Comparison of CT and MR Imaging of Cystic Renal Masses by Using the Bosniak Classification System

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Abstract

Purpose:

To compare the efficacy of computed tomography (CT) and magnetic resonance imaging (MRI) in evaluating cystic renal masses using the Bosniak classification system.

Materials and Methods:

Between January 2010 and December 2020, a total of 844 patients with suspected renal masses underwent total or partial nephrectomy at the Department of Urology, Heidelberg University Clinic. Among them, 123 patients presented with cystic renal masses. Out of this cohort, 15 patients underwent preoperative examinations using both MRI and CT within a 6-week timeframe. These examinations were retrospectively analyzed by two radiologists employing the Bosniak classification system. Each lesion was assessed based on CT images for lesion localization, volume, number, and thickness of septa/wall, calcification, presence of enhancing soft-tissue components, and lesion density. Pathologic correlation was available for all lesions.

Results:

Out of the 844 patients, 15 underwent both CT and MR imaging examinations (male-to-female ratio: 2.75, age range: 43-75 years; mean age: 60.5 years). Based on CT images, there were one category I, one category II, three category IIF, three category III, and seven category IV lesions. Findings based on CT and MR images were concordant in eleven (73.3%) renal lesions, while in 4 (26.7%) masses, differences were observed. In three (20%) cases, MR imaging revealed more septa/wall than CT, resulting in an upgrade of the classification at MR imaging. In one (6.7%) lesion, MR imaging showed no wall and/or septa thickness compared with CT, leading to a classification downgrade. MR imaging results led to a cyst classification upgrade in three masses (from category II to III, n=1; IIF to III, n=2) and downgrade in one lesion (from category IIF to II). Pathologically, 11 lesions (73.3%) were malignant (9 Cystic Clear cell carcinoma and 2 papillary renal cell carcinoma), while 4 lesions were renal cysts without malignancy.

Conclusion:

The majority of findings from both CT and MR imaging were similar in suspected cystic renal masses. MR imaging demonstrated additional septa/wall or septa/wall thickening, potentially upgrading lesions from borderline category IIF to III compared to CT. This distinction may contribute to improved case management.

Keywords:, renal mass, Bosniak classification, comparison of CT and MRI, diagnostic value

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Introduction

The accurate diagnosis of a renal mass relies on various factors, including the clinical history, the characteristics of imaging findings, the expertise of the radiologist, and the quality of the examination. Indeed, a fundamental component is a high-quality imaging examination, under the meticulous oversight of the radiologist. Renal masses are predominantly identified incidentally through computed tomography (CT), ultrasound (US), and magnetic resonance (MR) imaging (Tab.1). Fortunately, a significant proportion of these are simple renal cysts, easily diagnosed and often necessitating no treatment. However, there are instances of solid and complex cystic renal masses, many of which are clearly malignant and warrant surgical removal, while others may not require immediate intervention. Therefore, accurately characterizing these masses is imperative for appropriate case management.

Renal Cysts
Cortical cyst (simple cyst)
Parapelvic cyst
Conditions associated with multiple cysts
ADPKD (Autosomal dominant polycystic disease)
ARPKD (Autosomal recessive polycystic disease)
Acquired cystic disease
Von Hippel-Lindau disease
Medullary cystic disease / sponge kidney
Tuberous sclerosis
Cystic tumors
Cystic renal cell carcinoma
Multilocular cystic nephroma
Metastasis
Hydronephrosis
Calyceal diverticulum
Hematoma
Vascular origin
Arterio-venous fistula
Pseudoaneurysm

Tab.1: Renal cyst differential diagnosis (2)

Simple Renal Cysts:

Among renal masses, simple renal cysts stand out as the most prevalent type. They are prevalent in more than half the population over the age of 55 (1). Small cysts typically present asymptomatically, while larger cysts (>4 cm) may occasionally cause obstruction, pain, hematuria, or hypertension. Cysts are frequently multiple and can affect both kidneys (Tab.1). Both CT and MR imaging can conclusively diagnose simple renal cysts.

CT criteria:
1.well-defined borders
2.absence of a discernible wall
3.uniform attenuation approaching that of water density
4.lack of contrast enhancement.

MR criteria:
1.a uniformly shaped, well-defined, round or oval mass
2.hypointensity on T1-weighted images
3.hyperintensity similar to urine on T2-weighted images
4.no enhancement post-gadolinium administration (see Fig. 1)

Complicated Renal Cysts:

Complications in simple renal cysts may arise from hemorrhage or infection. Bosniak introduced a classification system in 1986 (Tab. 2) for cystic masses, effectively aiding in the categorization of these problematic lesions (3). Widely accepted among urologists and radiologists, this system demonstrates substantial interobserver agreement in most cases (5). While primarily based on computed tomographic (CT) criteria, this classification system can also serve as a valuable framework for magnetic resonance (MR) imaging evaluation

Bosniak classification	
Category	**Description**
I	A benign simple cyst with a hairline thin wall, without septa, calcifications, or solid components. It shows water density without Enhancement.
II	A benign cyst that may contain a few hairline thin septa without measurable enhancement. Fine calcification may be present in the wall. This group contains uniformly high attenuation lesions < 3 cm (so-called high-density cysts) without Enhancement.
IIF (F = follow-up)	Cysts that may contain multiple hairline thin septa or minimal smooth thickening of their wall or septa. Their wall or septa may contain calcification. They show no measurable contrast enhancement. Totally intrarenal nonenhancing high-attenuation renal lesions >3 cm are also included in this category. These lesions require follow-up studies.
III	“Indeterminate” cystic masses that have thickened irregular or smooth walls or septa in which measurable enhancement is present. These are surgical lesions, although some will be benign (eg, hemorrhagic cysts, chronic infected cysts, and multiloculated cystic nephroma), some will be malignant, such as cystic renal cell carcinoma.
IV	They are clearly malignant cystic masses that can have all the criteria of category III, but also contain enhancing soft-tissue component. These lesions require surgical removal.

Tab.2: Bosniak renal cyst classification system (3)

(6). It is essential to note that MR imaging may unveil findings not apparent in CT scans, and a direct correlation between MR imaging and CT findings may not always be straightforward (1). Classifying small renal lesions can be particularly challenging. Utilizing thin-section CT with bolus contrast enhancement and meticulous attention to detail is crucial for accurate lesion classification. MR images may exhibit fluid isointensity within the cyst, indicative of a simple cyst. Conversely, increased signal intensity on T1-weighted images may suggest a complicated cyst, posing challenges in differentiation from solid masses.

Parapelvic cysts (renal sinus cysts):
Situated within the renal hilum, exhibit imaging characteristics similar to those found within the parenchyma. These cysts often cause deformation of the collecting system and are frequently bilateral. Their attenuation is higher compared to sinus lipomatosis.

Renal cell carcinoma:
Renal cell carcinoma may manifest as a predominantly cystic or multiloculated cystic mass. Malignant tumor cells line the walls and septa, typically presenting with noticeable thick walls, septations (19), and contrast enhancement (Fig. 2).

Patients and Variables:

Patient Selection:
Between January 2010 and December 2020, 844 consecutive patients with suspected renal mass underwent total or partial nephrectomy in the department of Urology, Heidelberg University Clinic. Among them, 123 patients had cystic renal masses. Out of them, 15 patients undergone preoperative exami-nations using both MRI and CT within 6 weeks, which were retrospectively analyzed by two radiologists using the Bosniak classification system. For each lesion, images were compared for localization of lesion, volume of the lesion, number of septa/wall, thickness of septa/wall, calcification, enhancing soft-tissue components, and density of lesion based on CT. Pathologic correlation was available for all the lesions.

Statistical Methode:
Data of patients have been analyzed by Prof. Dr. Annette Kopp-Schneider and Prof. Dr. Renate Rausch from the division of Biostatistics, German Cancer Research Center (DKFZ) using biostatiscal software to determine the frequency, mean, median, mode of variants as well as the t-test, Fisher's exact test and Chi-Square to determine the possible relationship of different variants.

Scanners: Although the Bosniak renal cyst classification has been developed based on CT studies, it could be applied to other imaging modalities (ultrasonography and magnetic resonance imaging) (7). We have evaluated CT and MR imaging of our patients over 10 years. During that time period the parameters of both modalities have been changed. The parameters at the institution in sight are the following.

CT Scanning is usually performed using a multi–detector CT scanner using CT scanner Somatom (Siemens Medical Solutions, Erlangen, Germany) or Brilliance iCT (Philips Medical Systems) as a multistage study with thin slices. Precontrast scans are obtained from the kidneys through the bladder to detect urinary stones, calcifications and cysts. Arterial phase scans of the kidneys show early enhancement of renal tumors. The nephrographic phase scans are obtained at approximately 60 seconds following onset of contrast injection, which shows the normal renal parenchyma with uniform enhancement.

MR Imaging is a substitute for CT for patients in whom the use of IV iodinated contrast agents is contraindicated or whenever the CT study is equivocal. Multiphase postgadolinium administration acquisitions provide images very similar to multiphase postcontrast CT. MR urography provides effective evaluation of the uroepithelial tissue (8). The MR imaging examinations were performed recently by using a 1.5-T system (Sonata, Avanto or Symphony; Siemens Medical Systems, Erlangen, Germany) and a torso phased-array coil. All patients underwent transverse breath-hold T1-weighted MR imaging with a two-dimensional gradient-echo sequence and transverse breath-hold T2-weighted MR imaging with a half-Fourier single-shot turbo spin-echo sequence. Apparently MR Imaging protocols have been changed over time; however, the recent parameters for the T1-weighted gradient echo sequence were as follows: 128–160/3.0–5.3 (repetition time msec/echo time msec); flip angle, 70°–90°; matrix, 80–118x 256; and section thickness, 5–8 mm. The T2weighted sequences were performed with the following parameters: 3,300/100; flip angle, 130°–180°; matrix, 180–256x 256; and section thickness, 5–8 mm. A three-dimensional fat-suppressed T1-weighted fast low-angle shot (FLASH) pulse sequence was performed both prior to and 30, 60, 240 seconds after intravenous administration of Gadolinium. This

sequence was performed in the coronal and axial plane. All acquisition times were less than 30 seconds to facilitate breath holding at full expiration.

Results:

To compare the diagnostic efficacy of CT and MRI in assessing cystic renal masses utilizing the Bosniak classification system, we conducted a comparative analysis of imaging results from 15 patients who underwent both preoperative MRI and CT examinations (both conducted within a 6-week interval) out of a total cohort of 123 patients with cystic renal masses.

Based on CT imaging, the distribution of lesions included one category I, one category II, three category IIF, three category III, and seven category IV. Concordant findings between CT and MR images were observed in eleven renal lesions (73.3%) (Fig.3), while discre-pancies were noted in 4 masses (26.7%). Notably, MRI revealed a greater presence of septa (Fig.5) within the cystic lesions during T2w-Haste sequencing compared to CT, resulting in the reclassification of cases into different subgroups than those identified by CT (see Figure 4). Our investigation identified no significant correlation between the number of septa and the Bosniak classification (P-value > 0.3; chi-square may not be a valid test, given that 100% of cells have expected counts less than 5). However, a correlation was established between septa and Bosniak classification groups when considering the entire patient cohort (123 patients).

Within this cohort, we assessed the thickness of the cystic wall using both CT and MRI. Our findings demonstrated a statistically significant correlation between the thickness of the wall and the Bosniak classification (P-value < 0.024). Remarkably, in 3 lesions (20%), MR imaging revealed an upgrade in wall characterization from hairline thin to minimally thickened. This led to the reclassification of two masses from category IIF to III (n=2, one renal cell carcinoma and one benign cyst) as indicated in Table 3.

Classification based on			Pathology
	CT	MRI	
Case 1	2	3	Papillary RCC
Case 2	2F	3	Cyst (without malignancy)
Case 3	2F	3	Clear cell RCC
Case 4	2F	2	Cyst (without malignancy)

Tab.3: Shows the differences of Bosniak classification in 4 out of 15 patients in correlation to pathological report

In the contingency tables comparing Bosniak categories with histopathological findings, expected cell counts were below 5 in 90% of cells for CT and 88% for MRI.

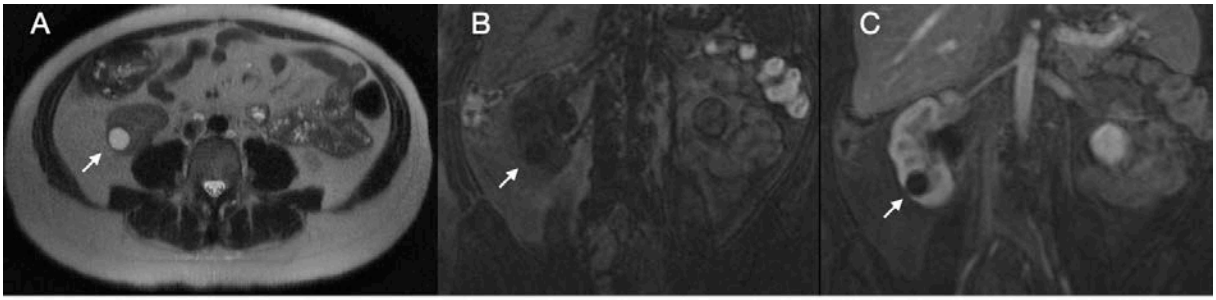


Fig.1: A) T2WI haste axial MR image of a male patient of the right kidney shows a simple type I renal cyst. **B)** Coronal T1WI FL3D FS non-contrast-enhanced MR image of the same patient shows apparently normal kidneys with evidence of the same renal cyst on the right side. **C)** Coronal T1WI FL3D FS Contrast-Enhanced MR image at the same level shows no enhancement of the cystic lesion of the right kidney.

Given these sparse counts, the chi-square approximation was unreliable for both comparisons. The results are therefore interpreted descriptively, and the reported tests do not establish whether Bosniak category was associated with histopathology for either modality.

Discussion:

The utilization of MR imaging for the assessment of renal masses is expanding, driven in part by the aim to minimize radiation exposure to the general population and primarily by the wealth of additional information it provides in evaluating renal lesions (9,10). MR imaging serves as a problem-solving tool in cases where CT scans lack decisiveness and is employed in the initial work-up of renal masses incidentally

discovered during other studies. Notably, MRI proves beneficial in characterizing complex cystic renal masses, enabling the evaluation of lesion vascularity (enhancement), and it has been demonstrated that the Bosniak classification is applicable to MRI (7, 10).

However, it is crucial to acknowledge that MRI boasts superior contrast resolution compared to CT, occasionally revealing findings — particularly on T2-weighted images — that render septa seemingly thicker, with enhanced visibility of septa and cyst wall enhancement that may elude identification on corresponding CT images (3,10,11,12). Another advantage of MR imaging is evident (Fig.5) in the assessment of hemorrhagic lesions or high signal intensity cystic lesions. While CT may not unveil the interior of the cyst in high-attenuation lesions, MR images facilitate the clear identification of wall thickness and any enhancing tissue inside the lesion. This ability allows for the potential downgrading of some hemorrhagic cystic lesions from category III to IIF or upgrading to category IV (10,19).

In our comparative study assessing the results of CT and MRI in evaluating cystic renal masses using the Bosniak classification system, we scrutinized 15 patients who underwent preoperative examinations with both MRI and CT. Based on CT images, we identified one case in category I, one in category II, three in category IIF, three in category III, and seven in category IV. Findings were concordant in eleven (73.3%) cystic renal masses, while differences were noted in four (26.7%) cases. MRI, employing the T2w Haste sequence, revealed more septa within the cystic lesions than CT, resulting in the categorization of cases into different subgroups than those determined by CT. Our study revealed no statistically significant correlations between the number of septa and the Bosniak classification in this subgroup, potentially attributed to the limited population size. However, a significant correlation was established between wall thickness and the Bosniak classification. In 20% of cases, MR imaging led to an upgrade in wall characterization from hairline thin to minimally thickened, resulting in the reclassification of two masses from category IIF to III (one RCC and one benign cyst). Furthermore, MR imaging influenced a downgrade from category IIF to II (correlating with pathology), significantly impacting patient management. These findings align with Bosniak MA's results (13).

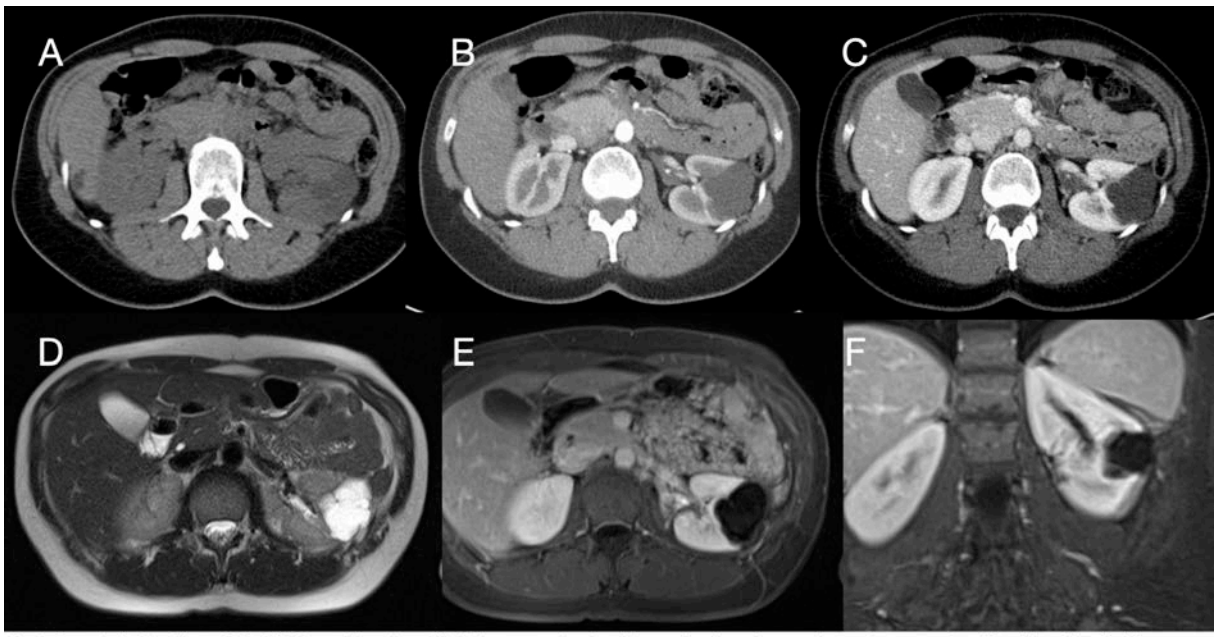


Fig.2: Case 1 **A)** CT without CM; **B)** CT arterial series; **C)** CT Venous series. In all the series there is a cystic renal mass on the lefts side with a hairline septa. We have evaluated the CT as Bosniak IIF **D)** MRI T2WI **E)** MRI CE T1WI axial, and **F)** MRI CE T1WI coronal. In T2W1 there are more than 6 septa inside the cystic mass with minimal thickened wall. After MRI examination, we upgraded the lesion to Bosniak III.

The challenge in classifying cystic renal lesions with MR imaging, compared to CT, lies in image quality. Indeed, there is more variability in the quality of MR images across different countries and institutions, impacting lesion evaluation. Some authors suggest the use of subtraction techniques in MR imaging to assess enhancement; however, we posit that the mandatory sequence for assessing enhancement may not be subtraction imaging due to the limited resolution caused by breathing artifacts (10,14,18). Ad-ditionally, the potential of DWI-MR imaging of the kidney as a reliable means for differentiation requires further exploration, encompassing the discrimination of normal

renal parenchyma from different renal tumors, the differentiation of benign from malignant

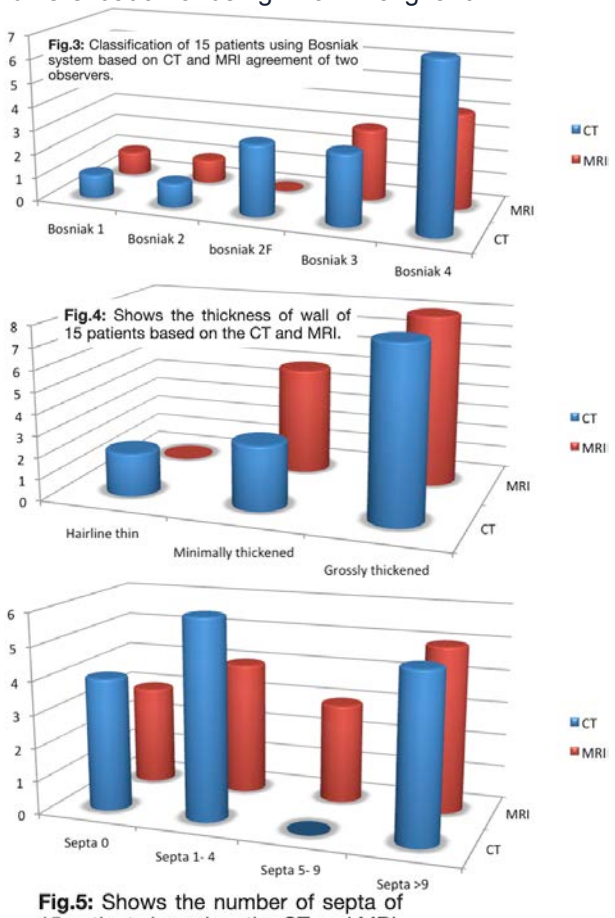


Fig.5: Shows the number of septa of 15 patients based on the CT and MRI.

tumors, and even the histological subtyping of renal cell cancer (15, 16, 17).
Furthermore, we examined the correlation between Bosniak classification results using CT and MRI in 15 cases. Our study demonstrated no statistically significant correlation between CT-based Bosniak classification results and lesion pathology. Intriguingly, a correlation was observed between MRI-based Bosniak classification results and lesion pathology, showing promise but necessitating further investigations.

Conclusion:

MR imaging demonstrates additional septa/wall or septa/wall thickening that may cause a lesion to be upgraded from borderline category IIF to III in comparisons to CT, which potentially leads to a better case management.

Conflict of interest:

The authors declare that there were no conflicts of interest within the meaning of the recommendations of the International Committee of Medical Journal Editors when the article was written.

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