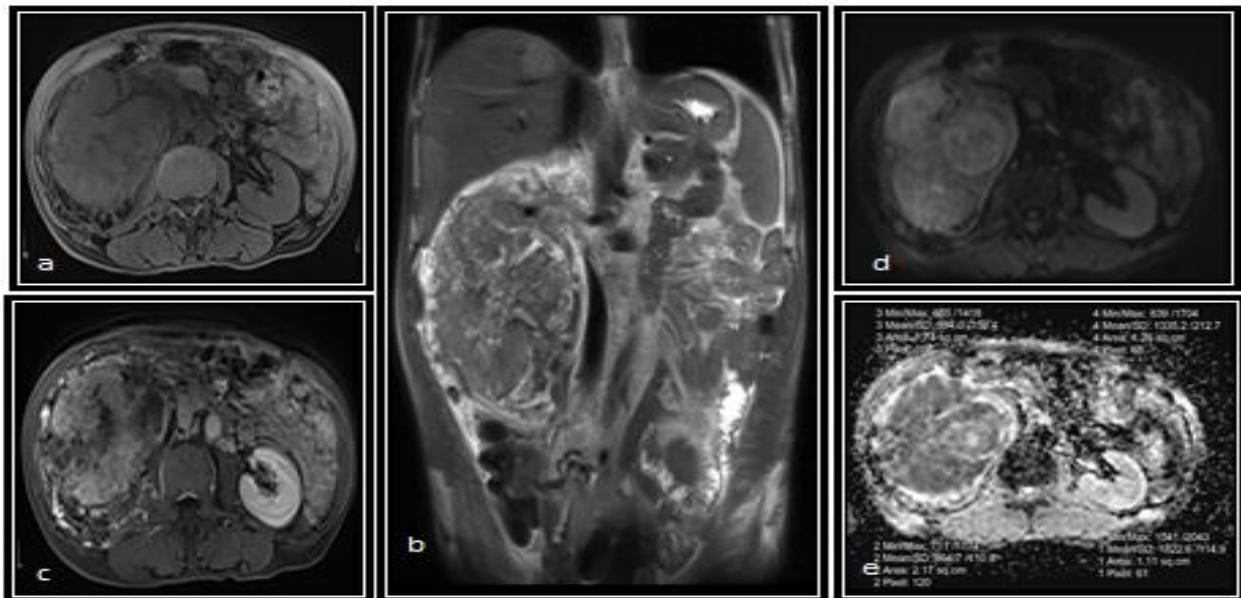
Sobh DM et al showed that the ADC values of benign lesions were significantly higher than those of malignant masses [ $3.2 (0.3-3.7)$  versus  $1.3 (0.3-2.9) \times 10^{-3} \text{ mm}^2/\text{s}$ ].<sup>16</sup>

Among malignant lesions, the mean ADC value was highest in the case of RMS ( $1.24 \times 10^{-3} \text{ mm}^2/\text{s}$ ) and lowest in the neuroendocrine lesions ( $0.58 \pm 0.08 \times 10^{-3} \text{ mm}^2/\text{s}$ ).

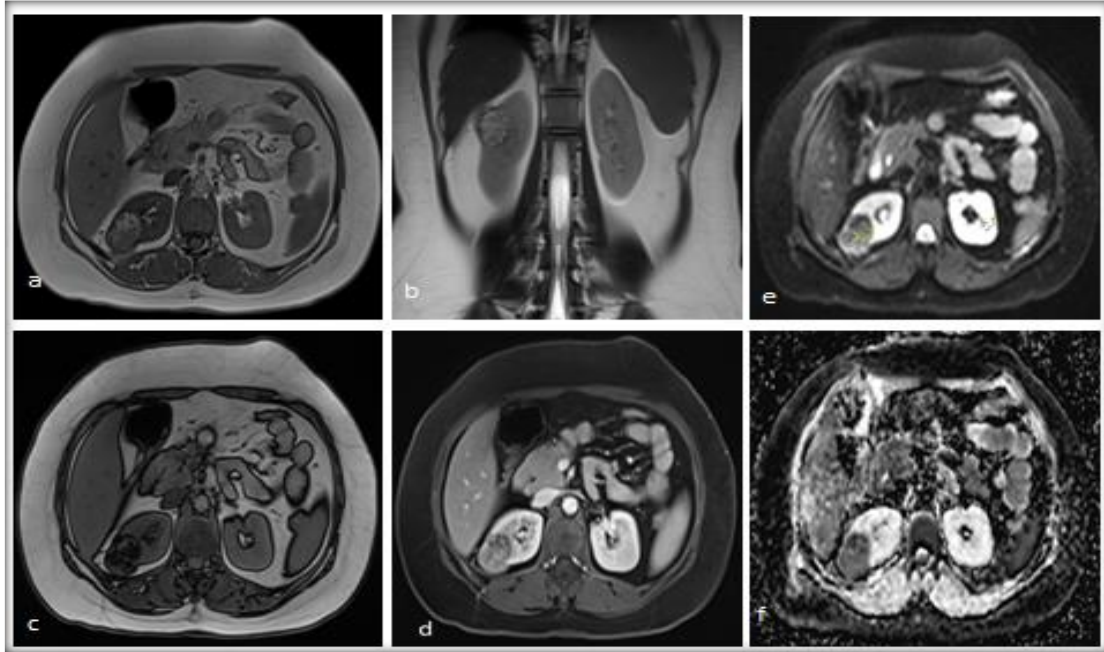
The cut-off level of ADC for differentiation among benign and malignant renal masses with b-value  $1000 \text{ s}/\text{mm}^2$  derived from the ROC analysis was  $1.08 \times 10^{-3} \text{ mm}^2/\text{s}$  ( $p=0.0001$ ). The resulting specificity and sensitivity of DWI were 85.71% and 71.43%, respectively. The AUC was 0.827 (95% CI - 0.637 to 0.942).



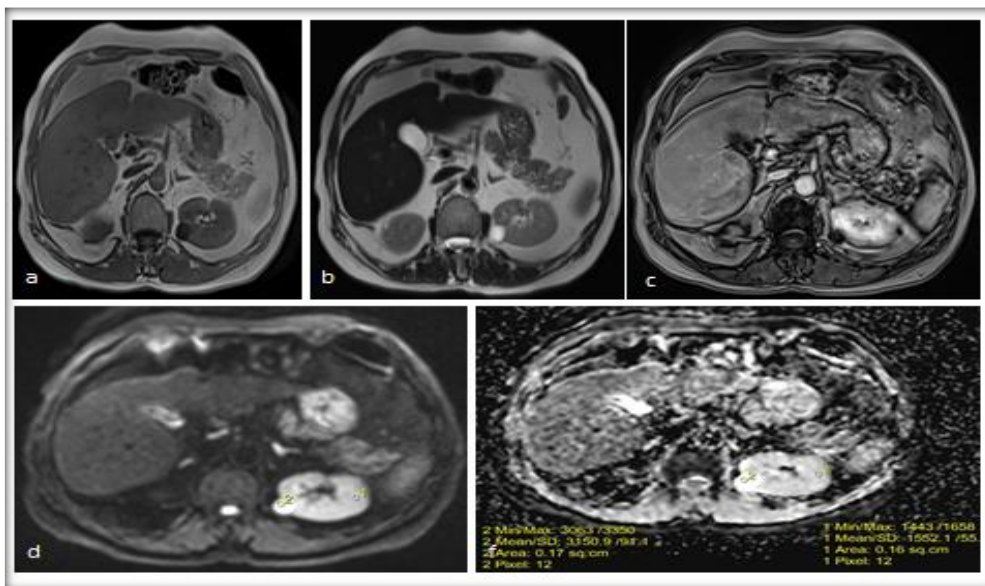
**Figure 6:** A 73-year old female with a well-defined mass involving the lower pole & interpolar region of right kidney. (a) The mass is hypointense on Axial T1-weighted image. (b)The mass is heterogeneously hyperintense on T2- weighted images. (c,d) The mass show peripheral thick rim of contrast enhancement with central necrotic area and surrounding multiple vascular channels on postcontrast axial and coronal T1-weighted images. (e) On axial DWI the mass shows restricted diffusion. (f) The mean ADC value of mass is  $1.08 \times 10^{-3} \text{ mm}^2/\text{s}$  in the corresponding ADC map, while contralateral normal renal parenchyma has ADC of  $1.34 \times 10^{-3} \text{ mm}^2/\text{s}$ . Histopathological Diagnosis- ccRCC.



**Figure 7:** A 35-year old female with a well-defined, round, mass at upper and interpolar region of left kidney. (a) Axial T1-weighted image shows hypointense lesion involving the right kidney and pelvis. (b)The lesion is hyperintense on T2- weighted image. (c) The lesion shows heterogeneous contrast enhancement on post-contrast axial T1-weighted image. (d) On axial DWI the mass shows restricted diffusion. (e) The mean ADC value of mass is  $1.06 \times 10^{-3} \text{ mm}^2/\text{s}$  in the corresponding ADC map, while contralateral normal renal parenchyma has ADC of  $1.82 \times 10^{-3} \text{ mm}^2/\text{s}$ . Histopathological diagnosis- TCC.



**Figure 8:** A 26-year old female with a well-defined, round, exophytic mass at upper interpolar region of right kidney. (a) Axial T1-weighted image shows mixed signal intense mass involving the right kidney. (b) The mass is predominantly hyperintense on coronal T2-weighted image. (c) The mass showing suppression of T1 hyperintense areas on axial out phase image. (d) The mass shows heterogeneous contrast enhancement on postcontrast axial T1-weighted image. (e) Diffusion- weighted image shows no diffusion restriction of mass. (f) The mean ADC value of  $1.1 \times 10^{-3} \text{mm}^2/\text{s}$  in the corresponding ADC map, while contralateral normal renal parenchyma has ADC of  $1.62 \times 10^{-3} \text{mm}^2/\text{s}$ . Histopathological diagnosis- Angiomyolipoma (AML).



**Figure 9:** A 53-year old male with a well-defined small lesion at upper pole of left kidney. (a) Axial T1-weighted image shows hypointense mass involving the left kidney. (b) The mass is hyperintense on T2- weighted image. (c) The lesion shows no contrast enhancement on post-contrast axial T1-weighted image. (d) On axial diffusion – weighted image the mass shows free diffusion. (e) The mean ADC value of mass is  $3.15 \times 10^{-3} \text{mm}^2/\text{s}$  in the corresponding ADC map, while contralateral normal renal parenchyma has ADC of  $1.4 \times 10^{-3} \text{mm}^2/\text{s}$ . Diagnosis - Bosniak cyst 1

### **Solid masses**

RCC is the most common malignant renal tumor in the literature and the current study, being encountered more frequently than other malignant lesions.<sup>17</sup> Other solid masses found in our study were TCC, RMS, NET, AML, and oncocytoma. RCC lesions have variable appearances on DWI because of their different degree of cellularity and cystic, necrotic, and hemorrhagic components, thus yielding different ADC values.<sup>18</sup>

Sobh et al showed that the ADC values for the solid malignant renal parenchymal masses were significantly lower compared with the benign solid parenchymal masses.<sup>16</sup>

### **Renal cell carcinoma**

In our study, all RCC cases showed restricted diffusion, with a mean ADC value of  $1.5 \pm 0.13 \times 10^{-3} \text{ mm}^2/\text{s}$  and range of  $1.34 \times 10^{-3} \text{ mm}^2/\text{s}$  -  $1.74 \times 10^{-3} \text{ mm}^2/\text{s}$  which is within the range as found in the previous study, with reported ADC values of  $1.65 \pm 0.38 \times 10^{-3} \text{ mm}^2/\text{s}$ .<sup>19</sup>

However, lower ADC values were also reported in other previous studies. Inci et al surveyed RCC and found that the ADC value was  $1.38 \times 10^{-3} \text{ mm}^2/\text{s}$  at a b value of 1000 s/mm<sup>2</sup>.<sup>20</sup> Taouli B et al also reported that the mean ADC for RCC was  $1.41 \times 10^{-3} \text{ mm}^2/\text{s}$  at a b value of 800 s/mm<sup>2</sup>.<sup>21</sup> Agnello F et al reported that mean ADC value for RCC was  $1.2 \pm 0.01 \text{ mm}^2/\text{s}$ .<sup>22</sup>

There is several subtypes types of RCC based on the histopathological appearance, clinical course and the presence of abnormal genetic patterns. These subtypes include ccRCC, papillary, chromophobe and unclassified RCC.<sup>23</sup>

In our study, we found only two subtypes of RCC, 15 cases of ccRCC and only one case of pRCC. The mean ADC value of pRCC ( $1.14 \pm 0 \times 10^{-3} \text{ mm}^2/\text{s}$ ) was higher than ccRCC  $0.85 \pm 0.29 \times 10^{-3} \text{ mm}^2/\text{s}$ , range-  $0.44$ - $1.31 \times 10^{-3} \text{ mm}^2/\text{s}$  ( $p=0.329$ ).

Sobh DM et al found that the ADC values for the ccRCC were significantly higher than those of the papillary RCC [ $1.8$  ( $0.8$ - $2.9$ ) $\times 10^{-3} \text{ mm}^2/\text{s}$  versus  $0.9$  ( $0.3$ - $1.9$ ) $\times 10^{-3} \text{ mm}^2/\text{s}$ , median (minimum-maximum)] respectively.<sup>16</sup>

Mytsyk Y et al showed that there was no difference between mean ADC values of ccRCC, pRCC and chromophobe RCC ( $1.82 \pm 0.22 \times 10^3$  versus  $1.61 \pm 0.07 \times 10^{-3}$  versus  $1.46 \pm 0.09 \times 10^{-3} \text{ mm}^2/\text{s}$  respectively).<sup>24</sup>

In our study, we found three histological grades of renal masses. The mean ADC for grade -3 ( $0.66 \pm 0.15 \times 10^{-3} \text{ mm}^2/\text{s}$ ) was lowest. The mean ADC for grade -2 was  $1 \pm 0.25 \times 10^{-3} \text{ mm}^2/\text{s}$  and for grade -1 was  $1 \pm 0.32 \times 10^{-3} \text{ mm}^2/\text{s}$ .

Sobh et al showed the ADC values for grades 1, 2 and 3 were  $1.3$  ( $0.3$ - $1.66$ ),  $1.2$  ( $0.8$ - $2.97$ ) and  $0.9$  ( $0.31$ - $1.38$ )  $\times 10^{-3} \text{ mm}^2/\text{s}$ , respectively.<sup>16</sup>

Mytsyk et al found an inverse relationship between mean ADC values and Fuhrman grade of solid ccRCCs was observed: grade 1- $1.92 \pm 0.11 \times 10^{-3} \text{ mm}^2/\text{s}$ , grade 2- $1.84 \pm 0.14 \times 10^{-3} \text{ mm}^2/\text{s}$ , grade - $1.79 \pm 0.10 \times 10^{-3} \text{ mm}^2/\text{s}$ , grade 4- $1.72 \pm 0.06 \times 10^{-3} \text{ mm}^2/\text{s}$ . This was significant ( $p < 0.05$ ) only between tumors of 1 and 4 grades.<sup>24</sup>

### **Transitional cell carcinoma**

In our study, mean ADC of TCC ( $1.06 \pm 0 \times 10^{-3} \text{ mm}^2/\text{s}$ ) was higher than RCC ( $0.87 \pm 0.29 \times 10^{-3} \text{ mm}^2/\text{s}$ ,  $p=0.052$ ).

We found that the mean ADC value of TCC was  $1.06 \pm 0 \times 10^{-3} \text{ mm}^2/\text{s}$ . This is slightly lower than the results of Sobh DM et al, and Paudyal et al who reported an ADC value of TCC was  $1.4 \pm 0.3 \times 10^{-3} \text{ mm}^2/\text{s}$  and  $1.61 \pm 0.80 \times 10^{-3} \text{ mm}^2/\text{s}$  respectively.<sup>16,25</sup>

A study by Paudyal et al concluded that the ADC value for the RCC was significantly higher compared with the TCC. TCC is histologically composed of solid and densely packed tumor cells with hyper-cellularity compared with RCC. Besides, RCC is frequently associated with the hemorrhage, necrosis and cystic parts. These may explain the higher ADC value of the RCC.<sup>25</sup>

Emad-Eldin et al also reported that the mean ADC value of TCC lesions was  $1.26 \pm 0.16 \times 10^{-3} \text{ mm}^2/\text{s}$ , which is similar to our study.<sup>4</sup>

### **Angiomyolipoma**

Angiomyolipoma (AML) is a typical benign lesion that occurs in 0.3-3% of the population.<sup>26</sup> AML is composed of angiomatous, variable amounts of fat and smooth muscle tissue. These tissues prevent the molecules of water from spreading freely and causing a low ADC value in these masses.<sup>20</sup>

In our study, the mean ADC value of AML was  $1.15 \pm 0.14 \times 10^{-3} \text{ mm}^2/\text{s}$  which was higher than renal cell carcinoma ( $0.87 \pm 0.29 \times 10^{-3} \text{ mm}^2/\text{s}$ ).

The mean ADC value of angiomyolipoma reported by Sobh et al, Eldin et al and Yoshikawa et al was lower than to our study.<sup>4,16,26</sup> The low ADC value of AML is attributed to its abundant fat content.

Inci et al and Agnello F et al reported that the mean ADC value of AML was  $1.19 \pm 0.36 \times 10^{-3} \text{ mm}^2/\text{s}$  and  $1.07 \pm 0.3 \times 10^{-3} \text{ mm}^2/\text{s}$ , which were similar to our study.<sup>20,22</sup>

Kilickesmez et al also found the ADC value of AMLs ( $1.40 \pm 0.21 \times 10^{-3} \text{ mm}^2/\text{s}$ ), which was slightly higher than the study.<sup>27</sup>



### **Oncocytoma**

In our research, we found only one case of oncocytoma and the mean ADC value was  $1.31 \pm 0 \times 10^{-3} \text{ mm}^2/\text{s}$  for oncocytoma.

Agnello et al showed that the mean ADC value of oncocytomas was  $1.56 \pm 0.08 \text{ mm}^2/\text{s}$ , which was slightly higher than our study ( $1.31 \pm 0 \times 10^{-3} \text{ mm}^2/\text{s}$ ).<sup>22</sup>

Zhang et al and Sobh et al also reported mean ADC value for oncocytoma which was  $2.16 \pm 0.02 \times 10^{-3} \text{ mm}^2/\text{s}$  and  $2.4 \pm 0.4 \times 10^{-3} \text{ mm}^2/\text{s}$ .<sup>17,16</sup> The mean ADC value of oncocytoma reported by them was higher than our study.

### **Bosniak cyst**

In our study, the mean ADC values of Bosniak cyst 1 was highest ( $3.18 \pm 0.05 \times 10^{-3} \text{ mm}^2/\text{s}$ ) among the lesions. Simple cysts have higher water content, which allows unrestricted diffusion.

The mean ADC value of Bosniak cyst 1 reported in our study was similar to a study by Zhang et al ( $3.2 \pm 0.61 \times 10^{-3} \text{ mm}^2/\text{s}$ ).<sup>17</sup>

Sobh DM at reported the mean ADC value ( $3.49 \pm 0.61 \times 10^{-3} \text{ mm}^2/\text{s}$ ) of Bosniak cyst 1, which was slightly higher than our study.

In a study by Göya et al the mean ADC value of Bosniak type 1 cysts was  $2.93 \pm 0.14 \times 10^{-3} \text{ mm}^2/\text{s}$  in, which is relatively lower than that in our study.<sup>28</sup>

### **Rare renal tumors**

In our study, we found 2 cases of NET and 1 case of RMS on histological follow-up, which are the types of rare renal masses. The mean ADC of RMS ( $1.24 \pm 0 \times 10^{-3} \text{ mm}^2/\text{s}$ ) was higher than RCC ( $0.87 \pm 0.29 \times 10^{-3} \text{ mm}^2/\text{s}$ ), and the mean ADC value in NET cases was  $0.58 \pm 0.08 \times 10^{-3} \text{ mm}^2/\text{s}$ . However, no previous study could be found for comparison to our study.

### **Limitations of study**

Our study had the following limitations such as the number of renal masses was relatively small in each group and subgroups, few renal lesions which are known to give false positive findings such as infarction and hemorrhage or infections were not included in the study.

### **Strengths of study**

MRI was performed using 3 tesla MR system which has been reported to be more sensitive than 1.5 MRI in published studies. The subjects underwent MRI evaluation using a dedicated imaging protocol. Standardized tools were used to measure ADC values. The measurement of ADC values was taken by choosing multiple ROI and

mean ADC values were calculated, which increased the reliability of the results obtained. Histopathological reports followed in most of the cases.

### **CONCLUSION**

DW-MR imaging may help to differentiate benign and malignant renal masses. To use DWI in routine practice, it is necessary to define a suitable and proper methodology for measuring ADC. However, there was some overlap among the ADC value of benign and malignant lesions, so it cannot be used as a single diagnostic tool.

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