



Review Article

Characterization and management of various renal cystic lesions by sonographic features

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Abstract

Renal cysts are common incidental findings in clinical practice. Most renal cysts detected in medical imaging are benign simple cysts. However, some are complicated by hemorrhage or infection or are associated with calcification. In these instances, difficulties can be encountered distinguishing the complicated cysts from cystic renal tumors such as cystic renal cell carcinoma, multilocular cystic nephroma, and mixed epithelial and stromal tumors. The Bosniak classification is widely used to categorize cystic renal lesions but is used to classify those discovered via computed tomography. Ultrasonography (US) and color Doppler US are the most frequently used imaging techniques for abdominal surveys and long-term follow-up because of their noninvasiveness, relatively low cost, wide availability, and frequently, lack of contrast medium. Herein, we review the features of various cystic lesions of the kidney that can be found using US, discuss differential diagnoses using US, and propose a feature-oriented algorithmic approach to classifying renal cystic lesions using US.

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1. Introduction

Because of its noninvasiveness, relatively low cost, and wide availability, renal ultrasonography (US) has become one of the most commonly used medical imaging techniques in patients presenting with suspicious renal disease. Although it

is less sensitive than computed tomography (CT) in detecting a renal mass, it can be used in differentiating a simple, benign renal cyst from a complex cyst or a solid tumor.¹ Renal cysts are common incidental findings during clinical practice. Most renal cysts are benign simple cysts and can be ignored.² It has been estimated that the incidence of simple renal cysts is about 50% in people older than 50 years and about 60% in those older than 60 years.² However, some benign renal cysts may be complicated by hemorrhage or infection or are associated with calcification.² These can be difficult to differentiate from cystic renal tumors such as cystic renal cell carcinoma (RCC), multilocular cystic nephroma, and mixed epithelial and stromal tumors (MESTs). Ultrasonography

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accompanied by color Doppler US (CDU) is the most frequently used imaging technique for abdominal surveys and long-term follow-up.^{3,4} Therefore, it is important that all clinical specialists involved in abdominal US be aware of the features of cystic renal lesions that can be distinguished with this technique. With this review, we will illustrate the features of various cystic lesions of the kidney that can be revealed via US. We will then propose an algorithm for using these features to separate cystic lesions that can be ignored and left alone (Bosniak Categories I and II) or followed (Bosniak Category IIF) from those requiring contrast-enhanced US or CT and/or magnetic resonance imaging (MRI) (Bosniak Categories III and IV).

2. Ultrasonography techniques

The operator should select the greatest proper frequency transducer. The practical range for broad-band frequency in general abdomen and renal studies is between 2 and 5 MHz in adults. In children aged less than around 18 months, a 6–12 MHz probe is preferred, but for older children, better images are obtained using a 3.5–5 MHz probe. Color and power Doppler techniques are useful adjuncts to the examination because vascularity within a nodule or septum greatly increases the likelihood of malignancy. Real-time compound US is one of the more important advances introduced in this technology. The principle of compound scanning is used to combine slices obtained from various spatial orientations, generating an improved sonographic image, delineated margins, reduced image artifacts and noise, and enhanced image contrast. Tissue harmonic imaging can reduce unwanted background noise, eliminating low-level echoes within an otherwise simple cystic lesion. Schmidt et al. reported that using pulse inversion harmonic imaging increased the accuracy of classifying renal cystic lesions from 64% to 84%.⁵ Recent reports suggest that harmonic US performed with second-generation contrast agents reveal promising perspectives in the diagnosis of renal cystic lesions.⁶ Quaia et al. and Park et al. found that contrast-enhanced US was better than unenhanced US or CT in diagnosing malignancy in complex cystic renal masses.^{7,8} Contrast-enhanced US is a valuable alternative to CT in assessing complex cystic or solid renal lesions where iodinated CT contrast or gadolinium is inappropriate.⁹ The compression elastography technique, also called the static elastography technique, provides a qualitative strain map of the organ by comparing an image recorded before compression with one recorded after compression. This technique is inadequate for renal tissue stiffness assessments because for one thing, the kidneys are usually located deep in the body and therefore do not easily allow direct access for applying external compression. For another thing, no normal tissue is available for comparing with abnormal tissues in the kidney. Therefore, an absolute stiffness assessment of the tissue must be attained using newer elasticity techniques such as acoustic radiation force imaging (ARFI); quasi-static elastography does not provide quantitative data.

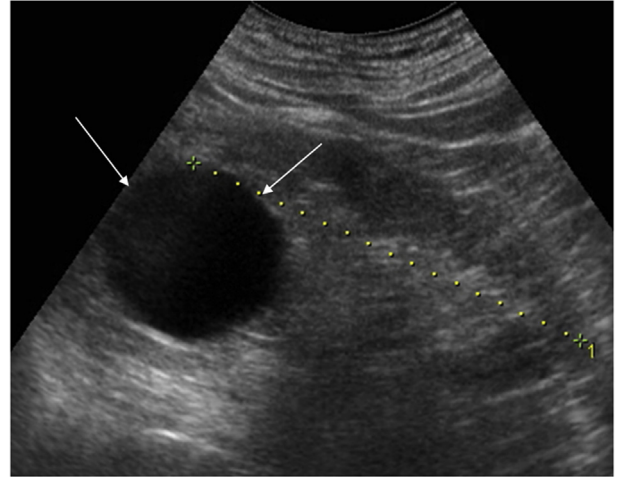


Fig. 1. A 49-year-old woman with a simple cyst. Gray-scale ultrasonography shows a renal cyst (arrow) with a hairline-thin wall and anechoic content without septa, calcifications, or solid components, representing a Bosniak Category I lesion.

Although ARFI can be used for differentiating benign lesions from malignant renal tumors, it can be effectively applied only to solid masses, excluding its utility for cystic or partially cystic renal masses.^{10–12}

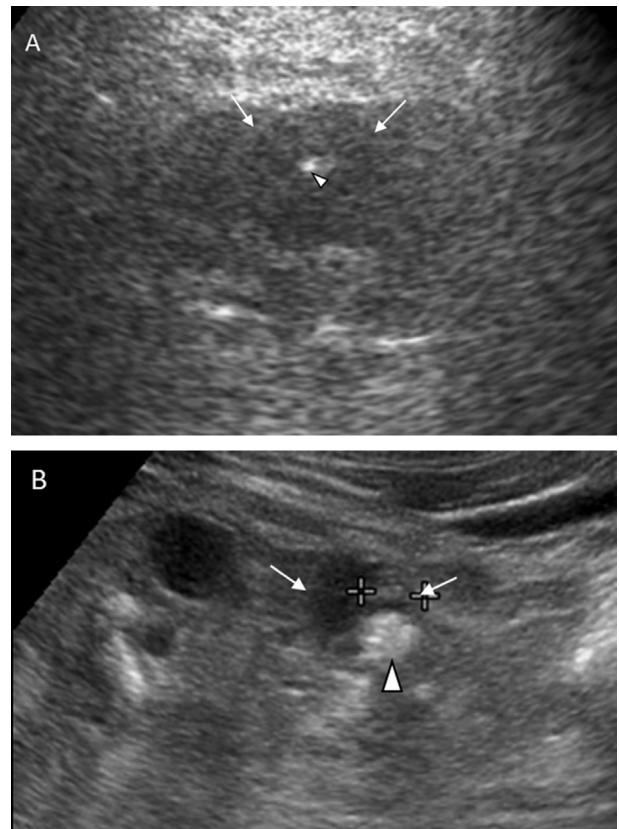


Fig. 2. Complex renal cysts: (A) A 47-year-old man with a complex renal cyst. Ultrasonography shows a renal cyst (arrow) with fine calcifications (arrowhead) in a short segment of the septa, representing a Bosniak Category II lesion. (B) A 39-year-old man with complex renal cyst. Ultrasonography shows a renal cyst (arrows) with a thick nodular calcification (arrowhead), representing a Bosniak Category IIF lesion.

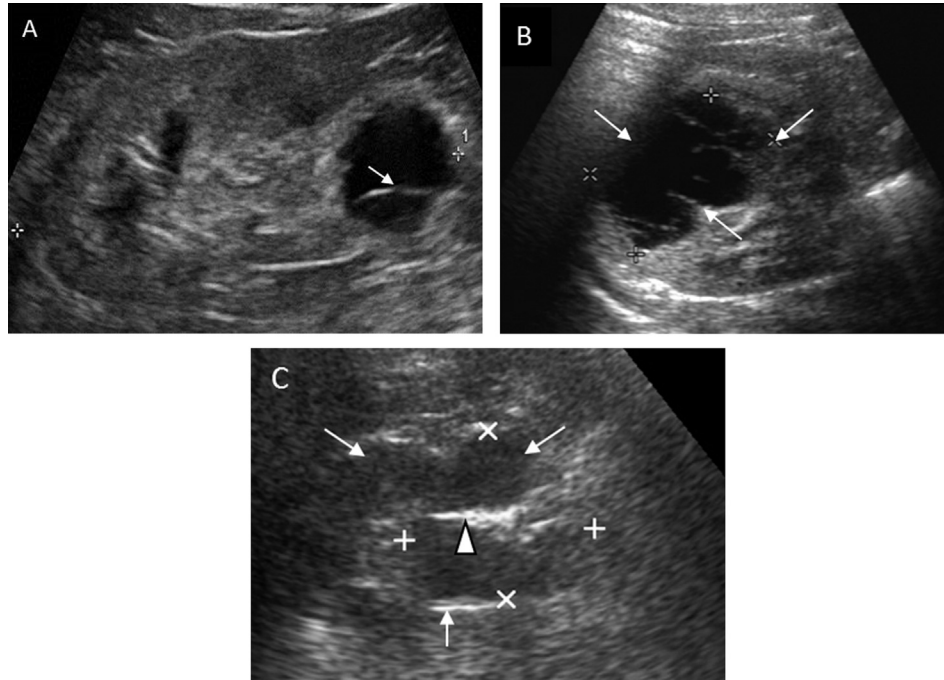


Fig. 3. Complex renal cysts: (A) A 67-year-old woman with a complex renal cyst. Ultrasonography shows a renal cyst with a hairline-thin septum (arrow), representing a Bosniak Category II lesion. (B) A 45-year-old woman with a complex renal cyst. Ultrasonography shows a renal cyst (arrows) with multiple hairline-thin septa, representing a Bosniak Category IIF lesion. (C) An 81-year-old man with a complex renal cyst. Ultrasonography shows a renal cyst (arrows) with irregular thickening of the septa and calcification (arrowhead), representing a Bosniak Category III lesion.

3. Bosniak classification of renal cystic lesions

The Bosniak classification categorizes renal cysts into Category I, II, IIF, III, or IV.²

3.1. Bosniak Category I

Bosniak Category I indicates a simple renal cyst with a hairline-thin wall and anechoic content without septa, calcifications, or solid components. A Category I renal cyst can be ignored (Fig. 1).

3.2. Bosniak Category II

Category II indicates a complex renal cyst with fine calcifications in a short segment of the wall or septa (Fig. 2A), single or few hairline-thin (<2 mm thick) septa, or smooth septa (Fig. 3A). A Category II renal cyst can also be ignored.

3.3. Bosniak Category IIF

A renal cyst that has a 5%–15% probability of malignancy is classified as Category IIF.^{13–18} They are not complicated

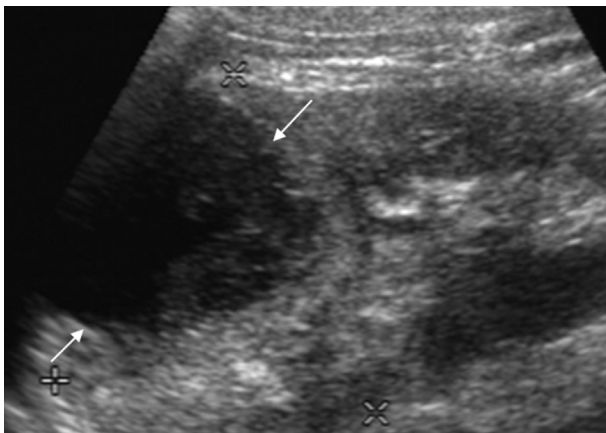


Fig. 4. A unilocular renal cystic lesion with internal echoes. An 8-year-old boy with an infected renal cyst. Ultrasonography shows a renal cystic lesion (arrows) with a thickened irregular wall and weak internal echoes, representing a Bosniak Category III lesion. Fluid aspiration yielded a pus component.

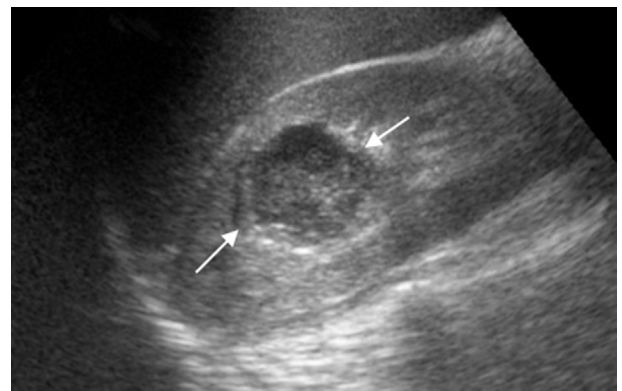


Fig. 5. A unilocular renal cystic lesion with internal echoes. A 62-year-old man with a hemorrhagic cyst. Ultrasonography shows a renal cystic lesion (arrows) with a relatively thickened irregular wall and internal echoes, representing a Bosniak Category III lesion.

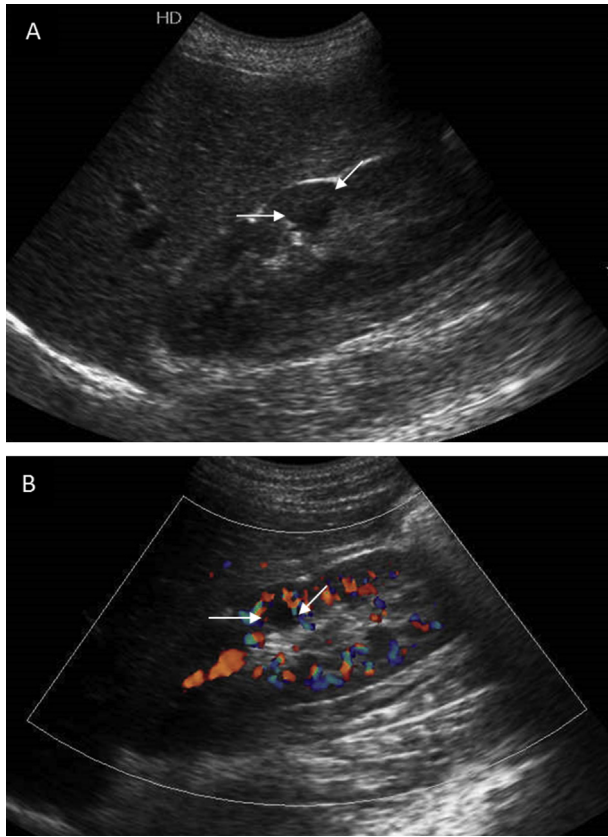


Fig. 6. A unilocular renal cystic lesion with internal echoes. An 18-year-old man with trauma history. (A) Ultrasonography (US) show a hypoechoic zone with a liquefied fluid space caused by an old injury to the right kidney (arrows). (B) Color Doppler US shows no evidence of increased vascularity, representing a Bosniak Category IIF lesion.

enough to fall into Category III, but are too complicated to fall into Category II.¹⁹ They can contain irregular or nodular calcifications but without soft tissue components (Fig. 2B) or can have multiple hairline-thin septa but without wall thickening (Fig. 3B). They are probably benign, but need to be followed. Initially, follow-up studies at 6 months and 1 year succeeded by 3- to 5-year follow-ups are generally recommended. Nevertheless, a Category IIF mass that exhibits no growth or morphologic change after 5 years is likely benign.¹³ It should be emphasized that growth rate is not a feature of the Bosniak cyst classification. Benign renal cysts grow, sometimes rapidly. Conversely, malignant lesions can grow slowly.²⁰ Therefore, when following cystic renal lesions, the radiologist should examine the lesion for morphologic change (e.g., septa becoming thicker or more nodular). Overall growth and lesion size are less important.²¹

3.4. Bosniak Category III

A Category III renal cyst bears a 50%–70% risk of malignancy.^{15,16,22} It can have a thickened irregular wall or septa (Fig. 3C), but no enhancing solid lesions are present. It is further classified into one of two subtypes based on the presence of septa as a unilocular or multilocular cystic mass.

Unilocular cystic lesions include RCCs (clear cell or papillary) showing the unilocular cystic pattern (from intrinsic cystic growth or massive tumor necrosis) and benign complicated cysts with complex features resulting from infection (Fig. 4), hemorrhage (Fig. 5), or other causes such as trauma (Fig. 6), renal surgery, or a percutaneous procedure. They are

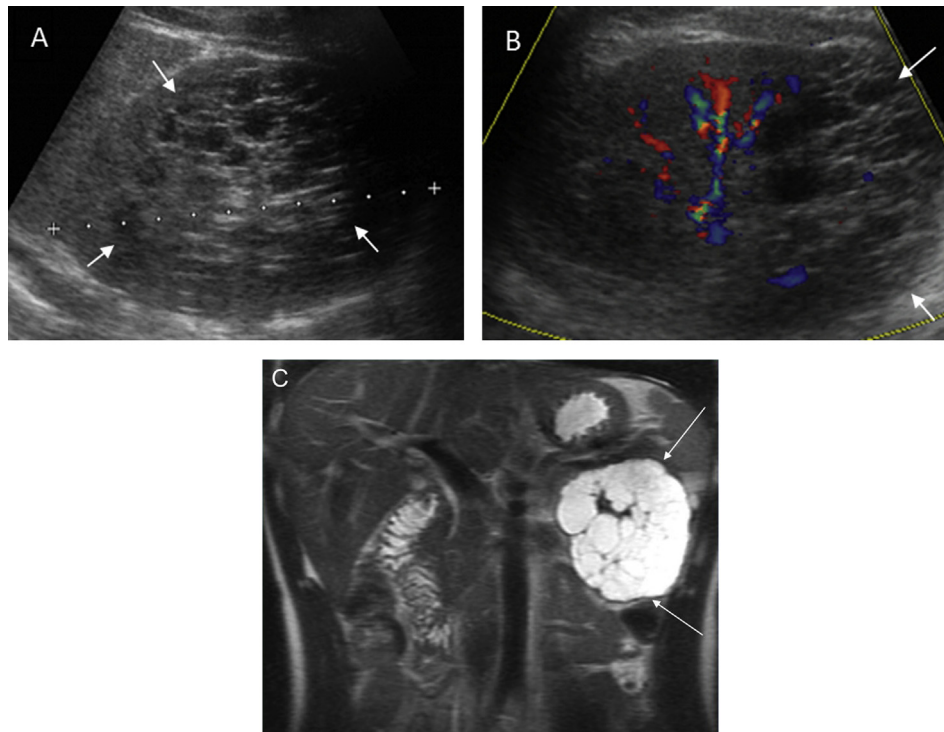


Fig. 7. A multilocular cystic mass in a 21-year-old male. (A) Ultrasonography shows a multiloculated renal cystic lesion (arrows) with a lobulated contour and thick septa, representing a Bosniak Category III lesion. (B) Poor vascularity of the multilocular renal cystic lesion on a color Doppler image (arrows). (C) Magnetic resonance imaging shows a multilocular cystic tumor in the left kidney (arrows). The lesion turned out to be a multilocular cystic nephroma.

smooth or slightly irregular and can be associated with grossly thickened (≥ 2 mm) walls. Thick or irregular calcification can be present.

Multilocular cystic masses are consistent with multilocular cystic neoplasms including malignant (clear cell RCC with a multilocular cystic growth pattern or multilocular cystic renal neoplasm of low malignant potential) and benign tumors (e.g., cystic nephroma [Fig. 7] and cystic MESTs [Fig. 8]).¹⁹ They are encapsulated cystic masses that contain numerous thickened smooth or slightly irregular septa and uniform smooth or slightly irregular wall thickenings. The cyst wall and septa are grossly thickened (≥ 2 mm). Thick or irregular calcifications can be present.

3.5. Bosniak Category IV

Category IV cysts are inevitably malignant and must be surgically excised. They can exhibit features similar to those seen in Category III lesions including multilocular and unilocular patterns, but they also demonstrate solid components with vascularity or enhancements (Figs. 9 and 10).

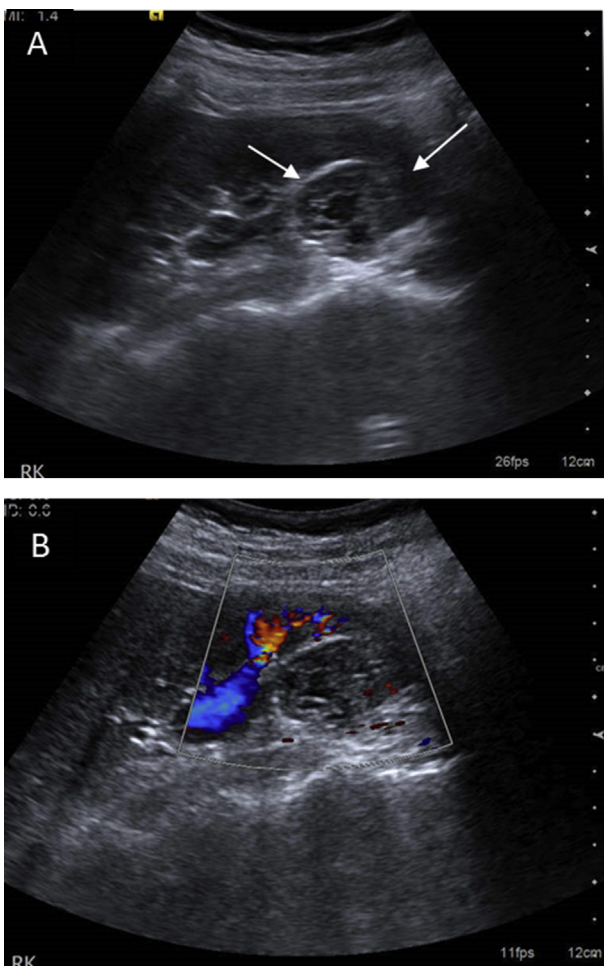


Fig. 8. A 39-year-old female with a mixed epithelial and stromal tumor. (A) Ultrasonography shows a multiloculated renal cystic lesion (arrows) with a lobulated contour and thick septa. (B) Poor vascularity in a multilocular renal cystic lesion, representing a Bosniak Category III lesion.

4. A systematic approach for characterization of renal cystic lesions (algorithm)

A systematic approach should be applied to initially identify unilocular and multilocular cysts (Figs. 7 and 8). In unilocular cysts, those with solid components will fall into Category III or IV (Fig. 9), then contrast-enhanced US, CT, or MRI should be arranged. For those without solid components, calcification patterns and septa or wall thickening should be interpreted next.

Renal cysts without calcifications, septa, or wall thickenings shall be classified into Category I. Category II cysts have fine calcifications in short segments or slightly thickened calcifications on the cystic wall (Fig. 2A), whereas Category IIF lesions have thick or nodular calcifications (Fig. 2B). Calcifications that are greater in number or size do not warrant upgrade to anything above Category IIF unless solid soft tissues appear.^{23,24} Therefore, calcification does not affect the differentiation between masses that are in Categories IIF and III.

Category II lesions have regular and hairline-thin septa (Fig. 3A). Category IIF lesions have smoothed multiple hairline-thin septa (Fig. 3B). Warren and McFarlane suggest that if the wall or septa thickness exceeds 1 mm, it is a sign of malignancy.^{23,25} However, other authors suggest that walls or septa of “more than hair-line thin” thicknesses favor malignancy.^{2,13} Accurate measures are difficult to obtain; some interindividual or intraindividual differences in measurements can be found.^{23,25} A unilocular cyst with slightly irregular and grossly thickened (≥ 2 mm) septa (Fig. 3C) falls into Category III, and contrast-enhanced US, CT, or MRI is required. Wall thickening in cystic lesions can also be seen in hemorrhagic cysts, infected cysts, or abscesses (Figs. 4–6). Sometimes it is difficult to differentiate cysts from tumors using US; therefore, patient history is important for the differential diagnosis and follow-up or intervention is needed.

Multilocular cysts separated from the normal renal parenchyma and lacking solid components can be classified into Category IIF. Contrast-enhanced US, CT, or MRI is required when cysts have solid components.^{26,27}

A multilocular Category III cyst (Figs. 7 and 8) is an encapsulated cystic mass containing numerous thickened smooth or slightly irregular septa and uniform smooth or slightly irregular wall thickening. The cyst wall and septa are grossly thickened (≥ 2 mm), but vascularity in soft tissue components is not enhanced or increased. If it is, the cyst will be classified into Category IV (Fig. 9).² Multilocular cystic renal masses with lobulated contours but no soft tissue components (Fig. 7) shall be classified into Category III.

5. Unilocular cystic lesions

5.1. Infected cysts

Untreated or inadequately treated acute pyelonephritis can lead to the formation of an infected cyst or abscess (Fig. 4). Ultrasonography will show a thick-walled, hypoechoic

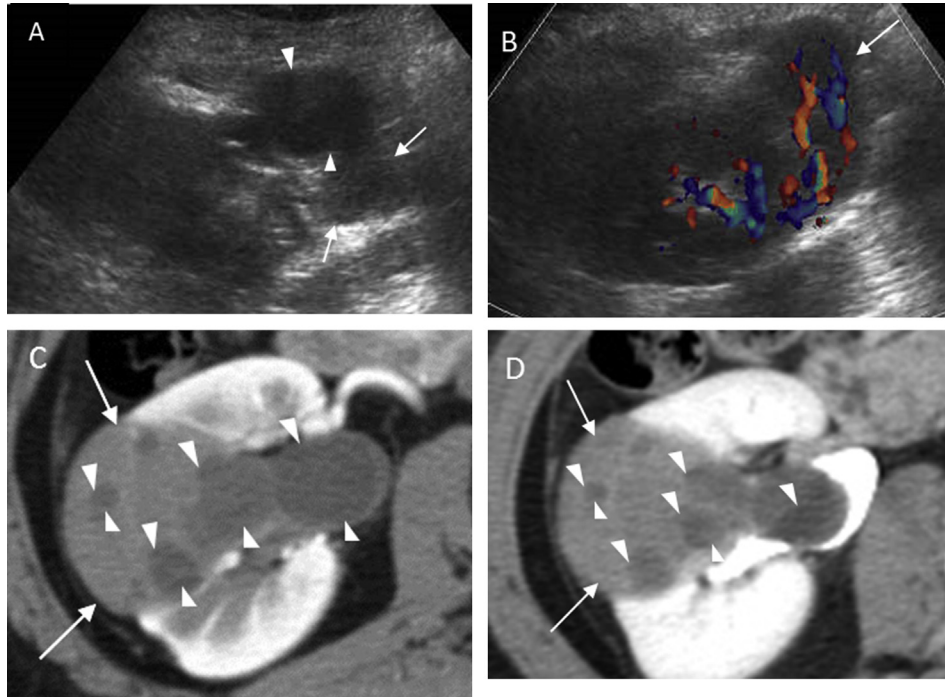


Fig. 9. A 58-year-old perimenopausal woman with a mixed epithelial and stromal tumor. (A) Gray-scale ultrasonography (US) shows a renal cyst lesion (arrowhead) containing a soft tissue component (arrows). (B) Color Doppler US shows minimally increased color flow signals in the soft tissue component (arrows), representing a Bosniak Category IV lesion. (C) Contrast-enhanced computed tomography (CT) image in the corticomedullary phase and CT nephrogram phase. (D) A minimally enhanced soft tissue component in the lesion (arrows) with cystic components (arrowheads).

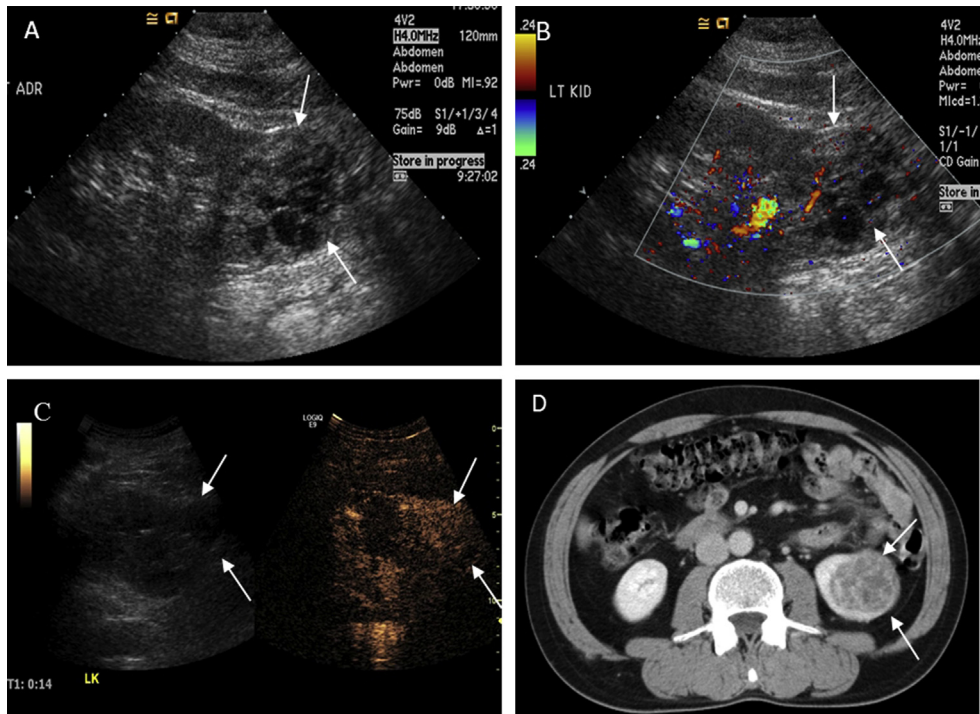


Fig. 10. A 51-year-old man with a renal cystic tumor. (A) and (B) Ultrasonography (US) shows a renal cyst lesion (arrows) containing a soft tissue component and thickened septa, but equivocal color Doppler ultrasonography, representing a Bosniak Category III or IV lesion. (C) Contrast-enhanced US shows enhancement. (D) Contrast-enhanced computed tomography at the nephrogram phase shows septal enhancement (arrows). Renal cell carcinoma was diagnosed based on contrast-enhanced US and confirmed upon surgical pathologic evaluation.

complex mass with internal mobile debris and, on occasion, septations. Infected cysts are difficult to distinguish from other Category IIF and III cystic masses. The clinical history of the patient can help differentiate between infected cystic masses and cystic neoplasms. These infected cysts must be followed up with an US study after antibiotic treatment or drainage.²⁸

5.2. Hemorrhagic cysts

Hemorrhagic cysts can have various appearances and can be classified into Category II, III, or IV. Hemorrhagic cysts with irregular walls or septal thickenings are classified into Category III (Fig. 5); they are the most common benign lesions among the surgically-removed Category III masses.^{23,29} Hemorrhagic cysts with contrast-enhancing soft tissue in the cystic walls or lumen are classified into Category IV.²³ Either CT or MRI can easily differentiate hemorrhagic cysts from other malignant tumors using high density or high signal change on the T1-weighted image.

5.3. Renal artery aneurysm

Renal artery aneurysms are saccular or fusiform dilations of the renal artery or one of its branches. The incidence of renal artery aneurysm is 0.09%–0.3%.^{30,31} Etiology can be congenital, inflammatory, traumatic, atherosclerotic, or related to fibromuscular disease. If large (>2.5 cm), noncalcified, or associated with pregnancy, the possibility of rupture increases, and treatment is recommended. On a gray-scale US image, a cystic mass can be seen. Adding either duplex or color Doppler imaging readily demonstrates arterial flow within the cystic mass³⁰ (Fig. 11).

6. Multilocular cystic lesions

When a cystic lesion has more than three or four septa, it should be considered a multilocular cyst. Contrast-enhancing US was found to be useful for evaluating cystic renal masses using Bosniak classifications, and it was superior to CT in terms of detecting additional septa and the thickness of walls and/or septa.^{7,8} Multilocular cystic lesions of the kidney include multilocular cystic nephroma (MLCN), multilocular cystic RCCs, and MESTs.³²

6.1. Multilocular cystic nephroma

In MLCN, US will show a multilocular cystic mass with hairline-thin septa. Peripheral and curvilinear calcifications and irregular borders can be present (Fig. 7). It is difficult to differentiate MLCN from multilocular cystic RCC using US. Therefore, multilocular cystic masses are classified into Bosniak Category III, and a biopsy or excision is suggested. Color Doppler ultrasonography shows cystic lesions with poor vascularity (Fig. 7B). Contrast-enhanced imaging studies of MLCN show poor enhancement within the septa.²³ Central sinus and renal pelvis extensions can be found in MLCN.³³

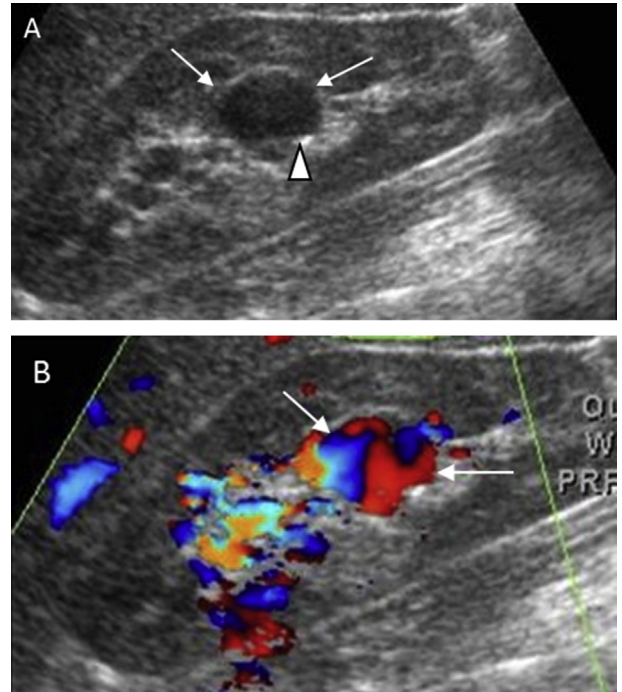


Fig. 11. A 41-year-old female with a renal artery aneurysm. (A) Gray-scale ultrasonography shows a cystic lesion (arrows) associated with small mural calcifications (arrowheads). (B) Color Doppler imaging shows color flow signals (appearing like a yin-yang sign) within the cystic lesion (arrows).

6.2. Mixed epithelial and stromal tumors

First defined in 1988, MESTs are benign cystic renal tumors. They are characterized by a biphasic proliferation of the epithelium and stroma cells.³⁴ These tumors always occur in perimenopausal women and are closely related to hormonal status.³⁵ Malignant transformation, recurrence, and metastasis rarely occur in MESTs. However, a few recent cases of MEST with metastasis have been reported in the literature.^{36–38} In one case, translocation t (1; 19) was described in a gene study.³⁹ Ultrasonography will show cystic lesions with septa, calcifications, and solid components (Fig. 9), rendering classification into Bosniak Category III or IV. It is difficult to distinguish MESTs from other cystic renal masses in image studies; therefore, biopsy or excision is suggested.

6.3. Multilocular cystic renal cell carcinoma

Multilocular cystic RCC is a cystic mass with internal septations, nodules, and possibly calcifications (Fig. 10). Nodular and septal enhancements in cystic tumors are highly sensitive for differentiation between RCC and MLCN. Renal cortex extension can be found in cystic RCC.³²

7. Multiple renal cysts

7.1. Polycystic kidney disease

Autosomal dominant polycystic kidney disease (ADPKD), also known as adult PKD, is an inherited renal disease in

which multiple or numerous cysts of variable size develop in the kidneys bilaterally. On US, they are seen as multiple round or oval smoothly-walled cysts of varying size. They are separated by normal renal parenchyma (Fig. 12). Cysts presenting with hemorrhage or infection will have thick walls, internal echoes, and debris in the fluid.³⁰ Small wall calcifications or a calcium milk is commonly seen inside the cysts. The prevalence of RCC is higher in patients with ADPKD under dialysis; therefore, ADPKD cysts should be classified into Category IIF.

7.2. Localized cystic disease

Localized cystic disease of the kidney is an uncommon benign condition that can be confused with PKD or simple renal cysts. In a study of 18 patients without family histories of PKD, the age at diagnosis ranged from 24 to 83 years (average, 54 years).⁴⁰ Imaging studies revealed multiple cysts of various sizes separated by normal or atrophic parenchyma

in one kidney (Fig. 13). In contrast to PKD, localized cystic disease is neither bilateral nor progressive, and in contrast to simple renal cysts, it is often symptomatic (hematuria, flank pain, or abdominal mass).

In conclusion, sometimes, clear-cut differentiations between Categories IIF and III are not as obvious as those between other categories. Herein, we proposed an algorithm for classifying renal cystic lesions (Fig. 14A and B). Contrast-enhanced US can be superior to unenhanced US or CT in diagnosing malignancy in complex cystic renal masses using features such as the presence of septa, thickenings in walls and/or septa, and solid components.^{7,8} Using contrast-enhanced US when evaluating renal cystic lesions is becoming more common partly because attempts are being made to decrease radiation exposure in the general population and also because it brings additional information to renal lesion evaluations.

Imaging-guided percutaneous core needle biopsies of indeterminate complex cystic renal masses (Category III) are more controversial. Biopsies of these complicated cystic

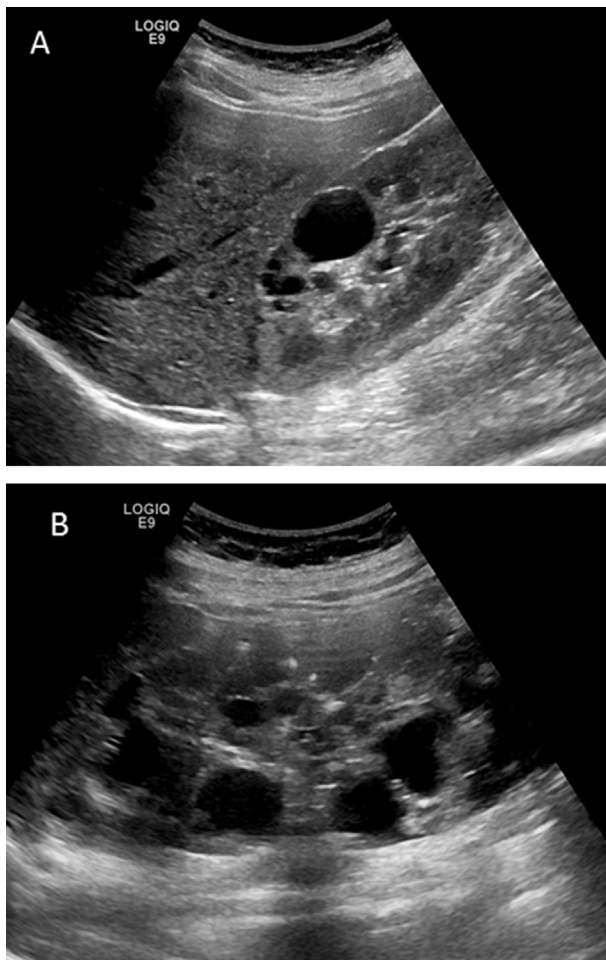


Fig. 12. A 26-year-old female with polycystic kidney disease, where both kidneys are enlarged. The right kidney measures 13 cm; the left kidney 16 cm. (A) A coronal scan of the right kidney shows cystic lesions. (B) A coronal scan of the left kidney depicts numerous cysts of various sizes, some of which have calcified spots or a calcium milk. The cysts are separated by normal renal parenchyma.

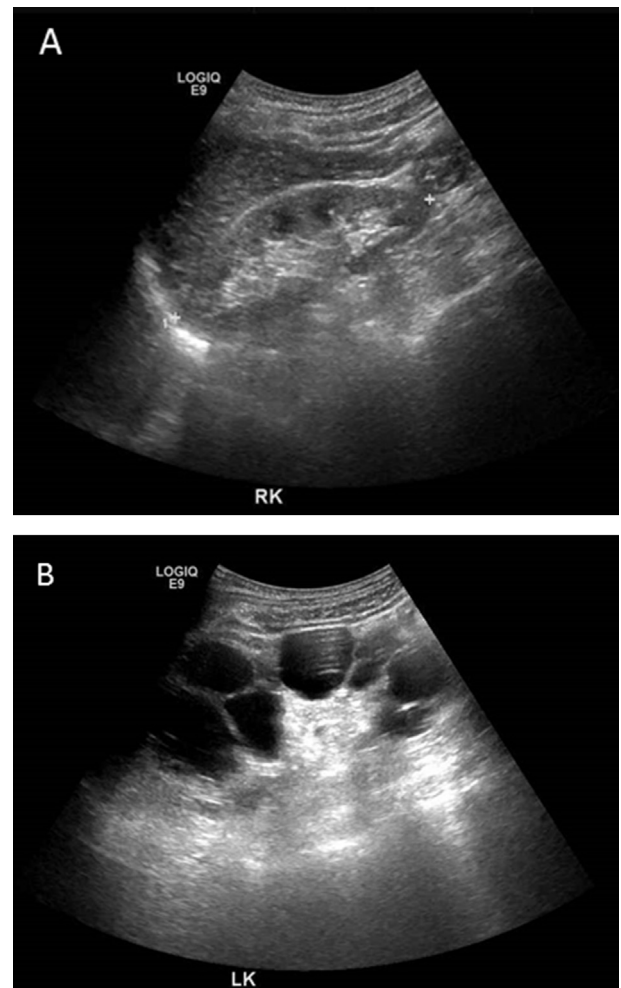


Fig. 13. An 85-year-old male with localized cystic disease. (A) Normal right kidney. (B) Multiple cysts in the left kidney separated by normal renal parenchyma.

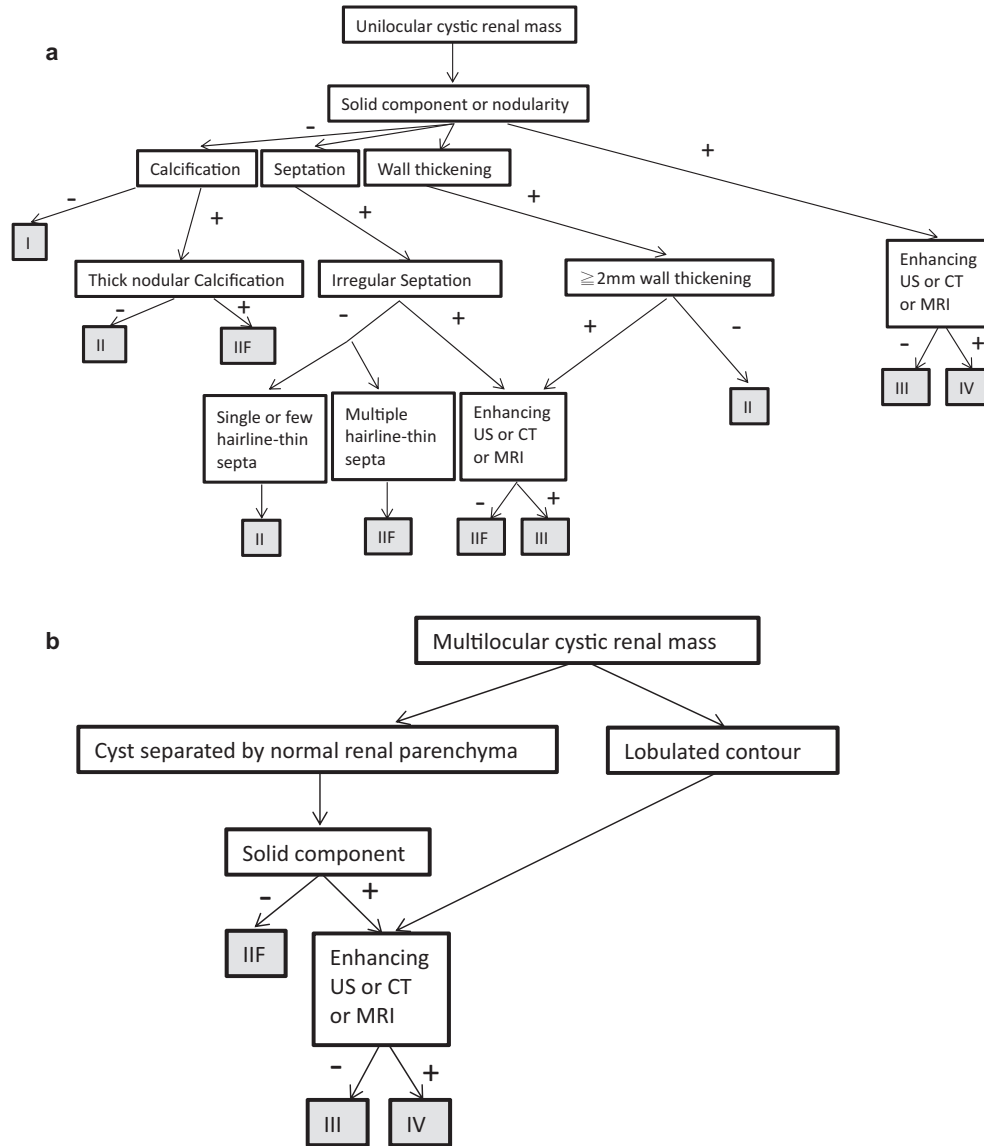


Fig. 14. A): Algorithm for classifying unilocular renal cystic tumors. (B) Algorithm for classifying multilocular renal cystic tumors.

lesions are not as reliable and successful as those for solid masses because they provide less tissue to sample. A biopsy that is negative for malignancy necessitates follow-up studies to ensure the lesion is truly benign. Biopsies for Category III lesions are of value in select cases (e.g., to avoid surgery in a patient who is a poor surgical candidate and when an infected cyst or abscess might be present). However, biopsy should not be used when imaging studies are inadequate or incomplete or when patients have Category IIF cystic lesions.⁴¹

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