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Role of multiparametric MRI in characterization of complicated cystic renal masses

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Abstract

Background Bosniak classification improves sensitivity and specificity for malignancy among cystic renal masses characterized with MRI. The quantitative parameters derived from diffusion-weighted imaging, and contrast enhancement, can be used in distinguishing between benign and malignant cystic renal masses.

Methods This prospective observational study included 58 patients (39 male and 19 female) with complicated cystic renal mass initially diagnosed by US or CT. All patients underwent multiparametric MRI study (Pre- and Post-Gd-enhanced T1WI, T2WI and DWI) by using 3 Tesla MRI scanner. Each cystic renal lesion was assigned a category based on Bosniak classification. Demographic data were recorded. ADC ratio, dynamic enhancement parameters in both corticomedullary and nephrographic phases as well as absolute washout were calculated and compared using ROC curve analysis.

Results The sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy of the multiparametric MRI in categorization of cystic renal masses according to Bosniak classification version 2019 were 90.32%, 100%, 100%, 90% and 94.83%, respectively, which was higher compared to biparametric MRI and conventional MRI.

Conclusions Multiparametric MRI can be utilized to confidently evaluate cystic renal masses, overcoming the traditional limitations of overlapping morphological imaging features. Quantitative parameters derived from multiparametric MRI allow better evaluation of complex cystic renal tumors to distinguish between benign and malignant complex cystic renal lesions.

Keywords Quantitative, Multiparametric, Bosniak 2019 classification, Renal cysts

Background

The classification of Bosniak that is utilized for classification of cystic masses detected in the kidney was first described in 1986, and it is considered by urologists and radiologists as one of the reliable approaches in the classification and management of cystic lesions detected in the kidney [1].

MRI offers several advantages over CT including improved contrast resolution, functional imaging techniques, and the lack of ionizing radiation [2].

Functional imaging (DWI and DCE) techniques combined the conventional renal MRI protocol (including fat-suppressed T1W and T2-weighted sequences), constitutes a comprehensive multiparametric MRI protocol of the kidneys mp-MRI is rapidly becoming the reference standard for renal MRI. mp-MRI can be performed in a time-efficient manner and provides an

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important information that is not available with standard renal MRI [2].

DWI allows for determination of cystic renal masses depending on their degree of water movement restriction, which is useful in cases with contrast injection contraindication. A mass that still of high SI on images of high b value and of low ADC value is suggesting of solid component [3]. On the other hand, hemorrhagic content of non-neoplastic nature inside cystic lesion may show diffusion restriction. Dynamic contrast-enhanced MRI (DCE-MRI) is used to assess contrast material kinetics within the solid component of cystic renal masses, reflecting the vascularity of the tissue [4].

The Bosniak classification system (version 2019) aims to decrease the limitations. In version 2019, previously terms, such as "thickened" and "multiple," are defined numerically, and other criteria, such as perceived versus measurable enhancement and lesion size, have been removed. MRI is formally added to the classification system. The CT criteria from the original classification system have been applied to MRI in previous studies (Table 1) [5]. Overall, masses categorized with Bosniak version 2019 were in lower classes compared with categorization with Bosniak version 2005[6].

MR imaging with 3.0 Tesla (3 T) systems, high-density phased-array coils, and newly developed sequences, such as multiecho Dixon (mDIXON), offers high image quality and excellent spatial resolution. 3 T magnets have the advantage of higher signal-to-noise, which can be used to yield shorter acquisition times and/or increased image resolution [7].

We hypothesized that quantitative parameters of MRI can accurately differentiate between benign and malignant cystic renal masses. Therefore, we conducted this study to evaluate the diagnostic performance of multiparametric MRI in Bosniak 2019 categorization of complex cystic renal masses.

Methods

This prospective observational study included 58 patients with complicated cystic renal mass diagnosed by US or CT during the period from June 2018 to June 2020. Patients were referred to the Radiology Department (MRI Unit) from the urology Department of the same center.

Patients were selected according to following criteria

- *Inclusion criteria*: Adult patients (older than 18 years) with complicated cystic renal lesions diagnosed by US or CT.
- *Exclusion criteria*: Patients with Bosniak I & II categories were excluded, patients with general contraindications for MR examination (as with pacemaker or metallic prosthesis), patients with impaired renal function (not suitable for intravenous gadolinium injection), and patients refusing consent.

MRI technique

All the patients underwent multiparametric MRI study (Pre- and Post-Gd-enhanced T1WI, T2WI and DWI). By using 3 Tesla MRI scanner, (Phillips, ingenia 3 T, Best, The Netherlands), imaging will be in the supine position using phased-array body coil using M-Dixon program and was include these sequences:

T2-weighted imaging: axial T2W images without fat suppression are obtained with TR (ms) 2112, TE (ms) 100, Flip angle (degree) 90, FOV (cm) 32, Matrix (mm) 268 X 344, Slice thickness (mm) 5, Slice gap (mm) 0–0.4 and Number of excitations 2–3.

Table 1 Bosniak classification of cystic renal masses, Version 2019 (5)

Class	MRI: Proposed Bosniak Classification, Version 2019
I	Well-defined, thin (≤ 2 mm) smooth wall; simple fluid (signal intensity similar to CSF); no septa or calcifications; the wall may enhance
II	Three types, all well-defined with thin (≤ 2 mm) smooth walls: Cystic masses with thin (≤ 2 mm) and few (1–3) enhancing septa; any non-enhancing septa; may have calcification of any type Homogeneous masses markedly hyperintense at T2-weighted imaging (similar to CSF) at non-contrast MRI Homogeneous masses markedly hyperintense at T1-weighted imaging (approximately 2.5 > normal parenchymal signal intensity) at non-contrast MRI
IIf	Two types: Cystic masses with a smooth minimally thickened (3 mm) enhancing wall, or smooth minimal thickening (3 mm) of one or more enhancing septa, or many (≥ 4) smooth thin (≤ 2 mm) enhancing septa Cystic masses that are heterogeneously hyperintense at unenhanced fat-saturated T1-weighted imaging
III	One or more enhancing thick (≥ 4 mm width) or enhancing irregular (displaying ≤ 3-mm) obtusely marginated convex protrusion(s) walls or septa
IV	One or more enhancing nodule (≥ 4-mm) convex protrusion with obtuse margins or a convex protrusion of any size that has acute margins

Fat-Suppressed T1W sequences & (DCE): Imaging before and after IV bolus administration of 0.1 mmol/kg of (Dotarem) (gadoteric acid) at 2 mL/s rate, and after that giving saline flush. (non-enhanced and gadolinium-enhanced DCE sequences: corticomedullary timed empirically at 35 s, followed nephrographic at 120 s, and excretory phases), TR (ms) 182, TE (ms) 4.6, Flip angle (degree) 70, FOV (cm) 37, Matrix 220 X 284, Slice thickness (mm) 5, Slice gap (mm) 0–0.4 and Number of excitations 1.

Diffusion-weighted imaging: was performed during free breathing with axial plane fat suppressed water-excited single-shot spin echo with high b value (0, 800 s/mm^2), TR (ms) 1500, TE (ms) 76, Flip angle (degree) 90, FOV (cm) 40, Matrix (mm) 180×194, Slice thickness (mm) 5, Slice gap (mm) 0.3–0.4 and Number of excitations 4–10.

Dynamic contrast-enhanced images were done by injecting Dotarem (Gadoteric acid) dose of 0.1 mmol/kg (maximum dose 15 mmol) IV at a rate of 2 mL/s and Post-Gad images were taken with start of injection and repeated every 30 s for 3 min and delayed phase at 5 min.

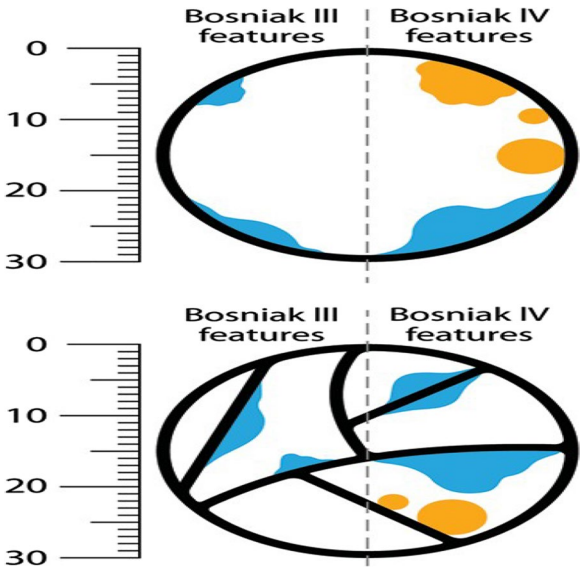

Fig. 1 Differentiation between wall and septa irregularity from nodules by using the Bosniak classification of cystic renal masses, version 2019. Orange features have acute margins and blue features have obtuse margins. Bosniak III features are examples of focal irregular thickening. Bosniak IV features are examples of nodules (5)

Image analysis

Two well-trained uroradiologist with 6 and 15 years of experience reviewed the MRI at an independent workstation. They were blinded to all clinical and pathologic data, including whether lesions were surgically resected or biopsied. Readers first independently assigned each cystic renal mass a Bosniak category based on original classification system and then a category based on version 2019 in the article published by Silverman et al. (Table 1). In the process, readers assessed the number of septa, septal thickness, septal enhancement, wall thickness, wall enhancement, T1 intensity (hypointense, isointense, or hyper-intense; homogeneous or heterogeneous), T2 intensity (hypointense, isointense, or hyperintense; homogeneous or heterogeneous), and convex protrusion (presence or absence; acute or obtuse; size).

Convex protrusions that arise from a wall or septa are either nodules (any size if they have acute margins with the walls or septa, or > 4 mm if they have obtuse margins with the wall or septa [a feature of Bosniak IV]) or irregular thickening (< 3 mm if they have obtuse margins with wall or septa, a feature of Bosniak III). Size measurements are obtained perpendicular to the wall or the septum of origin. If convex protrusion are on both sides of a wall or septum, the cumulative perpendicular distance is used and excludes the thickness of the underlying wall or septum (Fig. 1).

Lesions also qualitatively assessed for the approximate percentage of cystic changes (≤ 25% or > 25% enhancing components).

Quantitative analysis of MRI

Quantitative analysis was done by drawing an identical ROI on the mural nodule or the wall of the lesion, which were assessed on contrast-enhanced T1 WIs ROIs were reported in all sequences and placed on the enhanced portion of the tumor on each phase, also in the ADC ratio, the ROI was drawn on wall, soft tissue component of the tumor & on the normal renal tissue.

- We measured the apparent diffusion coefficient mean, pre-contrast Signal intensity, cortico-medullary phase SI and nephrographic phase SI. ADC mean of the same side non-lesion kidney was measured. We also measured precontrast SI, corticomedullary enhancement, and nephrographic enhancement of non-lesion cortex of the same side.

The following calculations were performed for each lesion (8):

1. ADC ratio = ADC mean lesion/ADC mean ipsilateral kidney.
2. Absolute corticomedullary enhancement = corticomedullary lesion − precontrast lesion.
3. Absolute nephrographic enhancement = nephrographic lesion − precontrast lesion.
4. Relative corticomedullary enhancement = corticomedullary lesion − corticomedullary non-lesion cortex.

5. Relative nephrographic enhancement = nephrographic lesion − nephrographic non-lesion cortex.
6. Absolute washout = corticomedullary lesion − nephrographic lesion.

We analyze and compare between conventional MRI (T1WI and T2WI), biparametric MRI (DWIs and T2WI) & multiparametric MRI (Pre- and Post-Gd-enhanced T1WI, T2WI , DWI).

Histopathological examination is the gold standard for cases underwent resection; However, follow-up is the gold standard for non-surgical group.

Statistical analysis

Descriptive statistics (mean, percent and frequencies) were utilized to represent the collected data of the results. The evaluation of the differences between malignant and benign cystic renal masses was carried out utilizing t tests or Wilcoxon rank tests, as suitable. The quantitative parameters were calculated and compared using ROC curve analyses. The level of significance was determined to be at ($p \leq 0.05$) for the current study. Analyses were carried out using SPSS 23.0 (Chicago, IL, USA) for windows software.

Results

This study was conducted on 58 patients (39 males and 19 female) with complicated cystic renal masses. The patients' age ranged from 19 to 79 years old and the number of cystic lesions was shown in each group (mean age 53 ± 14 SD).

Surgical and non-surgical groups

Of the 58 cystic masses analyzed, 30 lesions were resected and correlated with pathology reports. Three cases were abscesses and underwent percutaneous drainage. However, 25 cystic lesions underwent follow-up MRI rather than surgery; they were observed for periods ranging from 6 months to 2 years (Table 2).

Of the 30 cases with resected cystic renal lesions, 12 cases underwent partial nephrectomy and 18 cases underwent radical nephrectomy.

Table 2 Analysis of surgical and non-surgical groups in 58 studied cysts

Bosniak classification	Surgical Group	Nonsurgical group
Bosniak IIf	2	25
Bosniak III	10	3
Bosniak IV	18	–
Total	30	28

Histopathologic correlation

Pathologic correlation, which was available for 30 lesions, revealed 28 malignant and 2 benign lesions (Table 3). The most surgically removed cysts were proved to be papillary RCC (53%).

The mp-MRI classification accurately predicted outcome for categories IIf, and IV. Lesions of IIf category ($n = 27$) were proved to be benign; however, the 18 lesions assigned category IV were all malignant & 10 lesions of the 13 lesions in category III were malignant (Table 4 and Fig. 2).

Quantitative multiparametric MR analysis

Regarding the dynamic contrast enhancing parameters, no difference was detected in relative corticomedullary, relative nephrographic and absolute nephrographic enhancement between malignant and benign masses. On the other hand, absolute corticomedullary enhancement that was determined by subtraction of the precontrast lesion SI from the corticomedullary phase revealed alterations. There was also difference in absolute washout between benign and malignant that was calculated by subtracting nephrographic phase from the corticomedullary phase.

We also found that ADC values of the lesions can distinguish benign and malignant lesions with statistically significant differences ($p = 0.001$). There was no significant difference in ADC ratio between malignant or benign masses ($p = 0.108$). The mean ADC value of benign cystic renal lesions (1.4) was higher than malignant cystic renal lesions (0.8) with significant difference (p value < 0.001) (Table 5).

Table 3 Analysis of surgical group as regard histopathology results (30 lesions)

Pathology	Surgical group	Number	%
Benign	Multicystic nephroma	2	7 %
Malignant	Clear cell RCC	12	40 %
	Papillary RCC	16	53%
Total		30	100%

Table 4 Bosniak classification of cystic lesions in the kidney and outcome of 58 lesions

Bosniak Classification	Benign	Malignant	Total
Bosniak IIf	27	0	27
Bosniak III	3	10	13
Bosniak IV	0	18	18

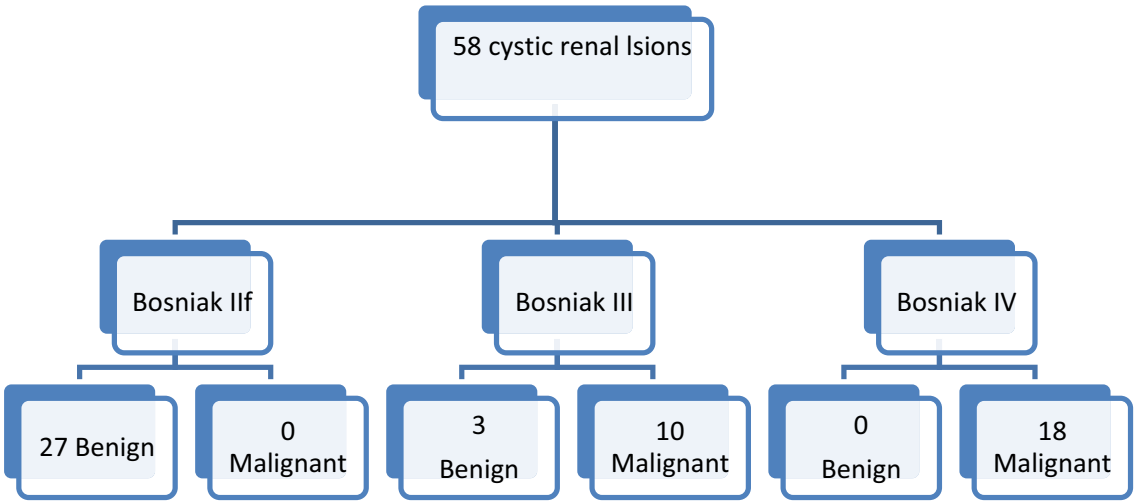

Fig. 2 Flowchart of Bosniak classification of cystic renal masses by multiparametric MRI & outcome of the 58 included cystic renal lesions

Table 5 Comparisons of benign versus malignant lesions as regard quantitative multiparametric MR analysis:

Variables	Benign lesion		Malignant lesion		*p* value
	Mean	SD	Mean	SD	
ADC of the lesion	1.4	0.46	0.87	0.39	0.001
ADC ratio	0.7	0.2	0.50	0.3	0.108
Absolute corticomedullary enhancement	110.2	64.2	248.5	168	0.030
Absolute nephrographic enhancement	119	79.6	129	131.4	0.839
Relative corticomedullary enhancement	59.6	57.2	156	132.6	0.055
Relative nephrographic enhancement	67.2	68.9	69.4	98.2	0.954
Absolute washout	5.2	59.9	87.6	56.6	< 0.001

According to ROC curve of the ADC value, the optimal cut-off point for ADC value to differentiate between benign and malignant cystic renal mass was (1.4×10^{-3} S/m) with sensitivity (85 0.7%) & specificity (75%) and area under the curve (AUC) = (0.857) (Fig. 3).

Bosniak classifications of cystic masses using different techniques

The conventional, biparametric and multiparametric MRI Bosniak classification of the 113 cystic renal masses are summarized in Fig. 4.

Bosniak classification diagnostic performance

The diagnostic values of the Bosniak classification using different MRI techniques for the discrimination between malignant and benign renal masses were estimated by arranging results into positive (Bosniak III and IV) and negative (Bosniak IIF) regarding the results of MRI. The standard reference for benign and malignant diagnoses was demarcated as the concluding diagnosis established by histopathological examination ± follow-up.

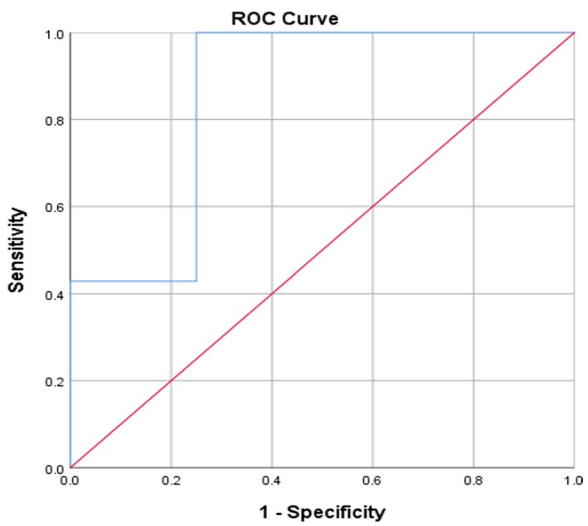

Fig. 3 ROC curve for ADC value in differentiation between benign and malignant cystic renal mass

Diagnostic performance, including sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy of different MRI techniques in the studied population are summarized in (Table 6).

Different examples of mp-MRI studies in assessment of different categories of Bosniak classification are presented in Figs. 5, 6, 7 and 8.

Discussion

Use of Bosniak classification version 2019 improves sensitivity and specificity for malignancy and results in reclassification of more lesions as Bosniak IIF [5].

Since MRI has demonstrated to be a respected modality in the assessment of cystic renal masses, we conducted this study to evaluate the diagnostic performance of multiparametric MRI in Bosniak categorization of 58 cystic renal masses compared to the conventional and biparametric MRI.

Balci et al. in a retrospective manner assessed 55 complex cysts detected in the kidney in 37 cases utilizing MR Imaging. They stated that MRI had correlation with histopathological outcomes in complex cysts and could be utilized in the assessment of complex cysts detected in the kidney [9].

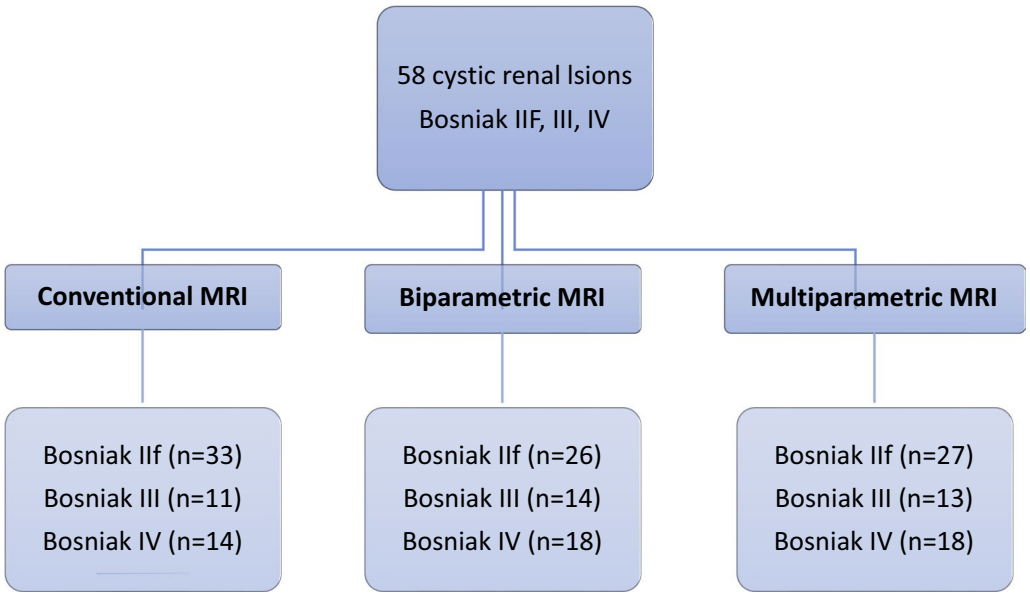

Fig. 4 Flowchart of Bosniak classification according to mp-MRI compared to conventional and biparametric MRI

Table 6 Diagnostic performance sensitivity, specificity, PPV, NPV and diagnostic accuracy of Bosniak classification of 58 cystic lesions

Variable	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic accuracy (%)
Conventional MRI	58.06	77.78	75	61.76	67.24
Biparametric MRI	70.97	92.59	91.67	73.53	81.03
MP-MRI	90.32	100	100	90	94.83

(See figure on next page.)

Fig. 5 Right renal cystic mass (Bosniak IV). Axial T1WI (**A**) demonstrated a well-defined right midzonal exophytic thick-walled parenchymal multilocular cystic lesion measuring 5.5 cm in its maximum dimension. The lesion is hypointense with mural nodules (Convex protrusion > 4 mm with obtuse angle) of intermediate signal inside. Axial T2WI (**B**) the lesion appears hyperintense with intermediate signal of the mural nodules (black arrow). Axial DWI (**C**) with $b = 800$ mm^2/s & axial ADC map (**D**) showed restricted signals of the mural nodules with ADC value (0.8×10^{-3} mm^2/s). Axial corticomedullary (**E**) and nephrographic (**F**) DCE-MRI subtracted images showed enhancing mural nodule (white arrow). The pathology was papillary renal cell carcinoma

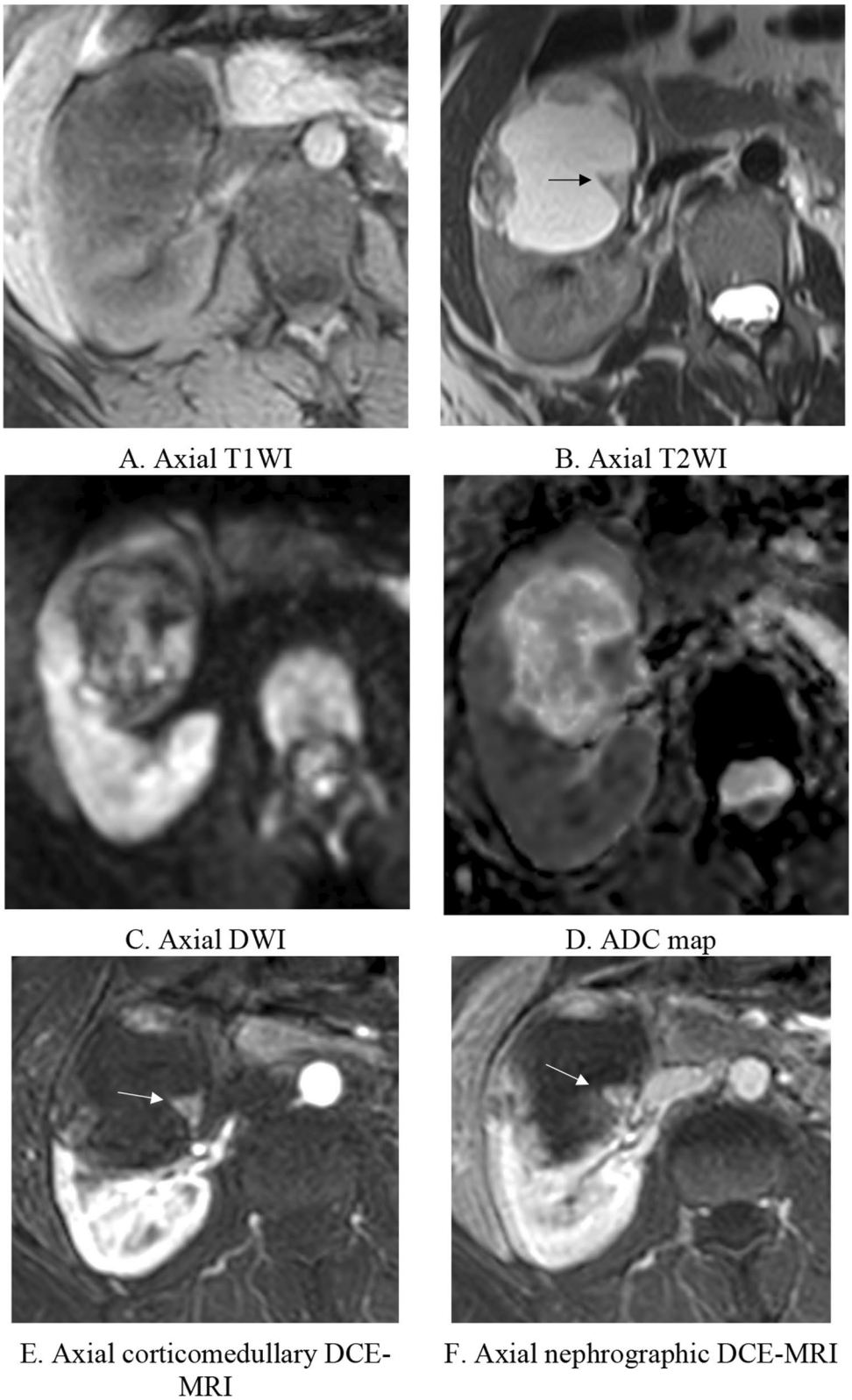

Fig. 5 (See legend on previous page.)

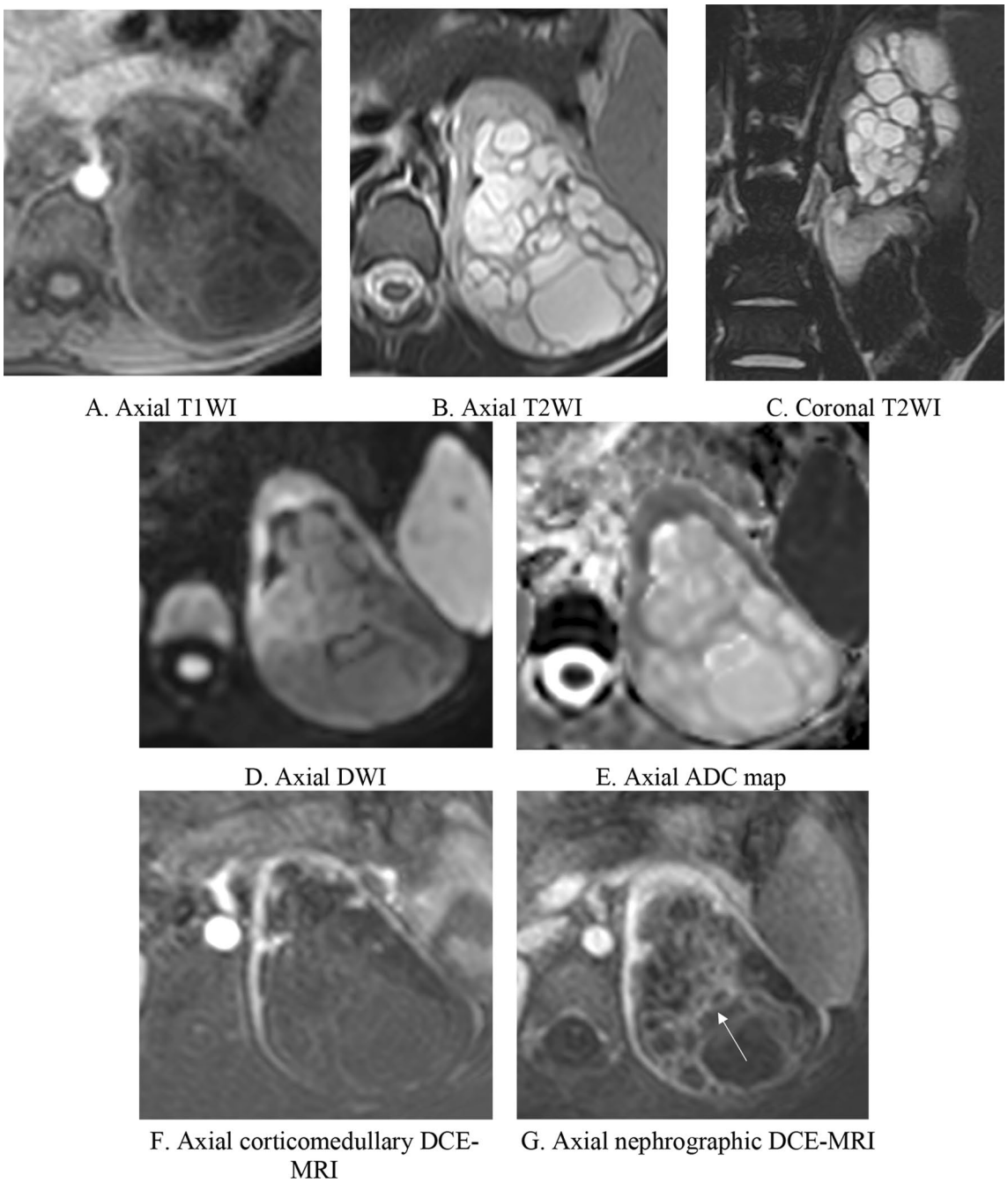

Fig. 6 Left renal cystic mass (Bosniak IIF). Axial T1WI (**A**) demonstrated a well-defined left upper polar endophytic thick-walled (3 mm) parenchymal multilocular cystic lesion measuring 7 cm in its maximum dimension. The lesion is hypointense with multiple (> 3) minimal thick septae (2–3 mm) of intermediate signal inside. In axial (**B**) and coronal (**C**) T2WI. The lesion appears hyperintense with intermediate signal of the septae. The mass is seen herniated into the renal pelvis. Axial DWI (**D**) $b = 800$ mm^2/s & axial ADC map (**E**) showed no restricted signals with ADC value (1.8×10^{-3} mm^2/s). Axial corticomedullary (**F**) and nephrographic (**G**) DCE-MRI subtracted images showed multiple enhancing septae (arrow). The pathology was Multicystic nephroma

Israel et al. reported that the sufficient septa depiction to decide their thickness and number is critical for appropriate utilization of the system of Bosniak classification. The septa characterization was the chief cause for migrations of category in their study from II-F to III, in the condition of confidently establishing both the thickening definition and septa enhancement [10].

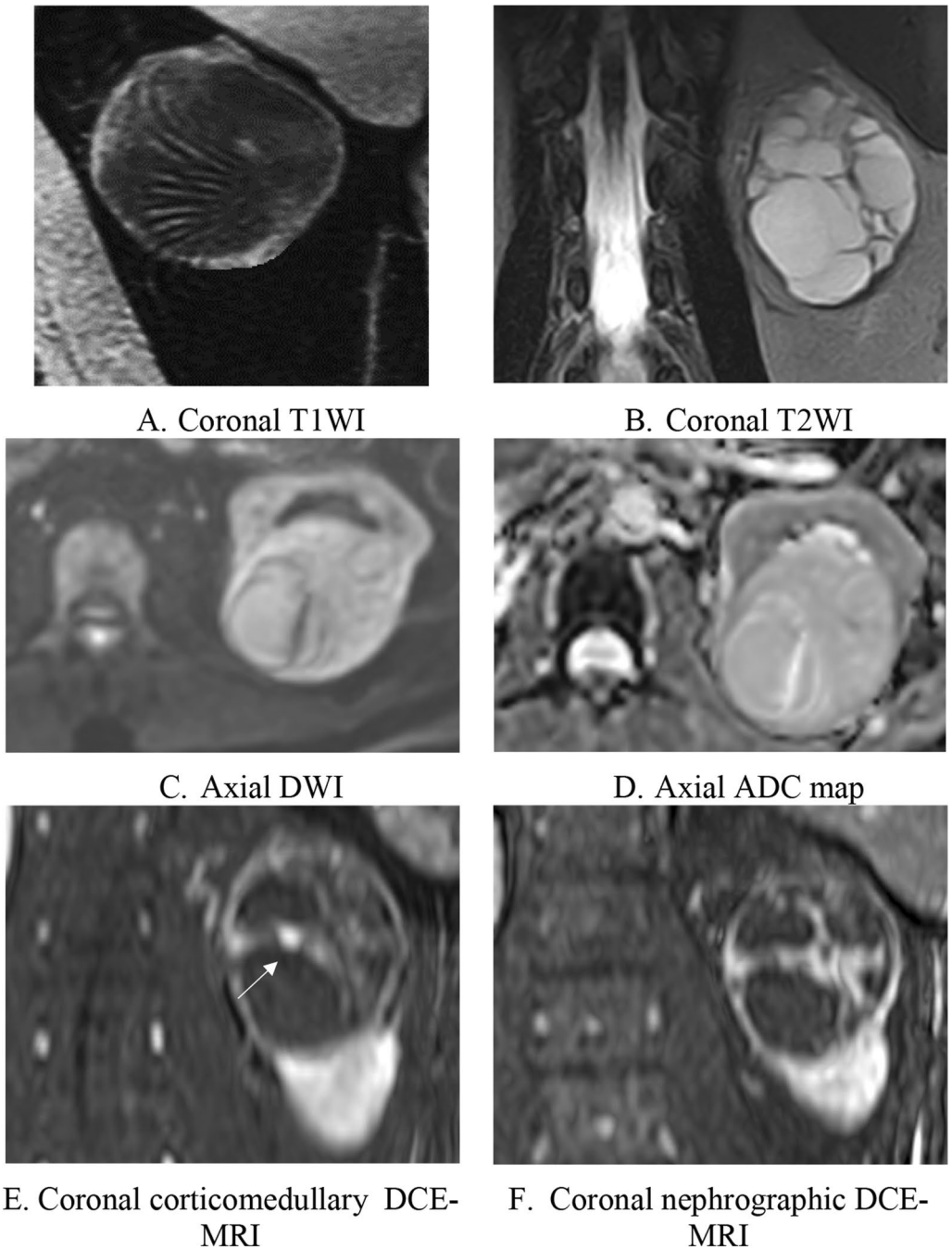

Fig. 7 Left renal cystic mass (Bosniak III). Coronal T1WI (**A**) a well-defined left upper polar and midzonal exophytic thick-walled parenchymal multilocular cystic lesion measuring 7.6 cm in its maximum dimension. The lesion is hypointense with thick septae of intermediate signal inside with no suspicious nodules inside. In Coronal T2WI (**B**), the lesion appears hyperintense with intermediate signal of the septae with no suspicious nodules inside. Axial DWI (**C**) $b = 800$ mm^2/s & axial ADC map (**D**) Showed no restricted signals. Coronal corticomedullary (**E**) and nephrographic (**F**) DCE-MRI subtracted images: showed multiple enhancing septae with enhancing septal mural nodule (Enhancing obtuse convex protrusion < 3 mm) (arrow). The pathology was papillary renal cell carcinoma

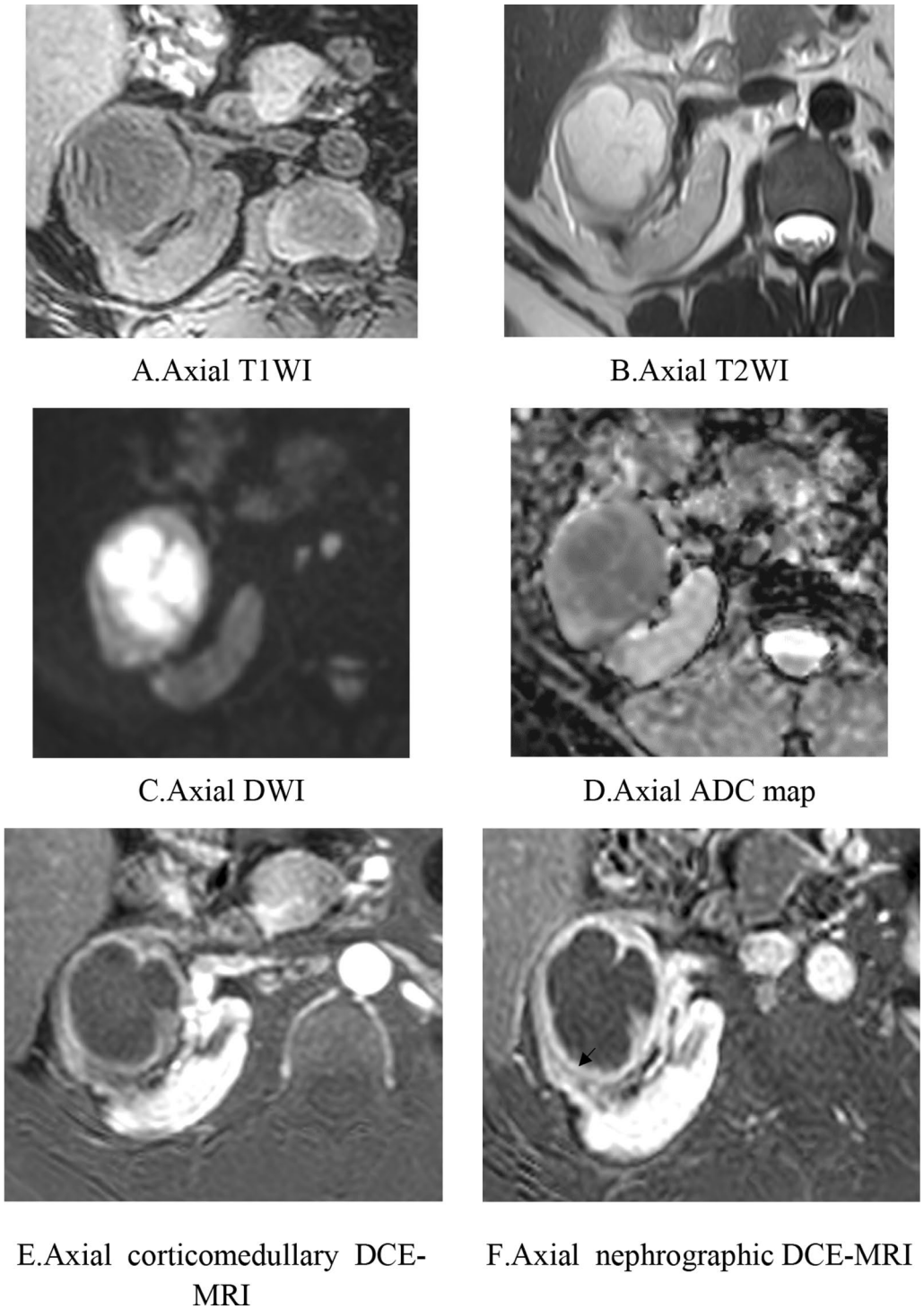

Fig. 8 Right renal cyst (Bosniak III). Axial T1WI (**A**) showed a well-defined right midzonal exophytic thick-walled parenchymal multilocular cystic lesion measuring 4.7 cm in its maximum dimension. The lesion is hypointense with thick incomplete septae of intermediate signal inside. Axial T2WI (**B**) the lesion appears hyperintense with intermediate signal of the septae. Axial DWI $b = 800$ mm^2/s & axial ADC map (**C**, **D**) Showed restricted content, no restriction of the wall or septae. Axial corticomedullary and nephrographic DCE-MRI subtracted images (**E**, **F**) showed smooth thick enhancing wall (4 mm) (arrow) septae. The pathology/cytology: Pus by percutaneous drainage tube (PCD)

In number of patients, especially in smaller masses, several septae within a lesion may be confluent and mass like. The septa may be irregular or thickened that is characteristic of Bosniak III masses [10].

We found in the present study that mp-MRI revealed septa within a mass with higher sensitivity than conventional and biparametric MRI and, consequently, it is predictable that mp-MRI could make a mass having a higher category of classification than it could have with conventional and biparametric MRI categorization.

DWI could be utilized in the assessment of the cystic masses detected in the kidneys besides the conventional MR Imaging. Balyemez et al. demonstrated that DWI may have a significant role in the prediction of presence of malignancy in the cystic masses detected in the kidneys. [11].

The most significant factor in the assessment of cystic mass detected in the kidney is the enhancement absence or presence. A cystic mass detected in the kidney is regarded malignant (Bosniak IV) in the condition of soft tissue enhancement inside the mass. Enhancing of the grossly thickening of the septa or walls in a cystic mass is found in Bosniak III masses that need surgical intervention but can be malignant or benign. Bosniak II and IIF masses do not show enhancement with contrast material administration [10].

Since the mp-MRI is superior to biparametric MRI, and conventional MRI, it should not be surprising that in number of patients, mp-MRI reveals structures enhancement that are not represented at conventional MRI. In four of the 58 lesions (Bosniak IIF to IV) in this current study, the mp-MRI demonstrated enhancing structures not detected at conventional MRI that is responsible for a superior category at mp-MRI in the four masses. The mp-MRI findings classified the four lesions as category IV (lesion requiring surgery) and they were proved to be renal cell carcinoma by histopathological analysis, but the findings of conventional MRI proposed Bosniak IIF.

Yan et al. found that using Bosniak classification version 2019 results in a higher proportion of Class IIF masses with less Class III [12]. In our study, the number of cysts of Bosniak IIf (27) category is also higher than of Bosniak III (13) as the version 2019 criteria limits the Bosniak III cysts to the cysts that have (≥ 4 mm width) or enhancing irregular (displaying ≤ 3-mm) obtusely marginated convex protrusion(s) walls or septa.

Category IIF lesions of Bosniak classification system show a decreased but non-zero malignancy possibility and should undergo follow-up with imaging at regular intervals. Category (III, IV) lesions of Bosniak classification system show a greater malignancy probability and are characteristically surgically removed unless the case shows decreased life expectancy or accompanied with diseases, which prefer imaging follow-up as an alternative [5].

With regard to contrast enhancement parameters in current study, there was no significant difference in relative corticomedullary (CME), relative nephrographic (NGE) and absolute nephrographic enhancement (NGE) between benign and malignant lesions. However, the mean value ± SD of the absolute corticomedullary enhancement calculated by subtraction of the SI of precontrast lesion from the CM phase was (110.2 ± 64.2 SD) for benign lesions Vs (248.5 ± 168 SD) for malignant lesions, demonstrated significant differences (p value 0.030). There was also significant difference in absolute washout between benign (5.2 ± 59.9 SD) and malignant (87.6 ± 56.6 SD) which was calculated by subtracting nephrographic phase from the corticomedullary phase (p value < 0.001). This was in agreement with Yano et al. who reported the CME ($p = 0.013$) as predictor of malignancy they found no difference in absolute NGE, relative NGE or relative CME between malignant and benign masses which was similar to our results. Contrary to Yano et al. study, we found that the absolute washout had statistically significant value to differentiate between benign and malignant complex cystic renal lesions [8].

Mirka et al. reported that the ADC values that are evaluated on DWI are low in solid component of malignant cystic renal masses in comparison with those that were benign [13]. Comparable principles may be applied to alterations in CE of malignant versus benign cystic lesions detected in the kidneys [14].

In this study, the mean ADC value of benign cystic renal lesions (1.4×10^{-3} m/s) was higher than malignant cystic renal lesions (0.9) with significant difference (p value < 0.001). The optimal cut-off point for ADC value to differentiate between benign and malignant cystic renal mass was (1.41×10^{-3} S/m) with sensitivity (85 0.7%) & specificity (75%) and area under the curve (AUC) = (0.857). We found that ADC values of the solid component can distinguish benign and malignant lesions with statistically significant differences which were in agreement with Lassel et al. [15]. However, there was no significant difference in ADC ratio between malignant or benign masses.

Göya et al. found that the mean ADC value of malignant renal lesions was 1.06×10^{-3} mm^2/s ($0.62–1.74 \times 10^{-3}$ mm^2/s); however, the mean ADC value of benign lesions was 2.03×10^{-3} mm^2/s ($0.31–9.72 \times 10^{-3}$ mm^2/s) which was comparable to our results [16]. There were significant differences between the ADC values of malignant and benign lesions detected in the kidney on DWI ($p < 0.001$).

Both qualitative and quantitative mp-MRI resulted in migration of the category and change of the management

of number of complex cysts detected in the kidneys in a major percentage of the patients. This was probably because of its high contrast resolution. On the other hand, the mp-MR Imaging effect on diagnosing the complex cysts detected in the kidneys (and its clinical importance) still necessitates more evaluation [17].

Limitations

The current study showed many limitations. First, it was carried out in a single center with relative small sample size in each category. However, MRI currently increasingly used in renal masses characterization at our institution and in the future more extended studies with large numbers will be available.

Second, we include cystic lesions with Bosniak IIF, we used the follow-up criteria to classify most of them as benign lesions, and we found the possibility of malignancy in this group near zero.

Third, we applied the quantitative parameters of mp-MRI only on cases with soft tissue component and this category migration proposed to decrease the debate in scoring pathological outcomes that resulted from bias of selection toward a larger percentage of Bosniak III–IV masses and malignant outcomes. This bias is not avoidable due to the requirement for pathological correlation as the standard reference in the current study to ultimately decide malignant versus benign pathological outcomes. Up till now, several reports do not involve cysts which could be classified as Bosniak I or II, decreasing appropriate studies number.

Conclusions

Multiparametric MRI can be utilized to confidently evaluate cystic renal masses, overcoming the traditional limitations of overlapping morphological imaging features. Quantitative parameters derived from multiparametric MRI allow better evaluation of complex cystic renal tumors to distinguish between benign and malignant complex cystic renal lesions.

Abbreviations

AUC	Area under the curve
RCC	Renal cell carcinoma
ADC	Apparent diffusion coefficient
SI	Signal intensity
MP	Multiparametric
DWI	Diffusion-weighted image
Gd	Gadolinium
DCE	Dynamic contrast enhancement
CE	Contrast enhancement
ROI	Region of interest
CM	Corticomedullary
NG	Nephrographic
CT	Computerized tomography

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Author contributions

MAZ and MAE gave idea and collected the patients' data and analyzed them. MAE put study design and followed the patients postoperatively. NET wrote the paper with revision. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of the Faculty of Medicine at Mansoura University in Egypt on 20 /05 /2018; reference number of approval: MS.18.05.131.

Consent for publication

All patients included in this research gave written informed consent to publish the data contained within this study.

Competing interests

The authors declare that they have no competing interests.

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