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Simple and complex renal cysts in adults: Classification system for renal cystic masses

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Abstract Ultrasound and slice imaging are currently the key modalities for diagnosing simple renal cysts. Benign simple renal cysts are defined by a set of strict criteria. Any cystic lesions that do not meet these criteria should be classified as "atypical" or "complex" and considered as suspicious. For over three decades, the Bosniak classification has been the central tool for diagnosing renal cystic masses larger than 1 cm. The Bosniak classification is based upon the results of a well-established pre- and post-contrast computed tomography (CT) protocol. Lesions that are difficult to classify or that remain indeterminate after CT can benefit from a multimodal diagnostic approach combining CT, non-contrast-enhanced and contrast-enhanced ultrasound, and magnetic resonance imaging.

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KEYWORDS
Kidney; Renal cyst; Cystic tumor; Ultrasound; Bosniak classification

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Simple renal cysts are defined as non-tumor lesions of the parenchyma, with an epithelial origin, and consisting of a thin-walled, completely fluid-filled renal mass. This definition excludes numerous cystic masses of the renal parenchyma; including those caused by dysplastic, dystrophic, or inherited conditions, or those acquired in chronic dialysis patients. Cystic tumors, various infectious, inflammatory lesions, and lesions of the excretory renal system can be difficult to differentiate from complicated benign cysts. When a cystic renal mass does not meet all the necessary criteria to be classified as a simple cyst, it is referred to as a complex or atypical cyst. If it seems suspicious, it is referred to as an atypical, cystic “lesion” or “mass”. The Morton Bosniak classification system is the central tool for diagnosing renal cystic masses using CT for the three last decades [1]. It is comprised of five lesion categories. These categories are used to predict the risk of malignancy as well as standardize the management of cystic renal lesions.

**Diagnosis of a simple cyst**

Typical simple cysts are typically discovered incidentally and are easily diagnosed upon cross-sectional imaging. Such cysts are often detected during a renal or abdominal ultrasound, and can generally be diagnosed with certainty using this modality. Intravenous iodine or gadolinium contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI) also generally results in definitive diagnosis. Simple cysts are classified as Bosniak category I within the Bosniak classification system.

**Ultrasound**

A simple cyst is defined by ultrasound as a rounded or oval mass of homogeneous anechoic content. The cyst must also exhibit marked posterior enhancement, smooth well-delimited margins, and an imperceptible sub-millimeter wall (Fig. 1A). The borders between the cyst and the surrounding structures should form a simple interface, and no wall should be visible around the lesion. When all the previous criteria are met, the reliability of ultrasound (US) is approximately 100% [2]; however, this should be balanced with the operator- and device-dependency of the method. The now widespread use of tissue harmonic imaging has resulted in increased diagnostic confidence and more stable performance due to improvement of cystic lesion analysis.

Color Doppler generally provides no further advantage for the diagnosis of a simple cyst. Some bilobar-shaped cysts that display a central septation may contain an artery that runs along the septation. Such features reflect the presence of two side-by-side cysts separated by a narrow band of kidney parenchyma. Similarly, simple renal sinus cysts can contain a segmental artery which originates on the periphery and runs deep within the cyst. The absence of vessels within a complex fluid-filled lesion does not allow an operator to suggest that the cyst is benign in nature. In this case, further imaging, such as CT or MRI, should be planned.

**Contrast-enhanced ultrasound**

Current low-mechanical index, real-time techniques which use the latest generation of contrast agents can be used to diagnose cystic lesions. These techniques provide excellent sensitivity for microbubble detection, and help resolve challenging cases in which cystic lesion diagnosis is difficult [3–8]. Following intravenous administration of microbubble contrast agents, simple cysts remain uniformly anechoic, devoid of signal, and show smooth margins (Fig. 1B).

**Key points**

Criteria to classify a cyst as ‘simple’ using ultrasound
- Anechoic.
- Homogeneous content.
- Posterior enhancement.
- Imperceptible wall.
Computed tomography

Simple cysts are classified as Bosniak category I. These cysts are defined by the following criteria: water attenuation similar to pure water (>-10 Hounsfield units [HU] and <+20 HU, practically -5 to +15 HU), entirely homogeneous, imperceptible wall, smooth and well-delimited margins. The cyst is non-enhancing, and its content remains homogeneous following intravenous administration of a contrast agent (Fig. 2). A lack of enhancement is defined by attenuation variation of less than +10 HU after administration of contrast material, providing technical and anatomical calculation conditions are adequate. For well-enhanced CT scans, the specificity is excellent. However, operators must be familiar with the difficulties and pitfalls that can be encountered when using CT in order to avoid misdiagnosis.

Key points
- Criteria to classify a cyst as “simple” (Bosniak category I) using CT.
- Water attenuation (from -5 to +15 HU).
- Homogeneous.
- Postcontrast.
  - Homogeneous.
  - <+10 HU increase in attenuation.
- Imperceptible wall.

Evaluating the density of a cyst

To calculate the attenuation value reliably, it needs to be measured over a region which covers at least 50% of the surface of the lesion. Furthermore, it should be measured in the cross section of the cyst’s largest diameter as well as some distance from its margins. The observation of a large renal parenchymal spur shows the proximity of the cyst’s implantation base on the craniocaudal axis, and a high risk for a partial volume effect. Partial volume effect can lead to falsely elevated attenuation (pseudoenhancement).

For patients with very small (< 8 mm), intraparenchymal cysts, this partial volume effect is practically unavoidable, especially when slice thickness is greater than 50% of the diameter of the lesion. For this reason, it is often impossible to confirm the cystic nature of lesions smaller than 8 mm using CT. Spontaneously hypoattenuating microlesions (compared with the renal cortex) combined with spontaneous water attenuation values (<+20 HU) should guide the operator to the diagnosis of a very small cyst, especially in patients with an inherent risk.

The calculation of the attenuation value, based on a region of interest in a lesion, may result in misinterpretation. Indeed, the absence of a significant increase in attenuation within the region should not be considered sufficient to classify a renal mass as avascular. All images should be reviewed visually to confirm that the lesion shows no postcontrast enhancement. Furthermore, they should be checked to confirm that neither a peripheral wall nor septations appear, and that the content remains homogeneous. These non-attenuation-based visual criteria can point towards vascularization and classify the mass as suspicious.

Figure 2. (A) Typical simple (Bosniak category I) cyst. Precontrast, and postcontrast computed tomography (CT) during the (B) corticomedullary phase and (C) nephrographic phase. (A) Homogeneous, water attenuation (+3 HU) lesion that is not significantly enhanced (+9 HU; Δ = +6 HU) on (B), which shows no post-contrast changes and an imperceptible wall. Note the image of the parenchymal spur at the implantation base of the cyst (arrows). An indeterminate, small lesion can also be seen on the anterior edge of the kidney (see also Fig. 2).
Inadequate system calibration can significantly change the apparent density of a cyst. The interpretation of attenuation values should incorporate the standard deviation [SD] displayed by the system. Attenuation values can also be compared to reference values such as the water attenuation of the gallbladder, renal pelvis, or bladder. Interpretation pitfalls can be avoided by using scanning parameters that favor an appropriate signal to noise ratio, a filter adapted for attenuation measurements, and systematic acquisition of pre-contrast images.

**Diagnosis of a simple cyst following initial contrast injection**

The definitive diagnosis of a benign cyst using CT does not always require pre-contrast imaging. Indeed, when all the criteria defining a simple cyst are met, the diagnosis of a simple cyst can be confirmed. It can be extremely difficult to diagnose a simple cyst using non-contrast-enhanced CT or during the early “arterial” phase. This difficulty occurs because type III lesions, type IV lesions, and some solid tumors with edematous or hyalin stroma can show all the features of a simple cyst before contrast injection or on early arterial post-contrast phase. Contrast enhancement is often only significant at the peak enhancement of the nephrographic phase.

**Cyst pseudoenhancement**

Pseudoenhancement of simple cysts is a well-known CT artifact. It is due to beam hardening that results from highly attenuating neighboring structures: calyces during the excretory phase or nephrographic parenchymal enhancement. Some phantom studies have shown that the water attenuation values of simple cysts can be artificially enhanced and exceed +20 HU. This especially occurs when a number of conditions are met: the cyst is small (< 20 mm), it has an intraparenchymal location, and it is assessed during the nephrographic phase, at peak enhancement of the tubular nephrogram (+250 to +300 HU) [9—11].

The intensity of pseudoenhancement seems to depend on various technological factors, particularly detector technology [11—13]. Indeed, higher levels of pseudoenhancement are observed with multidetector CT [11]. Furthermore, it increases with the number of detectors [14—16]. It is also affected by certain scanning parameters and increases notably at higher kilovolt (140 vs. 90 kVp) and wider collimator settings [11,12,17]. However, it does not appear to be affected by beam pitch [11].

In vivo studies have confirmed the importance of this artifact, particularly for small (≤ 20 mm), intraparenchymal cysts which were assessed during peak tubular enhancement in the nephrographic phase [10,18,19]. For such cysts, attenuation values can be artificially enhanced up to +20 HU (Fig. 3). Changes in cyst’s attenuation are lesser in magnitude for large cysts and exophytic subcapsular cysts [9,18]. Virtual monochromatic imaging with dual-energy CT can reduce the pseudoenhancement artifact [20,21].

![Figure 3](https://via.placeholder.com/150)

**Figure 3.** Pseudoenhancement of a small simple cyst, (A) pre-contrast and (B) post-contrast CT. (A) shows an indeterminate, hypodense, intraparenchymal mass of water attenuation (+10 HU) (arrows), while (B) shows pseudoenhancement +28 HU (Δ = +18 HU) on the postcontrast image during the nephrographic phase (arrows). This indeterminate mass was further investigated using (C) ultrasound (arrow) to reach the diagnosis of simple cyst.
The current imaging approach to cystic renal masses in adults

Key points

- Contrast enhancement on CT.
- Attenuation increase < +10 HU: non-enhancing.
- Attenuation increase > +20 HU: significant enhancement.
- Attenuation increase from +10 to +20 HU: indeterminate.

Figure 4. CT scan of simple (Bosniak category I) cysts (nephrographic phase). Parenchymal spur (arrows) mimicking a thick wall at the base of the cyst. "False" septation (double arrow) formed by a narrow band of parenchyma between two contiguous cysts. "False" wall thickening (arrowhead) caused by the colon wall which is in contact with the more anterior located cyst.

Apparent wall thickening of simple cysts

Normally, simple cysts have a sub-millimeter cell wall that remains imperceptible at imaging. Therefore, finding a visible wall, even if it is extremely thin, is uncommon. Any cystic lesions that are found to be delimited by a wall upon imaging, whether partially or totally, and regardless of the thickness of the wall, are considered as suspicious. Indeed, when a wall is visible, its thickness and appearance are used to classify the lesion into one of the Bosniak classification categories (see Section below). However, other occurrences can be responsible for a false thickened wall around a simple cyst. Several examples are laid out below:

- the tip of the parenchymal spur on an axial slice which is near to the implantation base of the cyst can take the appearance of a thick vascularized wall (Figs. 2 and 4).
- Misclassification can be avoided by analyzing contiguous slices that show the continuity between the pseudo-wall and the parenchymal spur.
- large subcapsular cysts that interface with neighboring structures and renal sinus cysts in contact with other sinus structures can display localized wall thickening due to the adjacent structure (Fig. 4). In these cases, analysis of post-contrast images during the early vascular phase or the excretory phase can help identify an adjacent vascular or pyelocalyceal structure;
- the presence of a narrow spur/band of parenchyma between two coalescent cysts can be confused with an abnormal septation (Fig. 4).

Magnetic resonance imaging

The fluid content of a simple cyst provides a signal similar to that of urine (long T1- and T2-relaxation times) on the different MRI sequences. It is observed as a homogeneous hypointense signal on T1-weighted images and with clear, homogeneous, high signal intensity on T2-weighted images (Fig. 5). Post-contrast fat-saturated T1-weighted images are essential to determine cyst morphology, especially for intraparenchymal cysts [22], and to confirm the lack of vascularity of the lesion. The morphological criteria for benignity are identical to those used with CT. Particularly, no wall should be visible, regardless of the sequence used.

With diffusion-weighted imaging, simple cysts display a low signal (Fig. 5) and an apparent diffusion coefficient (ADC) significantly higher than those of solid tumors [23].

Following intravenous administration of a contrast agent, dynamic sequences show no change in the cyst’s signal intensity during the vascular phase and later phases; there is a homogeneous hypointense signal throughout the sequence, and a well-delimited, smooth interface with the renal parenchyma (Fig. 5).

The quality of the contrast resolution obtained using MRI, particularly on fat-saturated T2-weighted images, allows the characterization of very small cysts that were classified as indeterminate using CT [24,25]. MRI is therefore indicated in certain circumstances, depending on the patient’s history and risk status for sub-centimeter lesions.

The wall thickening artifacts encountered using CT (see above) can also lead to the misinterpretation of MR images. Some artifacts, such as the chemical shift artifact or data truncation (Gibbs artifact), can result in signal heterogeneity or apparent wall thickening. The wall thickening artifact occurs notably in the phase encoding gradient plane, especially with low resolution dynamic sequences (e.g. spoiled gradient echo, fast spoiled gradient echo [FSPGR], and fat saturation). It can be eliminated or reduced by using a higher spatial resolution (e.g. increased scan matrix 512 × 512 and reduced field of view [FOV]) [26].

Diagnosis of a "complex" cystic mass

Definition and significance of a "complex" cyst

When a cystic renal mass does not meet all the necessary criteria to be classified as a simple cyst, it is referred to as a complex or atypical cyst. If suspicious, it is referred to as an atypical cystic "lesion" or "mass". Among cysts that have undergone morphological changes, the term "multilocular
cyst** refers to a cystic mass with multiple septations of uncertain etiology. Multilocular cysts occur rarely and, in theory, display the nearly the same histopathological features as a simple cyst. The only difference is the presence of numerous very thin, fibrous internal septations in Multilocular cysts. In fact, the boundary between a benign epithelial cyst with several septations and cystic nephroma is not clearly established, as demonstrated by the frequent use of the term **“multilocular cyst”** in the literature and the clinical practice of referring to **“multilocular cystic nephroma”**. Cystic nephroma is a neoplasm belonging to the family of mixed epithelial and stromal tumors (MEST) of the kidney. In any case, these benign cystic lesions are generally classified as multiple septated cystic lesions in the Bosniak categories II or III.

The term **“complicated cyst”** is generally used to designate cysts that undergo morphological changes because of a documented, acute complication, such as a rupture, a hemorrhage, or an acute infection. Such complicated cysts are generally not classified using the Bosniak system because they lead to specific imaging workup and management. Various other non-epithelial cystic lesions that present similar features to **“solitary”** cysts (of infectious or excreto-urinary origin) are of very different clinical relevance and should not be classified using the Bosniak system.

**Imaging features of a complex cyst**

Using ultrasound, atypical cystic lesions are diagnosed based on internal echo patterns, and the presence of thick or calcified walls or septations, with or without a nodular component. The remarkable sensitivity of ultrasound for detecting internal septations can sometimes explain the discordance observed with CT findings (a septated cyst may appear as a simple cyst using CT).

Atypical cysts are characterized using CT by high attenuation values (≥ +20 HU), the presence of a visible wall, mural nodules or septations, and calcifications. With the exception of calcifications, these morphological criteria can be identified using MRI. Morphological anomalies are detected by the combined analysis of T1- and T2-weighted sequences. T2-weighted images show high sensitivity for detecting intracystic septations. Fluid-content anomalies of suspicious cysts are reflected by an abnormal signal on T1-weighted images and/or T2-weighted images. These anomalies are often signal heterogeneity on T2-weighted images, which is suspicious regardless of the signal observed on T1-weighted images [25] (Fig. 6). In the same way, when the signal of a cystic mass is not clearly hypointense and homogeneous on T1-weighted images, the mass should be considered as suspicious, regardless of its signal on T2-weighted images.

Gadolinium contrast-enhanced, fat-saturated dynamic sequences are particularly effective for determining the potential vascularization of a solid component. Subtraction imaging can prove useful, especially in cases of hyperintense, hemorrhagic cystic lesions in which the high signal intensity on T1-weighted images may prevent detecting of the moderate enhancement of a solid component. MRI is therefore sometimes used as a **“problem-solving”** modality.
The current imaging approach to cystic renal masses in adults

Figure 6. Usefulness of MRI for characterizing the contents of a complex cystic mass. (A) Precontrast and (B) postcontrast CT (excretory phase). Right kidney mass with a slightly thickened wall and calcifications, and a relatively dense non-enhancing contents. (C) MRI, T1-weighted image, (D) fat-saturated T2-weighted image, and (E) diffusion-weighted sequence (b1300) with (F) the ADC map. The heterogeneous contents of the mass observed on T1- and T2-weighted images suggests hemorrhagic necrosis. Diffusion-weighted imaging shows a wall component (arrow) evidenced as a marked reduction of diffusion (F) which suggests a tissue component (see also Fig. 29).
in masses that remain indeterminate at CT. It is used in this way because of its superior contrast resolution for detecting cyst enhancement. Cyst enhancement is a decisive feature for characterizing complex cysts. Diffusion-weighted sequences with ADC calculation may provide additional information that can improve diagnostic confidence when trying to identify a solid tumor component (Fig. 6). However, findings must be interpreted with caution when the lesion contains hemorrhagic debris [27,28].

The presence of one or more of these features should result in the classification of the lesion in one of the Bosniak categories. Classification should be based on kidney CT findings, combined CT/ultrasound, or even CT/MRI findings [29,30].

Bosniak classification of cystic masses

The Bosniak classification system is used to classify renal cystic lesions of nephron epithelial origin (cysts and cystic neoplasms) based on CT imaging findings. It should only be used for cystic lesions larger than 1 cm (from 10 mm in practice). Fluid-filled masses of urothelial (calyceal diverticulum, hydrocalix), infectious (chronic abscess), or parasitic (hydatid cyst) origin that exhibit a thickened wall are also out of the scope of this classification system. The Bosniak system defines four main categories of cystic lesions based on CT findings and the possible histopathological nature of the lesion (Table 1) (Fig. 7). These categories are used to predict the risk of malignancy as well as standardize the management of cystic renal lesions [31,32,33]. Numerous studies have validated Bosniak’s diagnostic algorithm since its publication in 1986 [1], and have supported the relevance of its use in clinical practice. Two studies over the last two decades provide two important steps in the development of this classification system. The first paper, published in 1997 [34], introduced a new category, IIF (F for follow-up), and helps classify some lesions that do not fit into any of the original categories. The second extended the scope of the classification system, previously based exclusively on CT findings, to MRI. More importantly, it specified the role of MRI. MRI can, in some cases, cause lesions to be reclassified, particularly those classified IIF using CT [35].

**Table 1** Bosniak classification of renal cystic masses.

<table>
<thead>
<tr>
<th>Bosniak Category</th>
<th>CT Features</th>
<th>Diagnosis (risk of malignancy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bosniak I</td>
<td>Water attenuation (from −5 to +15 HU)</td>
<td>Simple cyst (0%)</td>
</tr>
<tr>
<td></td>
<td>Homogeneous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smooth margins without perceptible wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-enhancing (attenuation increase &lt; +10 HU)</td>
<td></td>
</tr>
<tr>
<td>Bosniak II</td>
<td>A few (1–3) thin septations</td>
<td>Complicated cyst (0%)</td>
</tr>
<tr>
<td></td>
<td>Thin calcification of the wall or septation</td>
<td></td>
</tr>
</tbody>
</table>
|                  | Hyperdense cyst (≥ +50 HU)
  (small and subcapsular) |                               |
|                  | Non-enhancing (attenuation increase < +10 HU) or moderate enhancement of septations |                               |
| Bosniak IIF      | Multiple thin septations (> 3) | Cystic tumor (cystic cancer, cystic nephroma or MEST) (5–15%) |
|                  | Thin (< 1 mm), just perceptible wall (not measurable) |                               |
|                  | Thick calcification |                               |
|                  | Large (> 3 cm) hyperdense lesion\(^a\) or intraparenchymal localization |                               |
|                  | Non-enhancing (attenuation increase < +10 HU) or moderate enhancement of septations or hairline-thin wall |                               |
| Bosniak III      | Numerous thick septations | Complicated cyst (cystic cancer, pseudocystic necrotic cancer, cystic nephroma or MEST) (50–60%) |
|                  | Uniform grossly (measurable) or slightly irregular thick wall |                               |
|                  | Thick and/or irregular calcifications |                               |
|                  | Enhancement of wall or septations |                               |
| Bosniak IV       | Thick, very irregular wall | "Cystic" cancer |
|                  | Mural nodule(s)/solid tissue elements | Pseudocystic necrotic cancer mixed epithelial and stromal tumor (MEST) (90–100%) |
|                  | Enhancement of wall or nodules |                               |

\(^a\) Small (< 3 cm), subcapsular (at least 25% exophytic), spontaneously hyperdense (50–90 HU), homogeneous, well-margined, non-enhancing cyst.

Technical considerations

CT is the modality upon which the classification system was developed and evaluated. It is based on careful analysis of CT images acquired using a kidney investigation protocol. This protocol was designed for the characterization of renal masses. It has multi-phase acquisition both pre- and post-contrast injection (approximately...
The initial enhanced to ''excretory'' mention of the secretion 2—4 performance (approx. 90 seconds) is always within the capillary phases) is 40—70 mm, can be sufficient in the assessment of most of renal cystic masses [36]. Use of the ''corticomedullary'' phase alone, or even of an intermediate ''portal-like'' phase (approx. 60—70 seconds), should be ruled out in order not to miss potential diagnostically-relevant contrast enhancement (Fig. 9).

Figure 7. Drawing of the Bosniak categories of renal cysts (with the exception of hyperdense cysts) (see Table 1). F: follow-up; ML: multilocular.

1.5 mL of 300—350 mg of contrast agent injected at 2—4 mL/s with early ''corticomedullary'' phase acquisition approximately 40 seconds after the start of contrast injection and ''nephrographic'' phase acquisition approximately 90 seconds after injection, using overlapped thin slice reconstruction (<3 mm every 0.5—1.5 mm). A third, delayed ''excretory'' phase acquisition is optional and depends on initial findings (e.g. unclear contrast enhancement during the early phases) and the type of lesion (e.g. detection of secretion within a potential calyceal diverticulum or hydrocalix) (Fig. 8).

The most relevant post-contrast phase for diagnostic performance is the parenchymal nephrographic phase. It should always be acquired and, in combination with the unenhanced phase, can be sufficient in the assessment of most renal cystic masses [36]. Use of the ''corticomedullary'' phase alone, or even of an intermediate ''portal-like'' phase (approx. 60—70 seconds), should be ruled out in order not to miss potential diagnostically-relevant contrast enhancement (Fig. 9).

Figure 8. Secretion of contrast agent (arrows) during the excretory phase (delayed postcontrast CT) within a hydrocalyx due to renal tuberculosis forming a complex cystic mass.

Typical Bosniak category I simple cysts

The Bosniak category I reflects typical CT features for simple cysts. It is defined by water attenuation similar to pure water (>−10 HU and <+20 HU (in practice −5 to +15 HU)), an entirely homogeneous appearance, an imperceptible wall, and smooth and well-delimited margins. The cyst is non-enhancing (postcontrast attenuation variation <10 HU) and remains of homogeneous appearance following the administration of contrast agent (Fig. 2). When all these criteria are met, the specificity of CT is approximately 100% [37—39].

Bosniak category II water-attenuation complex cysts

Those complex cysts that have undergone slight morphological changes are classified as Bosniak category II and are minimally suspicious. They exhibit a few rare (one to three) hairline-thin septations, and are less than 1 mm thick and perfectly regular. They also may have thin peripheral calcifications, which are either punctate or linear (rim calcification), or located within a septation (Fig. 10). To classify a complex cyst as Bosniak category II, an all other Bosniak category I criteria must be met and verified following injection of contrast. The presence of septations or calcifications within a simple cyst may reflect morphological changes secondary to past infection or intracystic hemorrhage [40]. Calcifications can be observed in the wall of 1—3% of benign cysts [41,42]. The septations consist of connective tissue or a narrow band of normal compact parenchyma (compressed between two coalescent cysts). The septations are generally enhanced following administration of contrast, and are most often only visible on postcontrast images. However, contrast enhancement should be moderate (borderline perceptible due to the thinness of the septations) and septations should appear hairline-thin and smooth. No other morphological changes should be visible; the cyst wall must not be perceptible. For Bosniak category II lesions that are large enough to be characterized (≥10 mm), the reliability of CT for diagnosing minimally complicated benign cysts is 100%. This reliability is accurate if the technical quality of
Figure 9. Unilocular cystic mass of category III in the Bosniak system. (A) Precontrast and (B) postcontrast CT during the arterial phase and (C) the nephrographic phase. The thickened, vascularized wall (arrows) is easily observable during the nephrographic phase (C). This is not the case during the arterial phase (B) and assessment based alone on this earlier phase could result in inappropriate classification of the lesion as Bosniak category IIF. Histopathological examination of excised tumor revealed cystic carcinoma.

Figure 10. Bosniak category II complex cyst. (A) Precontrast and (B) postcontrast CT during the nephrographic phase. Bosniak category II minimally septated and calcified cyst. Water attenuation cyst showing hairline-thin septation and calcification (arrow), without enhancement and in particular a non-enhancing imperceptible wall (B).

the scan is flawless and strict application of Bosniak criteria is ensured [34,38].

Bosniak category II hyperdense complex cysts

These cysts contain a hyperattenuating fluid and show an attenuation coefficient > +20 HU using CT, generally between 50 HU and 80 HU. Three mechanisms explain how the initially serous low-protein-content fluid of a simple cyst may become hyperdense [43–47]:

• a past intracystic hemorrhagic event with persisting red blood cell degradation products, notably iron atoms from the heme group in hemoglobin;
• a high glycoprotein content that makes the cyst fluid appear viscous;
• a suspension of precipitated calcium crystals that form a hyperattenuating “renal milk” and can show declive sediment.

Provided that they meet all the appropriate Bosniak criteria, typical hyperdense cysts are classified as Bosniak II. They are characterized by a perfectly homogeneous, well marginated, spontaneously hyperattenuating fluid content.
(> +50 HU) with an imperceptible wall. Following injection of contrast, the wall should show no changes on images acquired during the tubular nephrographic phase (Fig. 11). The lower attenuation threshold for defining a typical hyperdense cyst is yet to be clearly established in the literature; some authors suggest a threshold value of 60 HU. The most useful criterion for these cysts is spontaneous attenuation, which is observed as a clearly higher density compared with the adjacent renal parenchyma (density of 30–40 HU) that indicates a density gradient of at least 20 HU. The most useful criterion for these cysts is spontaneous hyperattenuation, which is observed as a clearly higher density compared with the adjacent renal parenchyma (density of 30–40 HU) that indicates a density gradient of at least 20 HU. When all these criteria are met, a small (< 3 cm), round, subcapsular (with at least one-quarter of the mass extending beyond the renal outline), hyperdense mass may be considered a benign, complicated cyst containing hyperdense fluid. Such cysts are always benign and do not require surgical evaluation or follow-up in most cases. Nevertheless, extreme caution is recommended when diagnosing these lesions in order not to overlook rare forms of hyperattenuating small-sized malignancies. Those containing hemosiderin which are spontaneously hyperdense show heterogeneity and contrast enhancement that can be subtle and difficult to demonstrate [48,49]. Some hyperdense intraparenchymal lesions with poorly defined margins from CT or large hyperdense hemorrhagic masses (> 3 cm) are often less well characterized. These lesions should be considered suspicious, especially if ultrasound findings are not typical for a benign anechoic cyst. Finally, some hyperdense cysts, whatever their size and location, do not quite meet the CT Bosniak criteria (Figs. 12 and 13). Such lesions should be considered indeterminate and suspicious, despite the absence of obvious contrast enhancement. They should be considered as such due to the possible risk of confusion with a hypovascular neoplasm.

**Bosniak category IIIF complex cysts**

The Bosniak category IIIF, which is the most recently defined category [34,50], is used to classify cystic lesions that are not complicated enough to fall into suspicious category III, but are too complicated for category II.

The risk of malignancy for the cystic lesions in this category is low, and is estimated at 5–15% in the literature [50–55]. Bosniak category IIIF lesions may display a visible wall or several septations (>2–3 septations), but the thickness of both the wall or septations must remain submillimeter (< 1 mm, not measurable), and they must show “just perceptible” contrast enhancement (Fig. 15). Cysts with thick or irregularly-shaped calcifications that show no enhancement following injection of contrast medium are also classified in this category (Fig. 14C and D). Bosniak category IIIF lesions should be followed-up using CT after 6 months, and then yearly for at least 5 years [50].

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**Figure 11.** Typical Bosniak category II hyperdense complex cyst. (A) Precontrast and (B) postcontrast CT during the nephrographic phase. Small subcapsular cyst of high density > 50 HU (arrow) on precontrast CT. The cyst is homogeneous and well-marginated, non-enhancing (attenuation increase < +10 HU) and shows no changes on postcontrast CT (B).

**Figure 12.** Schematic representation of the CT features of typical hyperattenuating cysts (type II) and atypical cysts of intermediate density (indeterminate) before and after intravenous administration of a contrast agent.
An even more prudent approach consists of planning MRI investigation before the first follow-up CT or MR examination to ensure that no suspicious contrast enhancement or other element was overlooked. The usefulness of MRI for upgrading lesions initially classified as Bosniak category IIF with CT was demonstrated by Israel et al. [35]. Israel et al. upgraded three out of ten Bosniak category IIF lesions following assessment with MRI (Figs. 15 and 16). Thus, depending on MRI findings, imaging workup may be changed or, in the majority of cases, confirmed as simple follow-up. Simple follow-up is confirmed if the Bosniak category IIF classification is observed using both modalities. Follow-up has shown that, in the great majority of cases, lesions that become pathological and require upgrading are detected within the first two years of the follow-up period [35,51]. Researchers have also shown that the risk of malignancy for a Bosniak category IIF lesion increases in the presence of Bosniak category III or IV lesions and in patients with a history of renal carcinoma [53]. Although of quite different clinical relevance, hyperdense lesions that could be classified as Bosniak category II but are located entirely within the renal parenchyma, or those of large size (≥4 cm) may also be classified as Bosniak category IIF. With the exception of ultrasound anechoic, hyperdense cysts (30–50% of cases) [30], such lesions should be followed-up yearly, or possibly immediately surgically evaluated. Surgical evaluation can be recommended depending on the setting and patient history. It is especially recommended for large hemorrhagic lesions with atypical MRI findings.

**Bosniak category III complex cystic lesions**

The Bosniak category III is used to classify suspicious cystic lesions, including benign cysts that underwent major morphological changes and cystic tumors [56–59]. Surgical removal is most often indicated for Bosniak category III lesions [34,37,60] due to the high risk of malignancy, estimated in the literature at 50–60% [38,51,53].
Two main types of features are described for Bosniak category III lesions:

- **unilocular cystic lesions that can display thickened, irregular peripheral calcifications and/or a thick wall (>1 mm, measurable) of uniform, smooth or slightly irregular appearance.** They should demonstrate unequivocal enhancement after contrast administration (mandatory for Bosniak category III) but without a nodular soft tissue component (Fig. 9). This category groups both thick-walled, complicated benign cysts (40–50% of cases) and cystic or pseudocystic necrotic carcinomas (50–60% of cases);

- **multilocular, thick-walled cystic lesions with numerous thick, smooth and contrast-enhanced septations.** The clinical significance of this subcategory is different from the unilocular because these lesions are always neoplasms (Figs. 17 and 18) They are either malignant (such as cystic carcinoma and multilocular cystic renal clear cell carcinoma) or benign (such as cystic nephroma or mixed epithelial and stromal tumor) (note: multilocular cystic renal clear cell carcinoma was more recently called multilocular cystic renal neoplasm of low malignant potential according to the WHO 2016 classification).

The main criterion for classifying a complex cyst as Bosniak III is contrast enhancement of the cyst wall. This determines the action to be taken and guides the decision for surgical removal (tumorectomy of a cystic lesion showing suspicious thickened wall vascularity). When no wall enhancement is observed or is unclear using CT, MRI may provide decisive, complementary information due to the superior sensitivity of gadolinium contrast-enhanced MR images (see below).

The interpretation of thick-walled unilocular cystic masses should also bear in mind the clinical setting that led to the discovery of the lesion. Indeed, when the clinical history suggests a possible acute inflammatory, post-inflammatory, or hemorrhagic lesion, it should not be classified using the Bosniak system because it generally does not require surgical management.

**Bosniak category IV cystic masses**

The Bosniak category IV is used to classify cystic masses with a vascularized, solid tumor tissue component. Between 90–100% of Bosniak category IV lesions are malignant and consistent with massively necrotic carcinomas or cystic carcinomas. These carcinomas have uni- or multilocular cystic architecture. Very rarely, mixed epithelial and stromal tumors of benign etiology which exhibit a high ratio of stromal component, can be classified as Bosniak category IV. However, the proportion of these tumors remains...
Figure 15. Multilocular cystic lesion classified Bosniak category IIIF using CT, upgraded to Bosniak category III using MRI. (A) Contrast-enhanced CT scan (nephrographic phase) and (B) gadolinium chelate enhanced, fat-saturated T1-weighted MRI. Left kidney cystic lesion with thin septations and imperceptible wall classified Bosniak category IIIF using CT (A). MRI (B) shows a greater number of septations which appear thicker and notably a thick contrast-enhancing wall (arrows), resulting in the lesion being upgraded to Bosniak category III that led to surgical removal. Histopathological examination of the lesion following resection revealed cystic carcinoma.

very low (< 5%). The lesions of this category, for which surgical removal is mandatory, are characterized by a thick, very irregular wall, mural nodularity, or endocystic nodules and contrast enhancement of these solid components (Fig. 19).

Fig. 20 summarizes the recommendations for cyst management based on Bosniak category (Table 1, Fig. 7).

Usefulness of percutaneous samples

Diagnostic fine-needle aspiration (FNA) of suspicious cystic lesions (Bosniak category III and IIIF) has now been abandoned by most teams. Its diagnostic relevance is limited due to a low level of sensitivity (high false negative rate) and poor specificity [61]. It was found to potentially delay, or even distort, the morphological diagnosis of tumor lesions requiring surgical removal. Only the collection of a clear, citrine-colored, cytologically negative sample with a very low fat content and a low level of lactic acid dehydrogenase (LDH) should be considered suggestive of a benign atypical cyst. Nonetheless, cystic cancer cannot be excluded based simply on a cytologically negative sample, even if the fluid is clear [62].

Percutaneous biopsy has recently been evaluated and suggested to help diagnose indeterminate lesions (categories III and IIIF), especially in patients with high surgical risk. It was shown to perform better than FNA, but nevertheless remains very variable. It has a sensitivity of 30–100% in the literature [63–66]. Contrast-enhanced ultrasound or CT-guided percutaneous sampling should aim to collect material from the solid component of the lesion (portion of thickened wall, septations) and can be used to collect both tumor tissue and cystic fluid. For a Bosniak category III lesion (with MR confirmation), a positive result will have the most impact upon high surgical risk patient management and can justify surgical removal (even in the presence of a high comorbidity or high nephron-related risk) if the findings are strongly suggestive of malignancy.

Although used routinely by some clinicians [66], percutaneous biopsy remains very controversial for the management of indeterminate cystic lesions [67–69]. The alternative approach is active surveillance of the lesion (category IIIF or III for high surgical risk patients). A negative or non-conclusive biopsy could induce morphological changes (hemorrhage, inflammation) and therefore decrease the efficacy of lesion follow-up [68].

Unclassifiable cystic masses

Based on CT findings alone, some cystic or pseudocystic lesions remain indeterminate under the Bosniak system. The interpretation of such atypical, indeterminate lesions with CT should, in practice, take into account data from additional modalities such as MRI or targeted ultrasound [70] (Fig. 21). Comparing data obtained using different imaging modalities can sometimes make cystic lesions unclassifiable or lead to a change of Bosniak category based on CT criteria alone [35,70]. Finally, in some cases, the clinical history of a patient with a suspicious thick-walled cystic lesion, generally classified Bosniak III, may suggest a benign condition and thus lead to changes in planned cyst management.

Very small indeterminate renal masses

Renal masses smaller than 10 mm (in practice of about 5 mm or less) cannot generally be characterized using CT [71,72]. The partial volume artifact affects the quality of attenuation measurements because small volumes are contaminated by the density of the adjacent tissue. They are particularly contaminated by the opacified renal parenchyma following injection of contrast. Precontrast image assessment can, in some cases, be sufficient to identify a fluid-filled, tiny cyst. In the general adult population aged over 50 years, a diagnosis of benign very small cyst is often suggested due to their frequent occurrence. It is suggested when spontaneous hypodensity of the lesion compared to the renal cortex (i.e. < +20 HU) is visible on precontrast images (Fig. 22) [72–75].
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Figure 16. Unilocular cystic lesion classified Bosniak category IIIF using CT, upgraded to Bosniak category III using MRI. (A) Precontrast and (B) postcontrast (nephrographic phase) CT scans and fat-saturated T1-weighted MR images before (C) and after (D) injection of gadolinium chelate. Cystic mass in right kidney displaying a thin wall and thin calcifications, classified Bosniak category IIIF using CT (B). MRI (D) shows a thick, somewhat irregular, enhancing (arrows), which resulted in the lesion being upgraded to Bosniak category III and an indication for surgical removal. Histopathological examination of the lesion following resection revealed cystic necrotic carcinoma.

When a tiny lesion is discovered in a young patient or a patient at risk for primary renal tumor (genetic predisposition such as von Hippel-Lindau disease, a history or synchronous renal carcinoma, etc.), the very small lesion is then designated as indeterminate. In such settings MRI can enable a purely fluid-filled microcyst to be better characterized due to its superior contrast resolution on T2 sequences (Fig. 23) and provide evidence of a solid component. This component appears as a hypointense signal on T2-weighted images and with marked high signal intensity on diffusion-weighted images (b800-b1300) (limited diffusion on the ADC map) (Fig. 24).

Atypical hyperattenuating cysts (intermediate density)

Two categories of attenuating cysts can be distinguished based on the attenuation values of the intracystic fluid: hyperdense cysts with a density > +50 HU, and atypical attenuating cysts with a density greater than that of simple cysts (> +20 HU) but less than typical hyperdense cysts (< +50 HU) (Fig. 13). The typical hyperdense cysts raise no diagnostic problem (classified as Bosniak category II cysts) (Fig. 11). The atypical attenuating cysts generally display the same spontaneous attenuation as the surrounding parenchyma on precontrast images (20–50 HU) and are unclassifiable using the Bosniak system. Such cysts are relatively common (approximately 1/3 of dense cysts).

Figure 17. Bosniak category III multilocular cystic mass. Postcontrast CT scan (nephrographic phase). Smooth, thick, significantly enhancing wall and septations. Histopathological examination of the lesion following resection revealed multilocular cystic renal cell carcinoma.
Despite insignificant contrast enhancement (attenuation variation \(< +10\) HU), these lesions can be very difficult to distinguish from hypovascular tumors. They can reflect dense cystic cancers that do not show detectable contrast enhancement using CT [48, 49]. Hartman et al. reported an isolated case of a cystic lesion with foci of clear cells within its wall [76], displaying no post-contrast enhancement but with a spontaneous attenuation value of \(+44\) HU (i.e. under the 50 HU threshold). This differential diagnosis challenge also includes various renal carcinomas. These can be either massively necrotic or solid and compact, hypovascularized, and of papillary or tubulopapillary architecture. With CT, following injection of contrast medium, they show only very moderate contrast enhancement (often \(< +30\) HU), sometimes during the delayed phase [77], or negative enhancement (change \(< +10\) HU) (Fig. 25). In a series reported by Couvidat et al. [78], the maximum postcontrast increase in attenuation for papillary carcinomas was under the significant threshold (between \(+10\) and \(+15\) HU) in 16.5\% of cases and was negative (\(< +10\) HU) in up to 5\% of cases. In the same series, maximum tumor enhancement, observed during the nephrographic phase for 67\% of cases (vs. 22\% in the delayed phase), was \(< +40\) HU in 82\% of cases.

Such atypical and generally small-sized solid tumors present as a homogeneous, spontaneously isodense mass, which resembles a hyperdense cyst in all aspects except for its attenuation \(< 50\) HU (same spontaneous density as the renal parenchyma). In addition, the small size of these lesions can be responsible for unreliable density measurements, making them uninterpretable on post-contrast images, and interfering with morphological assessment (homogeneity and margins). Such spontaneously isodense lesions which do not show significant contrast enhancement should be considered suspicious based on CT findings alone. This especially applies if technical conditions are suboptimal (injection of an insufficient quantity of contrast agent, prematurely acquired images, etc.).

Nearly 50\% of dense cysts are anechoic and show a typical cyst structure using ultrasound [30], and can therefore be perfectly characterized. Targeted ultrasound can therefore provide helpful information following CT assessment if the lesion is located precisely. Further investigation and unnecessary follow-up of an atypical dense cyst can be avoided by using targeted ultrasound (Fig. 26). In the special case of hyperdense cysts containing milk of calcium, the presence of a highly reflective hyperechoic deposit, generally clearly visible at the bottom of the cyst when scanning horizontally, and often combined with reverberation but without posterior acoustic shadowing (Fig. 27), is characteristic [29, 79].

In other cases (varying degrees of echogenicity using ultrasound), two main courses of action are possible to reach definitive diagnosis (excluding surgical investigation, which is generally not initially justified considering the small lesion size and low risk of tumor):

- MRI may demonstrate the cystic nature of the lesion if it displays the features of a typical "water-attenuation" benign cyst or, as is more often the case, a hemorrhagic cyst (homogeneous high signal intensity or fluid-level visible on all sequences). If it is non-enhancing following injection of contrast agent (Fig. 28), such a lesion can then be classified as a complicated Bosniak category II

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**Figure 18.** Bosniak category III multilocular cystic mass. T2-weighted MR images before (A) and after (B) injection of gadolinium chelate (nephrographic phase). Multiple thin moderately-enhanced septations combined with a thick, smooth, contrast-enhancing wall. (C) Macroscopic image of the excised tumor demonstrating cystic nephroma.
cyst. The specificity of MRI for masses showing homogeneously high signal intensity on T1-weighted images and a mass/parenchyma signal intensity ratio of > 2.5 within a well-marginated, smooth-shaped lesion was reported to be 99.9% by Davarpanah et al. [80]. If MRI evidences contrast enhancement of the whole lesion (atypical solid lesion) (Fig. 25) or a cystic lesion with a solid component (thick wall or septations, endocystic or mural nodularity), then a surgical approach is mandatory; 

- contrast-enhanced ultrasound can demonstrate, with an excellent level of sensitivity, contrast uptake in hypovascular solid tumors (papillary carcinoma) or within the solid component of a massively necrotic carcinoma [3–8]. Contrast-enhanced ultrasound is particularly effective for indeterminate lesions with a hemorrhagic component (hemorrhagic necrosis) that show high signal intensity on T1-weighted images, but inconclusive or negative contrast enhancement of the solid component from the MRI (Fig. 29). For atypical dense cysts which have been classified as indeterminate using CT, the total absence of enhancement following injection of microbubble contrast agents will lead to the diagnosis of a benign cyst (Fig. 30);

- if the findings with these modalities are inconclusive or if they are not available, ultrasound and CT follow-up every 6 months is recommended. This is done to search for confirming changes in lesion echogenicity or density (towards "water attenuation"). Although, the timeframe for such changes is very variable and unpredictable. This approach is justified only for small-sized lesions (< 3 cm).

**Indeterminate enhancement (between +10 and +20 HU)**

As previously mentioned, a renal mass is considered to be non-enhancing for increases in attenuation value < +10 HU and to display significant contrast enhancement
for increases in attenuation > +20 HU. The latter value (+20 HU) represents a threshold below which the calculation of lesion density may be affected in vivo by various artifacts (electronic noise, beam hardening). Based on these definitions, a lesion that shows a post-contrast increase in attenuation ranging from +10 HU to +20 HU and meets all the other criteria for a Bosniak category I or a hyperdense cyst, cannot be diagnosed definitively as a benign simple cyst (Bosniak category I) or a hyperdense cyst (Bosniak category II). In such cases, diagnosis calls for additional data from grey scale or contrast-enhanced ultrasound, or MRI. These complementary modalities help better characterize the fluid-content or complicated architecture of a cyst (Figs. 26 and 30), or suggest a diagnosis of hypovascular solid tumor (poorly vascularized or massively necrotic solid lesion) (Figs. 25 and 29).

Multilocular cystic masses classified as Bosniak category I or II

Multilocular lesions may reflect one of three following conditions: a cyst with multiple septations, a benign epithelial and stromal tumor of the kidney (cystic nephroma or, exceptionally, mixed epithelial and stromal tumor), or multilocular cystic cancer. However, no relevant criteria have been reported to distinguish with certainty between the two types of multilocular neoplasms in cases with thickened, enhancing wall and septations. Management of such lesions depends on their category according to the Bosniak classification system.

A specific subgroup of multilocular lesions should, however, be individualized and can benefit from a conservative, albeit prudent approach. This specific subgroup contains lesions showing many regular, thin septations that can be well visualized using ultrasound or MRI (septa are often demonstrated with more sensitivity on US and MRI than on CT) but are barely or not perceptible using CT, and that meet all the other criteria for benign cysts (Fig. 31). Such discrepant findings would cause a complex cyst to be reclassified in a higher category than it would be with CT features alone. On the basis of the number of depicted septa, it is possible to upgrade a renal cyst from category I or II to category II or IIF, respectively. Although upgrading a thin-walled cyst from category II to category IIF as a result of only the increased number of detected septa (with imperceptible wall) may affect patient management, the lesion is likely to be benign, as initially suggested by CT. Follow-up can alternatively consist of yearly ultrasound and CT or MRI investigations. It should be aimed at detecting suspicious wall/septation thickening or contrast enhancement that reflects the presence of a solid component, and therefore indicates surgical removal.

Non-enhancing Bosniak category III lesions using CT

The contrast enhancement of the thickened wall of Bosniak III lesions is the main criterion for determining the management of such Bosniak category masses and the decision for surgical resection (tumorectomy of a suspicious vascularized cystic lesion). When contrast enhancement is negative (non-enhancing wall) or inconclusive after CT, MRI can provide complementary information due to its better contrast resolution and evidence contrast uptake following injection of a gadolinium complex. These findings result in the lesion being classified as Bosniak category III, and therefore eligible for surgery. This is the case in particular for
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Figure 21. Characterization of unclassifiable or inadequately classified indeterminate cystic masses on CT before and after contrast injection. (A1) Indeterminate very small lesion or indeterminate changes in density (between +10 and +20 HU) after injection of contrast agent on CT scan for a cystic lesion described as simple anechoic cyst using ultrasound (Bosniak type I); (A2) Atypical dense cyst of intermediate attenuation described as simple anechoic cyst using ultrasound (Bosniak type I); (A3) Simple cyst classified Bosniak type I or II on CT found to contain numerous septations using ultrasound (Bosniak type IIF). (B1) Indeterminate tiny lesion or indeterminate changes in density (between +10 and +20 HU) after injection of contrast agent on CT for a cystic lesion found to be homogeneous with homogeneous water signal intensity on T2-weighted and contrast-enhanced T1-weighted MRI (Bosniak type I); (B2) Atypical dense cyst of intermediate attenuation showing a typical signal (water or hemorrhagic signal intensity) using MRI on (Bosniak type II); (B3) Simple cyst classified Bosniak category I or II on CT found to contain numerous septations using MRI (Bosniak type IIF); (B4) Thick-walled, non-enhancing cystic mass on CT displaying detectable wall contrast enhancement using MRI (Bosniak type III). CT: computed tomography; cat.: category; MRI: magnetic resonance imaging.
cystic masses with some wall calcification or a poorly vascularized solid component.

Unilocular Bosniak III cysts in a setting of acute inflammation

When a unilocular, thick-walled, vascularized, Bosniak category III lesion is diagnosed, the patient’s clinical history should be taken into account to determine the course of action. Indeed, when patient questioning or medical history suggests a possible acute inflammatory, post-inflammatory, or hemorrhagic lesion (Fig. 32), it should not initially be classified using the Bosniak system. In such circumstances, the inflammation of the wall of a benign cyst always takes the appearance of a Bosniak category III lesion. The lesion should therefore be followed-up at close intervals using CT (first follow-up after 1–2 months). Reassuring changes (gradual involution of the cyst) allow practitioner to confirm the hypothesis of a complicated cyst; whereas an ongoing suspicious appearance (Bosniak category III) or worsening (upgraded to more complex Bosniak category III or IV) should lead to further management determination, based on the Bosniak system.

Localized cystic renal disease

Localized cystic renal disease (LRCD) or unilateral renal cystic disease (URCD) is a rare condition characterized by the presence of multiple cysts in a single kidney that can be
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Figure 24. Indeterminate very small lesion in the right kidney classified as suspicious using MRI. (A) Postcontrast CT scan showing an indeterminate 5-mm lesion (arrow). (B) T2-weighted and (C) diffusion-weighted (b1300) MRI show features suggesting a solid very small tumor (arrow) that should lead to active surveillance considering its small size.
Figure 25. Small renal mass classified as indeterminate using CT due to its non-water attenuation (+20 HU) on (A) precontrast CT and despite non-significant contrast enhancement (Δ < +10 HU, measured value +7 HU) on (B) postcontrast CT. MRI showed a solid, vascularized tumor displaying a hypointense signal on T2-weighted images (C, arrow) and significant contrast enhancement on dynamic images (D: precontrast; E: postcontrast nephrographic phase). Examination of the lesion following resection revealed papillary carcinoma.
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**Figure 26.** Atypical dense cyst. Mass classified as indeterminate based on (A) precontrast and (B) postcontrast CT: the mass shows the same density as the cortex (+32 HU) and non-significant contrast enhancement ($\Delta = +16$ HU). (C) Targeted ultrasound shows anechoic typical simple cyst. (D) T2-weighted MRI shows typical water signal intensity.

**Figure 27.** Complicated cyst containing milk of calcium. Ultrasound: hyperechoic deposit with fluid level interface within the cyst (arrows).

**Key points**

MRI is recommended for the following lesions:
- cystic lesions classified Bosniak category IIF using CT;
- cystic lesions classified Bosniak category III showing no or inconclusive contrast enhancement using CT;
- mass of intermediate density (+20 to +50 HU) on precontrast CT showing no contrast enhancement using CT;
- indeterminate enhancement (+10 to +20 HU), whatever the density on precontrast CT;
- multilocular septated cystic mass as determined by ultrasound classified Bosniak category I or II using CT;
- unclassifiable very small (<10 mm) lesion using CT in a young or high-cancer-risk patient.

Scattered diffusely within the kidney or clustered together (often in a polar region) [81]. Cyst clustering in a coalescent mass differentiates this condition from clusters of common cysts. Some localized forms of LCRD can mimic multilocular...
Figure 28. MRI features of typical dense cysts (Bosniak category II) or atypical density cysts (intermediate attenuation using CT). (A) Schematic representation: T1- and T2 weighted sequences (respectively T1 and T2), T1-weighted image after injection of a gadolinium complex (T1 + Gd). (A1) Simple "water signal intensity" cyst; (A2) Homogeneous "hemorrhagic" cyst; (A3) "Hemorrhagic" cyst with fluid level (sedimented hemoglobin degradation products). Homogeneous "hemorrhagic" cyst on (B) T1- and (C) T2-weighted MR images. "Hemorrhagic" cyst with level (arrow) on (D) T1- and (E) T2-weighted MRI.
Figure 29. Pseudocystic necrotic carcinoma observed as an indeterminate mass using CT and MRI (as seen in Fig. 6). (A) Precontrast and (B) postcontrast T1-weighted MRI. The MRI features of the mass suggest the presence of hemorrhagic complications. Contrast enhancement is negative or inconclusive. (C) Contrast-enhanced ultrasound (left view) shows a peripheral, vascularized tissue component (arrows) within the necrotic tumor.
Figure 30. Atypical dense cyst. Non-enhancing renal mass with pre-contrast density between 20 HU and 50 HU (measured value: 32 HU). (A) Precontrast and (B) postcontrast CT, and (C) contrast-enhanced ultrasound. The total absence of enhancement following injection of microbubble contrast agents (C, left view) (arrow) resulted in a diagnosis of benign atypical dense cyst. Note the echogenic content of this atypical cyst that prevents its characterization using B mode ultrasound alone (right view).
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Figure 31. Multiple septated cyst that remained indeterminate using CT. (A) Postcontrast CT: Bosniak II cyst displaying a single visible thin septation. (B) Ultrasound: cyst containing multiple septations but no other signs of atypia. The lesion contains multiple septations and should be classified as Bosniak IIIF.

Figure 32. Complex thick-walled cystic lesion (similar to Bosniak III) following hemorrhagic rupture of a cyst on postcontrast CT scan. (A) Medially located cystic mass delimited by a smooth, homogenous, enhancing thickened wall. (B) Ruptured hemorrhagic cyst close to the upper pole. The diagnosis of an inflammatory cyst, suggested by the clinical history (acute hemorrhage of the renal compartment) and the perinephritis features related to blood effusion (also the cause of changes in cyst morphology), was confirmed by follow-up. Follow-up CT at 6 months (C) shows decreased wall thickness and lower cyst wall enhancement. The features reflecting inflammation of the renal compartment have also disappeared.
cystic tumor. The absence of cyst organization within a properly encapsulated mass (well-delimited and round) rather than a cluster of cysts (Fig. 33), as well as the enhancement of the renal parenchymal bands that remain isodense to the renal cortex during all phases [82], rule out the hypothesis of a multilocular neoplasm and indicate straight forward follow-up.

**Conclusion**

Benign simple kidney cysts are defined by a set of strict criteria and any cystic lesions that do not meet these criteria should be classified as 'atypical' or 'complex' and considered suspicious. For over three decades now, the Bosniak classification has been the central tool for diagnosing renal cystic masses over 1 cm in size. This classification is based on the results of a well-established CT protocol with both precontrast images and post-contrast images, and which includes the nephrographic phase. For certain lesions that are difficult to classify or indeterminate after using CT alone, a multimodal diagnostic approach combining CT, non-contrast-enhanced and contrast-enhanced ultrasound, and MRI can be advantageous. These categories are used to predict the risk of malignancy as well as standardize the management of cystic renal lesions [80–82].

**Disclosure of interest**

The authors declare that they have no competing interest.

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