Original Research Article

Diffusion-Weighted Magnetic Resonance Imaging Supplemented by Apparent Diffusion Coefficient in Evaluation of Renal Masses

Abstract

Background: Recent studies have shown that diffusion weighted imaging (DWI) may enable characterization of kidney lesions and in differentiating benign from malignant ones. However, there are only a few reports investigating the utilization of DWI and Apparent Diffusion Coefficient (ADC) measure in the differentiation of small solid kidney masses. The aim of this study was to evaluate the role of Diffusion Weighted MR Imaging (DW-MRI) supplemented with ADC measures in characterization of different kidney masses.

Subjects and methods: This cross-sectional study included thirty (30) cases presented to the Diagnostic Radiology Department in Tanta University Hospitals with signs and symptoms of kidney masses either by clinical or previous radiological examination. The duration of the study was 3-4 years. **?????**

Results: there were 13 participants had clear kidney cell carcinoma with mean ADC 1.32 ± 0.15. There were 7 participants had papillary kidney carcinoma with mean apparent diffusion coefficient (ADC) 1.33 ± 0.13. There were 6 participants had oncocytoma with ADC 1.3 ± 0. There were 4 participants had angiomyolipoma with mean ADC 0.76 ± 0.13. As regard ~~Diffusion-weighted imaging~~ (DWI) sequence parameters; the TR/TE **???** was 3150/55. **Authors should avoid abbreviations in the abstract section.**

Conclusion: DWI is a quick process that can be readily included into a standard MRI protocol. When gadolinium contrast agent cannot be provided, DWI is very useful for lesion identification and assessment. Due to the overlap of ADC measures between benign and

cancerous lesions, it cannot be utilised as a standalone diagnostic tool and must be evaluated concurrently with conventional MRI for effective ~~characterisation~~ characterization of kidney lesions.

Key words:

Kidney, Masses, Diagnostic Instrument, DWI, Apparent Diffusion Coefficient (ADC), and Renal Cell Carcinoma are the key phrases.

Introduction:

The initial stage in the evaluation of accidentally discovered kidney lesions is to distinguish benign cysts from solid tumours. Solid kidney masses contain little to no fluid and are mostly constituted of vascularized tissue (i.e., components that are enhanced by the introduction of exogenous contrast agents) [1].

Even though they are less prevalent than cystic lesions, up to 90% of solid masses are cancerous. Approximately fifty percent of lesions less than one **~~centimetre~~ centimeter** have a risk of malignancy, compared to more than ninety percent of masses bigger than or equal to seven **~~centimetres~~ centimeters** [2].

Over the past decade, the use of DW-MRI??? **Authors must write the meaning of the abbreviations.**

in extracranial organs has increased. Due to physiological motion artefacts (bowel, cardiac, and respiratory movements) and the varied composition of the organs, DW-MRI of abdominal organs is significantly more difficult to produce [3].

Recently, quicker imaging methods, such as **DW-MRI**,????? **Authors must write the meaning of the abbreviations.** have been extensively used for the functional evaluation of various organs and to predict the success of therapy [3].

Diffusion is a physical phenomenon that explains the random movement of molecules on a tiny scale in reaction to thermal energy, also known as Brownian motion [4].

Diffusion weighted imaging (DWI) employs pulse sequences and methods that are sensitive to very small-scale motion of H_2O protons. Single shot echo-planar imaging (EPI) DWI is used to provide extremely rapid imaging that is sensitive to subtle small-scale variations in diffusion. Displayed as areas of high signal intensity are regions of limited water diffusion [4] Cases with kidney masses must be accurately ~~**characterised**~~ **characterized** to ensure proper clinical care, staging, and prognosis. The clinical utility of apparent diffusion coefficient (ADC) measures in kidney disease has been documented: a higher measure of ADC was observed in simple renal cysts and the kidney pelvis of hydronephrotic kidneys, whereas a lower measure was observed in solid kidney tumours and kidneys with chronic and acute kidney failure [5].

The purpose of this study was to examine the contribution of DW-MRI with ADC measures to the characterisation of various kidney masses.

Patients and Methods:

This cross-sectional study was carried out on 30 cases aged from 45 to 55 years old with signs and symptoms of kidney masses either by clinical or previous radiological examination at the Diagnostic Radiology Department in Tanta University Hospitals from 2018 to 2022.

A written informed consent was obtained from all participants in this research. The study was done after approval from the Ethical Committee Tanta University Hospitals.

Exclusion Criteria were undergoing nephrectomy as treatment of kidney masses, other contraindication to MRI [metallic medical implants, impaired kidney function (serum creatinine > 1.5 mg /dl) or allergic to contrast media, any metallic fragment or foreign body such as retained bullet, claustrophobia]. The study performed on 1.5 Tesla MRI scanner machine with echo-planar capability.

All cases in this study were submitted to complete history taking, clinical examination (urinary symptoms and signs, duration of illness, past history for kidney masses or other

masses in the body, presence of any other disease, any previous operation, any metallic implantation such as cardiac pacemaker), laboratory investigation such as complete blood picture (CBC) and kidney function tests (serum creatinine, blood urea and urine analysis).

Radiological examination:

Both kidneys were examined both pre and post contrast for diagnosis of kidney masses using 1.5 Tesla MRI Scanner machine at Diagnostic Radiology Department Tanta University.

MRI protocols for dedicated kidney imaging sequence as a addition to T1- and T2-weighted anatomical imaging Our institution's **mpMRI??? Authors must write the meaning of the abbreviations.** consisting of numerous of anatomical T1-weighted VIBE (volumetric interpolated breath-hold examination), with and without fat suppression and before and after giving of gadolinium-based contrast agent, and T2-weighted fat suppressed HASTE (Half-Fourier Acquired Single-shot Turbo spin Echo) sequences. To identify tiny fat, further chemical shift imaging (in-phase and opposed-phase) is performed. The acquisition of subsequent DWI sequences and DCE T1-weighted CMP, NP, and excretory phase. We utilise b-measures of 50, 400, and 800 s/mm2 for DWI, but there is no consensus on which measures to employ.

DWI of both kidneys and apparent diffusion coefficient (ADC) measurement:

In DWI, the signal intensity is governed by an operator-specific factor and an ADC-specific tissue factor. The factor shows the degree of diffusion weighting. A small number corresponds to a high signal intensity, whereas a big measure denotes an increase in tissue contrast. Therefore, a small measure is advantageous for recognising **misspelling** a lesion with a high signal intensity, but a big measure is superior for characterising **misspelling** a

tumour with a high tissue contrast. The majority of lesions with limited diffusion exhibit hyperintensity on DWI and hypointensity on the ADC map.

Statistical analysis

The acquired data was entered into a computer and statistically analysed using version 26 of the SPSS (Statistical Package for Social Science) application. Using the Shapiro Walk test, the normal distribution of the data was examined. The representation of qualitative data as frequencies and relative percentages. The mean and standard deviation were used to convey quantitative data. A ROC curve analysis was utilised **misspelling** to predict the difference between cancerous and normal renal cells based on ADC values. P-value 0.05 indicates a statistically significant difference.

Results:

Table 1 shows patient characteristics and laboratory data of the studied cases.

Table 1: Demographic data, laboratory investigations and complaint of the studied patients (n = 30)

		n =30
Age (years)		50.77 ± 2.79
BMI (kg/m^2)		26.76 ± 2.08
Sex	**Male**	17 (56.67%)
	Female	13 (43.33%)
Hb (g/dl)		12.73 ± 1.14
RBCs (*10^3 cells/µL)		5.37 ± 0.66
WBCs (*10^3 cells/µL)		8.24 ± 2.35
Platelets (*10^3 cells/µL)		293.5 ± 90.01
Serum creatinine (mg/dL)		0.85 ± 0.15
Hematuria		18 (60%)
Loin pain		25 (83.33%)
Heaviness		20 (66.67%)
Fever		8 (26.67%)

Data are presented as mean ± SD or frequency (%). BMI: Body mass index, Hb: hemoglobin, RBCs: red blood cells, WBCs: white blood cells

Table 2 shows the type of masses and their characteristics in the studied patients.

Table 2: Type of masses and their characteristics in the studied patients (n = 30)

		n =30
Malignant		20 (66.67%)
Benign		10 (33.33%)
Malignant (n=20)	**Clear RCC**	13 (65%)
	Papillary RCC	7 (35%)
Benign (n=10)	**AML**	4 (40%)
	Oncocytoma	6 (60%)

Data are presented as frequency (%). RCC: renal cell carcinoma, AML: angiomyolipoma

Table 3 shows that all twenty cases who were diagnosed with malignant masses (clear RCC and papillary RCC) were able to display restricted diffusion in form of bright signals in DWI and dark signals in ADC map. The ten cases who were diagnosed with benign masses (AML and oncocytoma) were able to display restricted diffusion in form of bright signals in DWI and dark signals in ADC map

Table 3: Diffusion signals of the malignant and benign masses in the studied patients

Authors must write the meaning of the abbreviations.

	Type of mass	DWI	ADC
Restricted diffusion of the malignant masses	**Clear RCC (n=13)**	Bright	Dark
	Papillary RCC (n=7)	Bright	Dark
Restricted diffusion of the benign masses	**AML (n=4)**	Bright	Dark
	Oncocytoma (n=6)	Bright	Dark

RCC: renal cell carcinoma, AML: angiomyolipoma, ADC: apparent diffusion coefficient, DWI: Diffusion-weighted imaging

Table 4 shows the ADC values of malignant and benign masses at b1000 value.

Table 4: ADC values of malignant and benign masses at b1000 value

	Clear RCC	Papillary RCC
Malignant masses at b1000 value	1.32 ± 0.15	1.33 ± 0.13
	AML	**Oncocytoma**
Benign masses at b1000 value	0.76 ± 0.13	1.3 ± 0

Authors must write the meaning of the abbreviations.

Data are presented as mean ± SD. RCC: renal cell carcinoma, AML: angiomyolipoma.

ADC can significantly discriminate malignant masses from benign (AUC= 0.82, P value<0.001) at cut off >1.29 ($x10^{-3}$ mm^2/s) with 70% sensitivity, 40% specificity, 70% PPV and 40% NPV. Table 5; Figure 1

Table 5: Diagnostic performance of ADC in discrimination of malignant masses from benign ones Authors must write the meaning of the abbreviations.

	Cut-off	AUC	Sensitivity	Specificity	PPV	NPV	P value
ADC value	>1.29	0.82	70	40	70	40	<0.001*

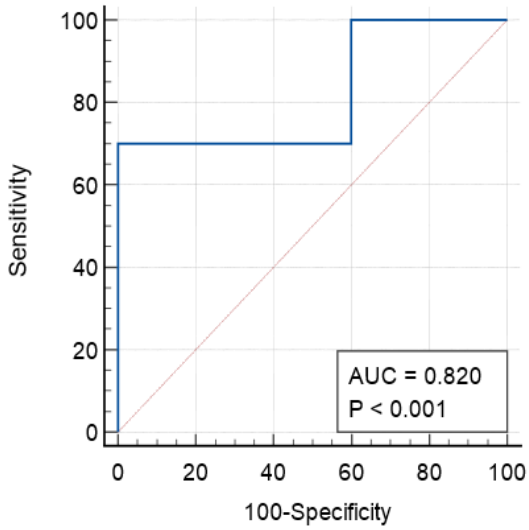

Figure 1: ROC curve of ADC in discrimination of malignant masses from benign ones

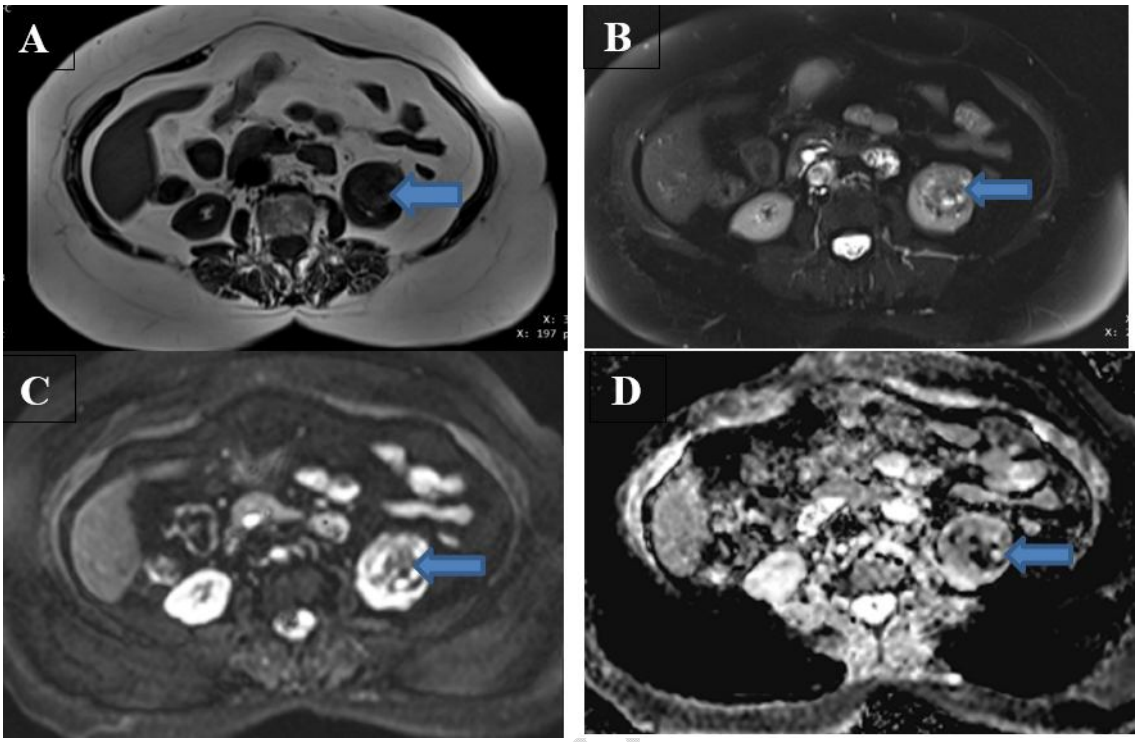

Figure 2: (A) Axial renal MRI (T1 sequence) shows left renal heterogeneously intense mass, (B) Axial renal MRI (T2sequence) shows left renal hyperintense mass, (C) Axial renal MRI (DWI sequence) shows partially restricted diffusion, (D) Axial renal MRI (ADC) shows heterogenous signal. Patient underwent nephrectomy and pathology revealed diagnosis as left papillary RCC

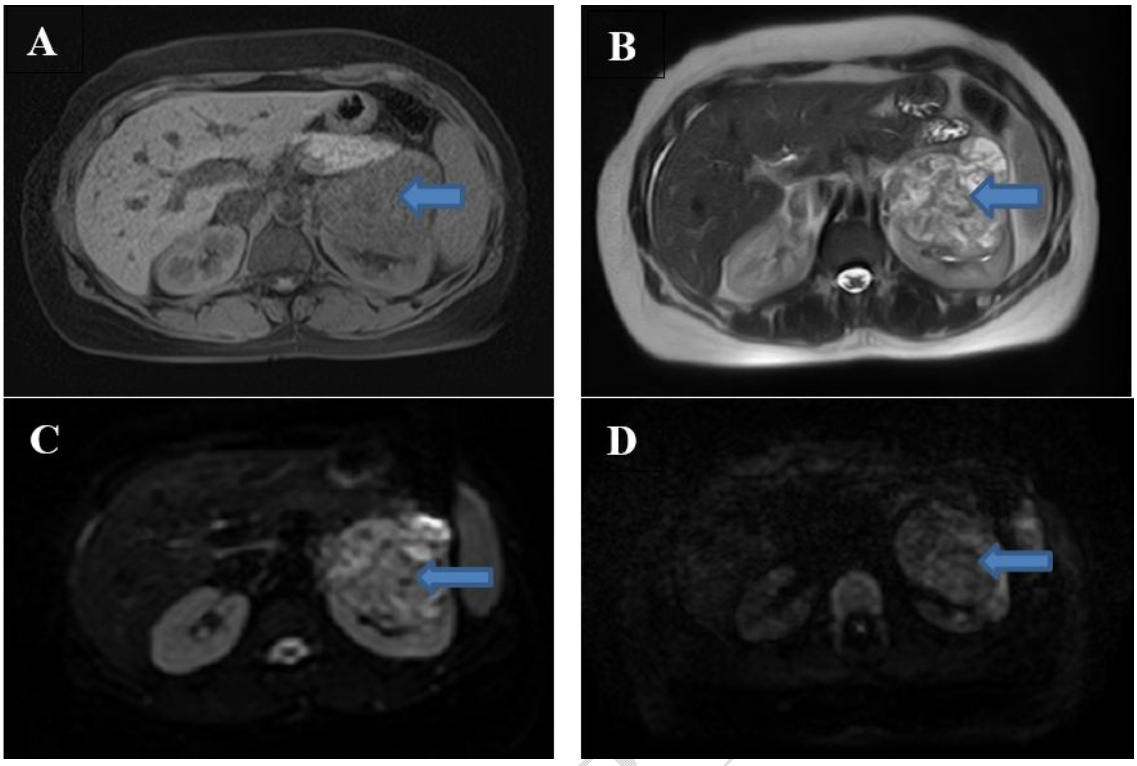

Figure 3: (A) Axial renal MRI (T1 sequence) shows left renal isointense mass, (B) Axial renal MRI (T2sequence) shows left renal heterogeneously intense mass, (C) Axial renal MRI (DWI sequence) shows facilitated diffusion, (D) Axial renal MRI (ADC) shows low signal. Patient underwent nephrectomy and pathology revealed diagnosis as left clear cell RCC

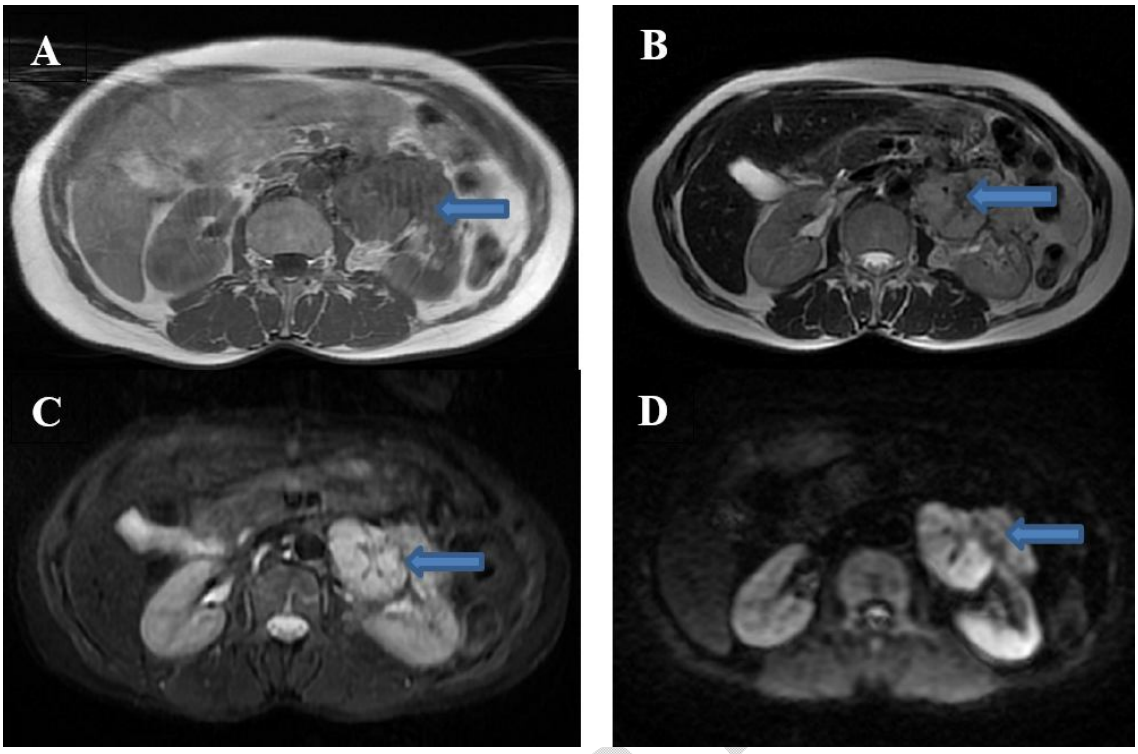

Figure 4: (A) Axial renal MRI (T1 sequence with contrast) shows left renal isointense mass, (B) Axial renal MRI (T2sequence) shows left renal isointense mass, (C) Axial renal MRI (DWI sequence) shows restricted diffusion, (D) Axial renal MRI (ADC) shows high signal. Patient underwent nephrectomy and pathology revealed diagnosis as left renal oncoytoma

Discussion

The present study showed that there were 18 cases had hematuria, 25 cases had loin pain, 20 cases had heaviness and 8 cases had fever.

While, in the study of Razek et al., [6] **Authors must use the format recommended by the journal** their studied group presented with hematuria (n = 23), loin pain (n = 12), flank swelling (n = 8), and 9 cases were asymptomatic and discovered incidentally during ultrasound or CT scan for another reason.

In our study, there were 13 participants had clear renal cell carcinoma (RCC) with ADC 1.32 ± 0.15. There were 7 participants had papillary renal carcinoma with ADC 1.33 ± 0.13. There

were 6 participants had oncocytoma with ADC 1.3 ± 0. There were 4 participants had angiomyolipoma with mean ADC 0.76 ± 0.13.

As regard DWI sequence parameters; the TR/TE was 3150/55. The thickness was 5 mm. The FOV was 330 mm. The matrix was 96 X 94.

ROC curve analysis of the cutoff ADC measure used for differentiating cancerous from benign kidney masses. At measure 1190 the sensitivity was 70 % and specificity was 40%.

Our results were supported by study of Emad-Eldin & Ibrahim, [7] as they reported a final diagnoses of kidney lesions that included 29 cancerous lesions and 21 benign lesions. Cancerous lesions include RCC (n=13), Transitional Cell Carcinoma (TCC) (n=3), and lymphoma (n=13). Benign lesions include AML (n=9) and pyelonephritis (n=12). The final diagnosis was pathologically confirmed in the RCC, TCC, and lymphoma cases. The ADC of normal kidney parenchyma ($2.1\pm0.18\times10^{-3}$ mm^2/s) was higher than that of benign and cancerous lesions ($P<0.005$). There was no statistical significance between the ADC means of benign ($1.02\pm0.2\times10^{-3}$ mm^2/s) and cancerous kidney lesions ($1.07\pm0.39\times10^{-3}$ mm^2/s) ($P=0.5$). Among the cancerous lesions, the ADC mean was the highest in the RCC lesions ($1.4\pm0.22\times10^{-3}$ mm^2/s) and the lowest in the lymphoma lesions ($0.679\pm0.08\times10^{-3}$ mm^2/s), showing a statistically significance difference between the two groups ($P=0.0001$).

In the study by Agnello et al. [8], who found a lower ADC mean of the solid kidney lesions compared with kidney parenchyma (1.22±0.3 vs. 1.85±0.12). They found that the majority of lesions were kidney-hyperintense on high b-value DWI and kidney-hypointense on the ADC map. Lesions had a substantially lower ADC than kidney (1.22± 0.3 vs 1.85± 0.12 mm2/s; p 0.005). The ADC varied substantially across RCCs (1.2± 0.01 mm2/s), metastases (1.25± 0.04 mm2/s), angiomyolipomas (1.07 ±0.3 mm2/s), and oncocytomas (1.56± 0.08 mm2/s; p 0.05). The ADC of clear cell (CC) RCCs differed considerably from that of non-CC RCCs (p

0.005): 1.38 ±0.34 mm2/s vs 0.83 0.34 mm2/s. There was no significant difference in the ADC of angiomyolipomas with and without fat (1.06± 0.48 versus 1.11± 0.33 mm2/s).

Similarly, Cova et al. [5] reported a lower ADC mean of the solid kidney lesions compared with kidney parenchyma (1.55±0.2 vs. 2.19±0.17).

Sandrasegaran et al. [9] demonstrated that 20 and 22 individuals, respectively, had benign lesions (three abscesses and 31 cysts) and cancerous lesions (three abscesses and 31 cysts) (17 CC, five papillary, one chromophobe, and two transitional cell cancers). Cancerous lesions were bigger than benign lesions (mean diameter, 4.2 vs 2.6 cm, p = 0.01) the ADC means of benign lesions were substantially greater than those of cancerous lesions (p< 0.0001): 2.72 versus 1.88* 10^{-3} mm2/s. The ADCs of 31 benign cysts were substantially greater than those of seven cystic kidney malignancies (p 0.001): 2.77* 10^{-3} mm2/s versus 2.02* 10^{-3} mm2/s. There was no significant difference between the ADCs of CC and non-CC malignancies (1.85 vs 1.97 *10^{-3} mm2/s; p = 0.18), however only CC cancer had an ADC of less than 1.79 103 mm2/s. The ADCs of high-grade CC malignancies (Fuhrman grades III and IV) were typically lower than those of low-grade CC tumours (1.77 vs 1.95* 10^{-3} mm2/s; p = 0.12). ADC values larger than 2.12* 10^{-3} mm2/s were observed exclusively in CC tumours with low-grade histology. The area under the receiver operating characteristic (ROC) curve for distinguishing benign from cancerous lesions was 0.989 (95% confidence interval: 0.919–0.996; p< 0.0001).

In a metanalysis conducted by Zhang et al. [10], Data extraction and diagnostic performance calculation was admissible for nine articles with eleven subsets. Included were 988 apparent diffusion coefficient (ADC) measurements. The differences between the ADC measures of benign (2.47 ±0.81* 10^{-3} mm2/s) and cancerous (1.8± 0.41 *10^{-3} mm2/s) lesions were statistically significant (P< 0.001) with 95% confidence intervals were 20,05 (95% CI: 12.56–32.02), 3,32 (95% CI: 2.13–5.18), 0.20 (95% CI: 0.15–0.27), 88% (95% CI: 0.84–

0.91), and 72% (95% CI: 0.67–0.72), respectively. The summary receiver operating characteristic's area under the curve was 0.90.

Whereas Taouli et al. [11] demonstrated that the 109 kidney lesions (81 benign lesions and 28 RCCs) had a mean diameter of 4.2 cm± 2.5 cm, the mean diameter of the 81 benign lesions was 1.9 cm ±1.1 cm (standard deviation). At DWI with b measures of 0, 400, and 800 mm2/s, the ADC for RCCs (1.41* 10^{-3} mm2/s 0.61) was substantially lower (P< .0001) than that for benign lesions (2.23 *10^{-3} mm2/s 0.87) (P< .0001).

Area under the ROC curve (AUC), sensitivity, and specificity of DWI for the identification of RCCs (excluding angiomyolipomas) were 0.85, 86%, and 80%, respectively, at a threshold ADC of less than or equal to 1.92* 10^{-3} mm2/s. CE MR imaging's matching AUC, sensitivity, and specificity were 94%, 100%, and 89%, respectively. The specificity of combined DW and CE MR imaging was 96%. The AUC for the diagnosis of solid RCC based on DWI vs oncocytoma was 0.854%. ADCs were lower in papillary RCCs than in nonpapillary RCCs.

Conclusions:

DWI is a rapid procedure that may be readily included into a standard MRI protocol and is particularly useful for lesion assessment and identification when gadolinium contrast medium cannot be supplied. Due to the crossover of ADC measures between benign and cancerous lesions, it cannot be utilised as a solitary diagnostic tool and must be evaluated concurrently with conventional MRI for effective characterisation of kidney lesions.

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