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Role of magnetic resonance imaging in characterization of cystic renal lesions based on Bosniak classification version 2019

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Abstract

Background In 2019, the Bosniak classification system for cystic renal lesions underwent modifications aimed at addressing the limitations of the original classification.

Results The revised 2019 version demonstrated notable differences from its predecessor. Specifically, it showed an increased proportion of class IIF cystic lesions (31% compared to 16.7%) and a decreased proportion of class III cystic lesions (27.4% compared to 45.2%). Additionally, the malignancy rate for class III cystic renal lesions was lower in the 2019 version (37.8% vs. 42.2%). When it came to diagnosing malignancies, the 2019 version exhibited higher specificity (74.4% compared to 41.03%) while maintaining a comparable sensitivity (97.8% vs. 100%) compared to the original Bosniak system.

Conclusions The Bosniak 2019 version demonstrated enhanced specificity and diagnostic accuracy for malignancies in comparison to the original Bosniak system, all while maintaining an equivalent sensitivity.

Keywords Bosniak 2019, MRI, Diagnostic accuracy, Bosniak classification, Renal cysts

Background

Cystic renal lesions are frequently seen in radiologic examinations, and their characterization can be challenging due to the potential representation of both malignant and non-malignant conditions [1]. To improve differentiation between malignant and benign cystic renal lesions and for risk stratification of cystic renal lesions, the Bosniak classification was first established in 1986 [2].

As a living system, modifications were made in 1993 and 2005 (the original classification), yet with this original Bosniak classification, several shortcomings have

been noted, such as wide inter-reader agreement that ranges from 6 to 75% in several studies. According to the original Bosniak classification, approximately half of class III cystic lesions are benign; however, these lesions are frequently resected [3, 4].

In response to these limitations, a new Bosniak classification was published in 2019, aiming to increase the specificity for identifying malignancy and increase inter-reader agreement by clarifying the definitions of the descriptors [5].

An important change in the Bosniak classification, version 2019, is the formal addition of MRI, as MRI has advantages over CT such as better contrast resolution and the lack of ionizing radiation [6].

To distinguish cystic lesions from more aggressive tumors with necrosis, the Bosniak version 2019 classification defines a cystic lesion as one with no more than 25% solid component. Additionally, previously subjective

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terms such as thin (vs. thick) walls, few (vs. many) septa, and nodule (vs. an irregularly thickened wall or septa) have been defined: For example, “thin” is now defined as ≤ 2 mm, “minimally thick” as 3 mm, and “thick” as ≥ 4 mm; “few” is defined as 1–3 septa and “many” as ≥ 4 septa, and perceived versus measurable enhancement and size of lesion are no longer criteria [7].

The goal of our study was to compare the newly revised Bosniak classification version 2019 utilizing MRI to the original one in the characterization of cystic renal lesions, as well as to evaluate recently proposed imaging findings and their relationship to pathological diagnosis within version 2019.

Methods

This prospective observational study included 97 patients; 13 patients were excluded (3 cases with a solid component $>25\%$; 1 case with APCKD; 7 cases missed follow-up; and 2 cases did not complete the study); and 84 patients with cystic renal lesions were included in the final analysis. There were 45 malignant lesions (53.6%) and 39 benign lesions (46.4%) among the evaluated 84 cystic lesions; 13 cystic lesions showed a static course on follow-up (up to 24 months), denoting a benign nature. Sixty-six lesions were resected (1 lesion underwent decortication, 32 lesions underwent partial nephrectomy, and 33 lesions underwent radical nephrectomy), and 4 lesions underwent US-guided aspiration and were correlated with pathology reports. Those lesions were diagnosed by US or CT between May 2021 and June 2023. Patients were referred from an outpatient’s clinic.

- *Inclusion criteria:* Patients with cystic renal lesions identified by other radiological modalities who were older than 18 years.
- *Exclusion criteria:* Patients who were generally contraindicated for MR scan, patients with an estimated GFR <30 ml/1.73 m², and lack of histopathology results or missed follow-up.
- *MRI technique:*
- All patients had their MRIs performed using a 3 Tesla MRI scanner (Phillips, Ingenia 3 T, Best, The Netherlands).
- MRI scan was performed while the patients were in the supine position using a phased-array body coil. Axial T2WI and M-Dixon sequences were performed with the following parameters:
 - Axial T2WI: time of repetition (TR) 2112 ms, time of echo (TE) 100 ms, flip angle 90°, slice thickness 5 mm, slice gap 0–0.4 mm, size of matrix 268 × 344 mm, field-of-view (FOV 32 cm), and number of excitation is 2–3.

- T1W sequence with fat suppression and DCE Imaging with an IV bolus injection of 0.1 mmol/kg (Dotarem) (gadoteric acid) at a rate of 2 mL/s, followed by a saline flush. (non-enhanced and gadolinium-enhanced DCE sequences: corticomedullary phase at 35 s; nephrographic and delayed phases; TR 182 ms; TE 4.6 ms); flip angle 70°; slice thickness 5 mm; slice gap 0–0.4 mm; size of matrix 220 × 284 mm; FOV 37 cm; and number of excitations is 1.

Image analysis

- After image acquisition, images were saved in DICOM format and transferred to a digital workstation supplied by the manufacturer (intellispace portal Workspace 6.0.1 Philips Medical Systems Netherlands B.V.) for processing.
- All cystic renal lesions were analyzed individually by two well trained urologists (senior and junior of 20 and 8 years of experience, respectively), and then the Bosniak class was assigned by consensus. All cystic renal lesions were classified according to the Bosniak version 2019 and the original one based on the article published by Silverman et al. and Schieda et al. The analysis included assessment of septal number, thickness of septa and wall, wall and septal enhancement, T2 and T1 signal intensities, and the absence or presence of mural nodularity and if it was acute or obtuse angle. Bosniak class was compared to histopathology or follow-up results within 24 months. The radiologists were not aware of all clinical and pathologic data.
- The gold standard is histopathological examination for lesions that have been resected or biopsied; nevertheless, for non-surgical patients, follow-up is the gold standard.

Statistical analysis and data interpretation

Data analysis was performed by SPSS software, version 25 (SPSS Inc., PASW statistics for Windows version 25). Chicago: SPSS Inc. Numbers and percentages were used to describe qualitative data. Median (minimum and maximum) for non-normally distributed data and mean \pm Standard deviations for normally distributed data were used to explain quantitative data after testing normality using the Kolmogorov–Smirnov test. The results’ significance was assessed at the (≤ 0.05) level. Chi-Square, Fischer exact test, and Monte Carlo tests were used to compare qualitative data between groups as appropriate. Mann Whitney A U test was used to compare the two

studied groups for non-normally distributed data. A student *t* test was used to compare two independent groups for normally distributed data.

Results

This study included 97 patients. The final analysis included 84 cystic lesions. The mean age ± SD was 53.83 ± 13.75 (range 18–78) years for 61 male and 23 female patients.

The histologically proved malignant lesions were: 26 clear RCC, 2 chromophobe RCC, 1 tubulocystic carcinoma, 1 adenocarcinoma (mucinous type), 1 primitive neuroectodermal tumor (PNET), 1 adult nephroblastoma, 9 papillary RCC, 2 cystic RCC, and 2 MLCN LMP. The histologically proved benign lesions were: 7 cystic nephroma, 4 suppurative smears, 4 hemorrhagic cysts, 1 xanthogranulomatous pyelonephritis, 2 simple cysts, 4 oncocytoma, 2 mixed epithelial stromal tumor (MEST), and 2 renal tuberculosis and 13 cystic lesions showed static course on follow up denoting benign nature.

Distribution of cystic renal lesions according to Bosniak 2019 and original Bosniak

According to the original Bosniak, the 84 cystic lesions were classified into 2 Bosniak class II, 14 Bosniak class IIF, 38 Bosniak class III, and 30 Bosniak class IV lesions, but according to the Bosniak classification version 2019, the 84 cystic lesions were classified into 4 Bosniak class II, 26 Bosniak class IIF, 23 Bosniak class III, and 31 Bosniak class IV lesions.

The prevalence of class IIF cystic lesions was higher for version 2019 than for the original one (31% vs. 16.7%). On the other hand, the incidence of class III cystic lesions

was lower for version 2019 than for the original one (27.4% vs. 45.2%). The proportion of class II cystic lesions was slightly higher for version 2019 than for the original version (4.8% vs. 2.4%). Also, the proportion of class IV cystic lesions was slightly higher for version 2019 than for the original one (36.9% vs. 35.7%) (Table 1).

Change in distributions and malignancy rates

The majority of lesions that changed classes were recategorized as Bosniak IIF (14 lesions underwent downgrading to IIF), the proportion of which increased from 16.7 to 31%; only 2 lesions were reclassified as Bosniak II, and one lesion was reclassified as Bosniak IV (upgraded) (Table 2).

Relationship of newly proposed criteria to malignancy

There was a significant association between wall thickness, septal thickness, and the presence of ≤ 3-mm obtuse convex protrusion, ≥ 4-mm obtuse convex protrusion, or acute convex protrusion of any size and malignancy; mean wall thickness of 3 mm for benign lesions versus 4 mm for malignant lesions; mean septal thickness of 2 mm for benign compared to malignant (4 mm); heterogeneous high T2 and heterogeneous low T1 SI also had a significant association with malignancy. For all those criteria, there was a significant difference; *p* < 0.001, while there was no relationship between the number of septa and malignancy (*P* value = 0.051) (Table 3).

Diagnostic performance of Bosniak classification

The Bosniak classification’s diagnostic values utilizing different MRI sequences for distinguishing between malignant and benign cystic renal lesions were estimated by categorizing the results of MRI as positive (Bosniak III and IV) or negative (Bosniak I, II, and IIF). The final diagnosis obtained by histological examination ± follow-up was designated as the standard reference for benign and malignant diagnoses.

The diagnostic performance of Bosniak version 2019 and the original one in the examined population was summarized in (Table 4), including sensitivity,

Table 1 Distribution of cystic renal lesions in each class

Bosniak class	Original Bosniak	Bosniak 2019
II	2(2.4%)	4(4.8%)
IIF	14 (16.7%)	26 (31.0%)
III	38(45.2%)	23 (27.4%)
IV	30 (35.7%)	31(36.9%)

Table 2 Shift in distribution and malignancy rates among cystic renal lesions

Bosniak category	Original	Version 2019	Downgraded	Not changed	Upgraded	Change from original (%)	Malignancy rate	
							Original	Version 2019
II	2	4	0	2	0	0.0	0.0	0
IIF	14	26	2	12	0	14.2%	0.0	3.8%
III	38	23	14	23	1	39.5%	50.0%	73.9%
IV	30	31	0	30	0	0.0	86.7%	87.1%

Table 3 Relation between proposed criteria of cystic renal lesion and malignancy

	Benign n = 39 (%)	Malignant n = 45 (%)	Test of significance
Wall enhancement			FET = 3.59
No	3 (7.7)	0	$P = 0.096$
Yes	36 (92.3)	45 (100)	
Septal enhancement			$\chi^2 = 8.28$
No	12 (30.8)	3 (6.7)	$P = 0.004^*$
Yes	27 (69.2)	42 (93.3)	
Number of septa			$\chi^2 = 5.94$
No	6 (15.4)	3 (6.7)	$P = 0.051$
Few	8 (20.5)	3 (6.7)	
Multiple	25 (64.1)	39 (86.7)	
Wall thickness (mm)	3 (1–10)	4 (2–8)	$z = 4.45$
Median (range)			$p < 0.001^*$
Septal thickness (mm)	2 (1–8)	4 (2–6)	$z = 4.87$
median (range)			$p < 0.001^*$
Mural nodule			MC = 55.56
No	35 (89.7)	4 (8.9)	$P < 0.001^*$
≤ 3-mm obtuse convex protrusion	0	14 (31.1)	
≥ 4-mm obtuse convex protrusion or acute convex protrusion, any size	4 (10.3)	27 (60)	
T2			
Homogenous low	2 (5.1)	0	$P = 0.212$
Homogenous high	25 (64.1)	1 (2.2)	$P < 0.001^*$
Heterogenous low	3 (7.7)	3 (6.7)	$P = 1.0$
Heterogenous high	9 (23.1)	41 (91.1)	$P < 0.001^*$
T1			
Homogenous low	28 (71.8)	1 (2.2)	$P < 0.001^*$
Heterogenous low	8 (20.5)	36 (80)	$P < 0.001^*$
Heterogenous high	3 (7.7)	8 (17.8)	$P = 0.17$

Table 4 Diagnostic performance for malignancy diagnosis based on the original Bosniak Classification and Version 2019

	Original Bosniak (%)	Bosniak 2019 (%)	Test of significance
Sensitivity	100	97.8	0.202
Specificity	41.03	74.4	$< 0.001^*$
PPV	66.2	81.5	0.458
NPV	100	96.7	0.095
Accuracy	72.6	86.9	0.02 [*]

specificity, positive predictive value, negative predictive value, and overall accuracy.

Different examples of MRI studies in assessment category change on using Bosniak 2019 were presented in Figs. 1, 2, 3, 4 and 5.

Discussion

In June 2019, an update (version 2019) was proposed to address the flaws of the original Bosniak classification [5]. We conducted this work to compare the newly revised Bosniak version 2019 to the original one in the characterization of 84 cystic renal lesions using MRI. We also analyzed the recently proposed imaging features and their relationship to pathological diagnosis within version 2019.

We found an increase in the proportion of class IIF cystic lesions when using version 2019. The majority of lesions that changed classes were recategorized as Bosniak IIF (downgrading), the proportion of which increased from 16.7 to 31%, and this was due to a proportion of category III lesions that were reclassified as class IIF. Yan et al. and Tse et al. reported the same findings. Tse et al. reported that when Bosniak version 2019 was used, the proportion of class IIF increased from 8 to 24%. There was only one case in our study

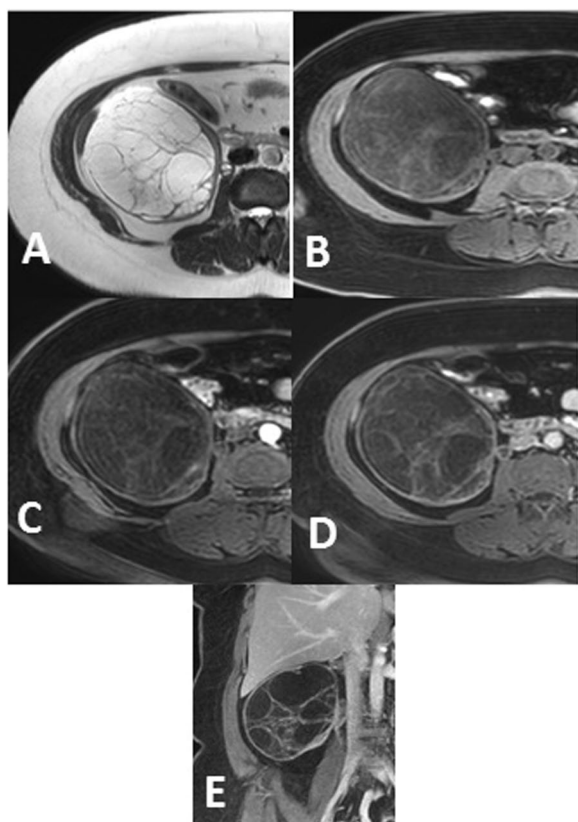


Fig. 1 A 54-year-old female patient complaining of right loin pain. Axial T2-WI of the right kidney (A) showed a lower polar cystic lesion of homogenous high SI and multiple septa. This cystic lesion showed homogenous low SI at axial T1WI (B) and showed multiple enhancing septae (thickness = 3 mm), enhancing wall (3mm) at axial corticomedullary (C), nephrographic (D), and coronal DCE-MRI images (E). By consensus, cystic lesion was initially categorized as Bosniak class III in view of the presence of an enhancing thick wall and multiple irregular enhancing thick septa, while version 2019 defines a thickening of 3 mm, and the lesion was downgraded to Bosniak class IIF. The patient underwent right radical nephrectomy, and histopathology was adult cystic nephroma

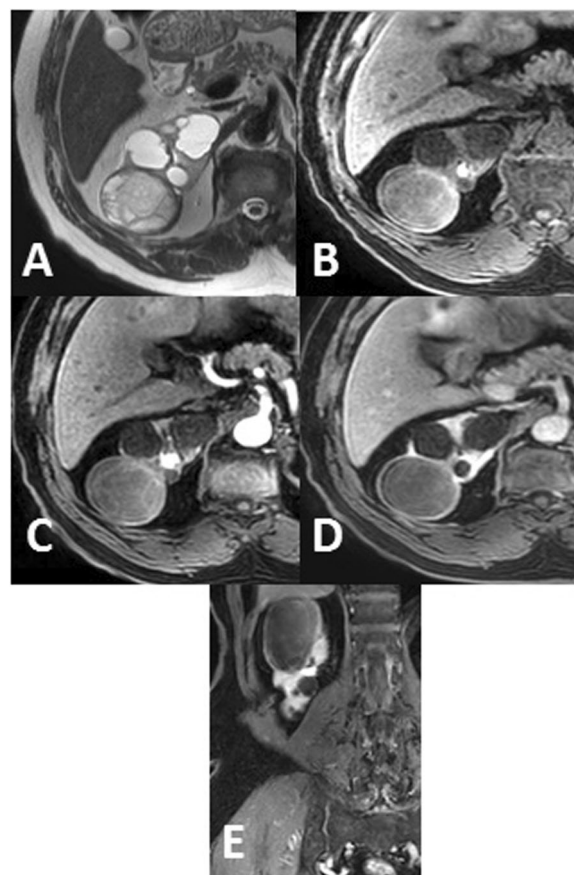


Fig. 2 A 71-year-old male patient complaining of right loin pain. Axial T2-WI of the right kidney (A) showed an upper polar cystic lesion of heterogeneous high SI, multiple septa, multiple parenchymal cysts of fluid SI, and a small hemorrhagic one. This cystic lesion showed heterogeneous low SI at axial T1WI (B) and showed non-enhancing wall and non-enhancing septa (wall and septal thickness were 3 mm) at axial corticomedullary (C), nephrographic (D), and coronal DCE-MRI images (E). By consensus, cystic lesion was initially categorized as Bosniak class III in view of thick wall and multiple irregular thickened septa. As version 2019 defines thickening at 3 mm, the lesion was downgraded to Bosniak class IIF. The patient underwent right partial nephrectomy, and histopathology was a hemorrhagic cyst

of class III that upgraded to category IV with Bosniak 2019. Pitra et al., Ferrerira et al., and Israel et al. also reported this. They observed an upgrade of the Bosniak class of a minority of lesions using MRI, which resulted in changes to the management plan [8].

We found that over all specificity, sensitivity, and diagnostic accuracy were 41.03%, 100%, and 72.6%, respectively, with the original Bosniak, while according to Bosniak 2019, overall specificity, sensitivity, and diagnostic accuracy were 74.4%, 97.8%, and 86.9%, respectively. We found that the new Bosniak had a better diagnostic specificity for malignancy than the original Bosniak (*P* value 0.001), and the greater specificity

for malignancy in version 2019 was owing to the proper downgrading of more pathologically established benign cystic renal lesions into the lower class, which increased the classification's specificity for malignancy while the sensitivity showed no difference (*p* value 0.202).

Zhang et al. found also that version 2019 demonstrated significantly higher specificity for malignancy than the original one (0.62 vs. 0.41, *p* < 0.001); however, it came at the expense of a considerable reduction in sensitivity (0.88 vs. 0.94, *p* = 0.001) (7), as well as Bai et al. reported the same specificity (83% vs. 68%,

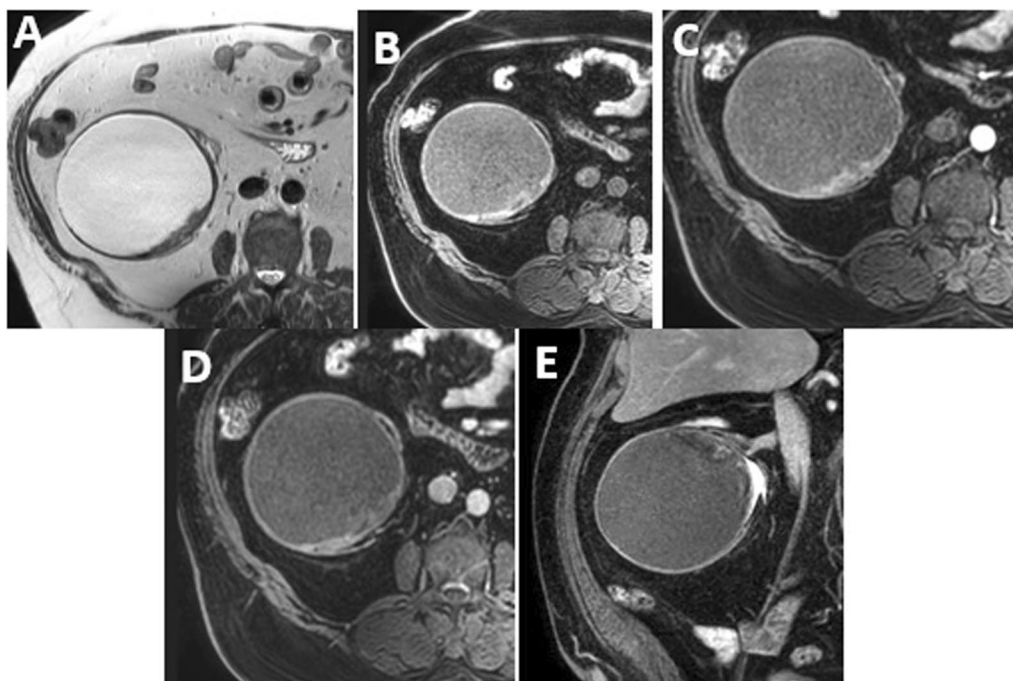


Fig. 3 A 65-year-old male patient complaining of right loin pain. Axial T2-WI of the right kidney (A) showed a right mid-zonal cystic lesion with heterogeneous high SI and low SI mural nodule at its infero-medial aspect. This cystic lesion showed heterogeneous low SI at axial T1WI (B) and showed a thick, non-enhancing wall (4 mm) and an enhanced mural nodule reaching 6 mm with an obtuse angle to the wall at axial corticomedullary (C), nephrographic (D), and coronal DCE-MRI images (E). By consensus, cystic lesion was categorized as Bosniak class IV with both original and version 2019 systems. In view of the enhanced mural nodule that was seen with an obtuse angle to the wall, the patient underwent right radical nephrectomy, and histopathology was papillary renal cell carcinoma

respectively; $P = .001$), without a difference in sensitivity (85% vs. 84%, $P = 0.34$) [4].

We found that increased wall and septal thickness were associated with malignancy (statistically significant P value < 0.001). The areas under the receiver-operator-characteristic (ROC) curve for detecting malignancy by wall and septal thickness were 0.84 (95% CI (0.75–0.93) and 0.81 (0.71–0.92), respectively. The best cut point with the highest accuracy for the diagnosis of malignancy was ≥ 3.5 mm (sensitivity 75.6%, specificity 82.1%, diagnostic accuracy 78.6%) for wall thickness and ≥ 3.5 mm (sensitivity 66.7%, specificity 87.9%, diagnostic accuracy 76%) for septal thickness. This matched Yan et al. results; he found that wall and septal thickness became thicker in malignancy; the cut point was slightly lower than in our study (≥ 3 mm); the areas under the ROC curve to detect malignancy were 0.66 (95% CI 0.54–0.79) and 0.61 (0.45–0.78), while the sensitivity and specificity for wall thickness were 33.3%, 86.7% and for septal thickness were 53%, 73%, respectively [9].

Tse et al. found that septal and wall enhancement were sensitive, not specific for malignancy; this was in concordance with our results. In our study, septal and wall enhancement sensitivity were 93.3% and 100%,

respectively, and their specificity were 30.8% and 7.7%, respectively, while the Tse et al. study sensitivity result for both wall and septal enhancement was 87%, while the specificity was 33% [10].

In our study, the presence of protrusions ≥ 4 mm with an acute margin or those ≤ 3 mm with an obtuse margin had a significant relationship with malignancy (significant P value < 0.001). The proportion of malignancy in the category with irregularity was lower than that with nodules (it was 73.9% and 87.1%, respectively). However, there was an overlap in the proportion of malignancy when comparing malignant lesions with irregularity against malignant lesions with nodules, implying that classifying septa and wall protrusions as "irregularity" versus "nodule" might not alter the likelihood of malignancy. This was similar to what had been reported by a study done by Tse et al. 2020; it was 71% and 87%, respectively [9]. Also, nearly the same result was reported by McGrath et al. (79% vs. 84%) [11].

Our study demonstrated no correlation between the number of septa and malignancy, supporting the Bosniak v2019 classification of cystic lesions with many (four) septa as Class IIF ($P = 0.051$), and this was consistent with Yan et al.'s results [9].

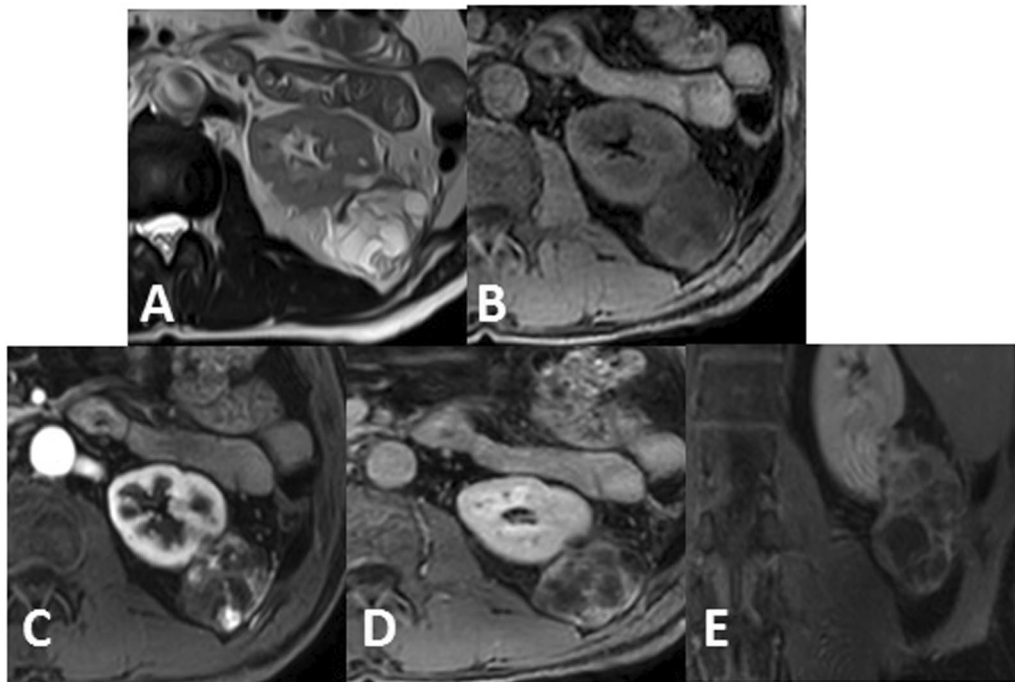


Fig. 4 A 52-year-old male patient with an incidentally discovered left renal cystic lesion. Axial T2-WI of the left kidney (A) showed a lower polar cystic lesion with heterogeneous high SI and multiple septa. This cystic lesion showed heterogeneous low SI at axial T1WI (B) and showed an enhancing thick wall (4mm), multiple thick enhancing septa (5 mm), and an enhancing mural nodule at its posterior aspect at axial corticomedullary (C), nephrographic (D), and coronal DCE-MRI images (E). By consensus, the cystic lesion was categorized as Bosniak class IV with both the original and version 2019 systems, as there was an enhancing mural nodule with an acute angle with the wall at the posterior aspect of the cystic lesion. The patient underwent left radical nephrectomy, and histopathology showed clear renal cell carcinoma

Depending on the criterion of signal intensity of the cystic lesions in T1 and T2, heterogeneous high T2 and heterogeneous low T1 SI had an association with malignancy (P value $P < 0.001$) and high specificity for malignancy (71.8% for T1 and 69.2% for T2 WI), while homogenous high T2 and homogenous low T1WI had a high association with benign cystic lesions. There was one literature that assessed the heterogeneous T1 hyper-intensity criterion on T1WI that was done by Yan et al.; it was specific for malignancy but not sensitive (specificity was 81% for SI at T1) [9]. This was in contrary to our results, and this might be due to the fewer cases of this criterion in our study.

In our study, we found 9 cases with papillary RCC and 26 cases with clear RCC among histologically proven malignant cystic lesions. It is well known that papillary RCC are usually of a more solid appearance. The histologically proven papillary RCC lesions we found in our study also had a solid component, but it was less than 25%, and this was in concordance with the Yan et al. study, in which there were 10 cases of papillary RCC, 1 mixed conventional clear and clear cell papillary RCC, 42 clear cell RCC, and 3 chromophobe RCC [9].

Our study had some limitations. First, not all cases had histopathology, as most Bosniak IIF lesions underwent follow-up with MRI within 24 months, and a small proportion was resected. Second, our study was done in one center with a small sample size, as not all patients in our institution underwent MRI study for a renal mass. Nonetheless, we believe that MRI will be employed more frequently in regular cystic renal lesion assessment. Third, as we needed tissue confirmation, there were fewer cases of class II compared with what would be predicted in a general patient population as these lesions were unlikely to be surgically removed, and finally, interobserver agreement was not calculated since the interpretation of cystic renal lesions was set by two expert urologists by consensus; if other observers had been there, the outcomes might have been different.

Conclusions

The Bosniak classification version 2019 had the potential to minimize overtreatment of cystic renal lesions significantly with a significant increase in specificity. Further studies of Bosniak classification revisions should be done on a larger sample and a longer time

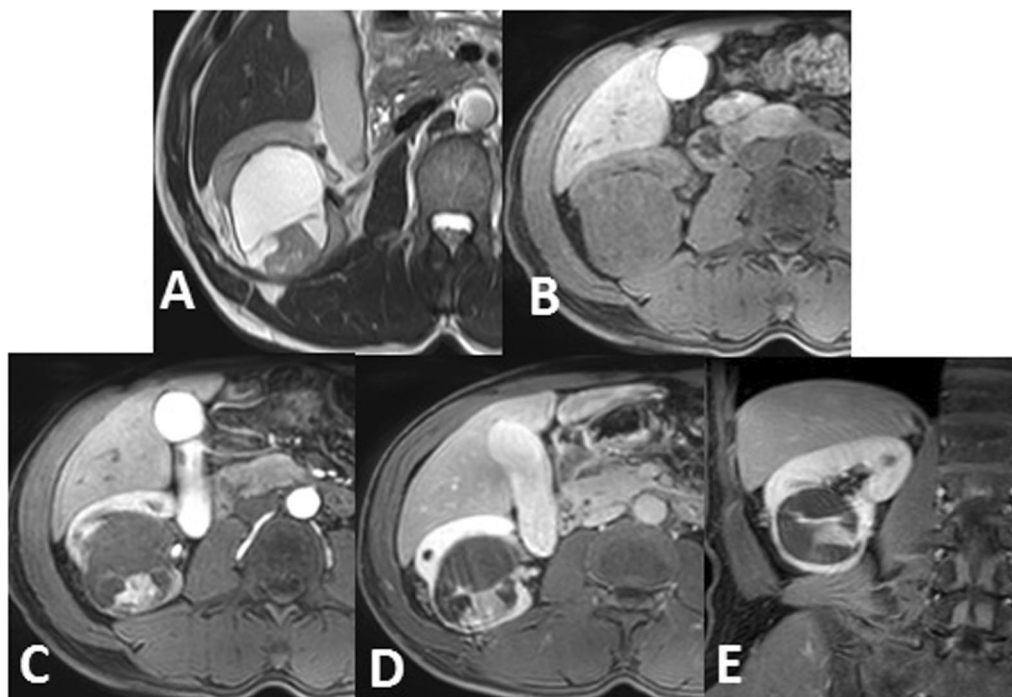


Fig. 5 A 49-year-old male patient with incidentally discovered a right cystic renal lesion. Axial T2-WI of the right kidney (**A**) showed a right lower polar cystic lesion with few septa and a low SI mural nodule. This cystic lesion showed heterogeneous low SI at axial T1WI (**B**) and showed a thick enhancing wall (3 mm), a few enhancing thick septa (reaching 4mm), and an enhanced mural nodule at the axial corticomedullary (**C**), nephrographic (**D**), and coronal DCE-MRI images (**E**). By consensus, cystic lesion was categorized as Bosniak class IV with both original and version 2019 systems. In view of the large enhancing mural nodule that was seen with an acute angle to the wall, the patient underwent right radical nephrectomy, and histopathology was cystic renal cell carcinoma

scale for patients who need follow-up, as it is like any new proposal that needs multiple studies before widespread clinical use.

Abbreviations

AUC	Area under the curve
APCKD	Adult poly cystic kidney disease
CE	Contrast enhanced
DCE	Dynamic contrast enhancement
FOV	Field of view
Gd	Gadolinium
GRE	Gradient
MEST	Mixed epithelial stromal tumour
MRI	Magnetic resonance imaging
PNET	Primitive neuroectodermal tumour
SI	Signal intensity
TE	Time of echo
TR	Time of repetition
US	Ultrasound

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Author contributions

MZ and MEA gave idea and collected the patients' data and analyze 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 26 /2 /2021; Reference Number of Approval: MD.21.01.409.

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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