Bosniak Classification of Cystic Renal Masses, Version 2019: A Pictorial Guide to Clinical Use

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Abbreviations: ISUP = International Society of Urogenital Pathology, RCC = renal cell carcinoma, ROI = region of interest

RadioGraphics 2021; 41:814–828

https://doi.org/10.1148/rg.2021200160

Content Codes: CT GU OI

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Cystic renal masses are commonly encountered in clinical practice. In 2019, the Bosniak classification of cystic renal masses, originally developed for CT, underwent a major revision to incorporate MRI and is referred to as the Bosniak Classification, version 2019. The proposed changes attempt to *(a)* define renal masses (ie, cystic tumors with less than 25% enhancing tissue) to which the classification should be applied; *(b)* emphasize specificity for diagnosis of cystic renal cancers, thereby decreasing the number of benign and indolent cystic masses that are unnecessarily treated or imaged further; *(c)* improve interobserver agreement by defining imaging features, terms, and classes of cystic renal masses; *(d)* reduce variation in reported malignancy rates for each of the Bosniak classes; *(e)* incorporate MRI and to some extent US; and *(f)* be applicable to all cystic renal masses encountered in clinical practice, including those that had been considered indeterminate with the original classification. The authors instruct how, using CT, MRI, and to some extent US, the revised classification can be applied, with representative clinical examples and images. Practical tips, pitfalls to avoid, and decision tree rules are included to help radiologists and other physicians apply the Bosniak Classification, version 2019 and better manage cystic renal masses. An online resource and mobile application are also available for clinical assistance.

An invited commentary by Siegel and Cohan is available online.

SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Discuss the changes to the Bosniak classification of cystic renal masses with the 2019 update and the rationale for those changes.
- Identify when and how to apply the updated Bosniak Classification, version 2019 and the decision process for the classification of cystic renal masses at CT, MRI, and, to some extent, US.
- Describe the imaging features and terms used in the Bosniak classification to help reduce interobserver agreement and improve the management of cystic renal masses in clinical practice.

See rsna.org/learning-center-rg.

An earlier incorrect version of this article appeared online and in print. This article was corrected on October 22, 2021.

TEACHING POINTS

- The Bosniak Classification, version 2019 defines a *cystic renal mass* as a mass that, based on subjective visual inspection, is composed of less than approximately 25% enhancing components.
- For a renal mass to be characterized as Bosniak IIF or higher, there must be enhancement. The only exception is nonenhancing masses with heterogeneously hyperintense signal on fat-suppressed T1-weighted images.
- A nodule or irregularity is measured perpendicular to the wall or septa and does not include the wall or septa. Measurements of cystic mass structures should be obtained on contrast-enhanced CT or MR images. Cystic mass structures should not be measured on T2-weighted images because debris or blood products can exaggerate the size or thickness of a structure.
- If a cystic mass meets the criteria for more than one Bosniak class, the highest class is assigned.
- Bosniak Classification, version 2019 cannot be applied to masses in patients with a hereditary renal cancer syndrome.

Introduction

The imaging-based approach to the diagnosis of cystic renal masses has recently undergone a major revision (1). The revised classification of cystic renal masses, known as Bosniak Classification, version 2019, was intended to improve the ability of radiologists and other physicians to differentiate benign from malignant cystic renal masses. Cystic renal masses are ubiquitous at imaging, and detection, characterization, and classification of cystic renal masses are a daily task of radiologists who evaluate images of the kidneys (2).

While the vast majority of cystic masses are benign, malignant causes, although far less common, do occur. The Bosniak Classification, version 2019, like the original classification system, continues to stratify cystic renal masses according to their malignant potential to help determine management. However, the revision attempts to address some of the shortcomings associated with the original classification. First, because of a historical goal of detecting kidney cancers at an early curable stage, the original Bosniak classification emphasized sensitivity for detection of renal cell carcinoma (RCC). This led in part to many unnecessary follow-up imaging examinations and surgeries for treatment of benign cystic masses, contributing to excess cost, procedural morbidity, and loss of kidney function (3). Even among Bosniak III and IV cystic masses, both historically thought to be "potentially" or "highly likely" to be malignant, benign causes are commonly found at surgery (4,5). For example, a systematic review showed that approximately half of Bosniak III masses were benign and approximately 10% of Bosniak IV masses were benign (6). Estimating the true prevalence of malignancy among Bosniak IIF cystic masses is challenging owing to the limited number that are confirmed at histopathologic analysis. In the same systematic review, only 17% of Bosniak IIF masses that were resected were malignant, and 94% (of Bosniak IIF masses that were not resected) were stable at follow-up (6).

Even in pathologically confirmed RCC with cystic changes (hereafter referred to as cystic RCC), data indicate that these malignancies are almost certainly overdiagnosed and overtreated. The estimated 10-year risk of death from a T1a (<4 cm, limited to the kidney) cystic RCC is approximately 0.2% (6). Moreover, cystic renal masses that were previously considered to be cancers are being reclassified. For example, multilocular cystic RCC, previously considered malignant, is now considered an indolent neoplasm and defined as a multilocular cystic neoplasm of low malignant potential, owing to typical benign behavior (7,8).

The understanding of the natural course of cystic RCC also has evolved. Its clinical management has shifted to recognize its typical indolent course. For example, there is a low likelihood of local recurrence or metastatic disease among cystic RCCs, particularly among those that are International Society of Urogenital Pathology (ISUP) grade 1 and 2 clear cell types (8). As a result, active surveillance rather than surgery is being used for treatment of many Bosniak III and even some Bosniak IV masses, with favorable outcomes (9,10).

In response to this experience, the Bosniak Classification, version 2019 attempts to emphasize specificity rather than sensitivity in the diagnosis of cystic RCC (1). The anticipated outcome of these changes is a greater number of cystic renal masses placed into lower Bosniak classes and a reduction in the number of cystic renal masses that are unnecessarily imaged or treated (1). Data are already emerging that show that the use of Bosniak Classification, version 2019 results in down classifying some masses compared with the use of the original Bosniak classification in histologically confirmed cystic masses imaged with MRI, while maintaining sensitivity for RCC (11), and also did not result in any systematic bias toward upgrading or downgrading of class when comparing CT and MRI in one study (12).

A second shortcoming of the original Bosniak classification relates to substantial interobserver variability among radiologists, particularly among Bosniak classes IIF–IV masses (13,14). Bosniak classification, version 2019 attempts to directly address interobserver variability by providing explicit definitions for each class and for each imaging feature used to classify each

mass. Imaging features such as thin (vs thick) walls or septa, few (vs many) septa, and nodule (vs an irregularly thickened wall or septa) have been explicitly defined. What constitutes contrast material enhancement has been redefined for both CT and MRI, and the implication of enhancement for each feature and each class is clearly explained. Preliminary studies evaluating interobserver agreement while using Bosniak Classification, version 2019 show moderate (MRI) to substantial (CT and MRI) agreement between readers. However, data are limited by a small sample size (11,12, 15)

Lack of explicit definitions for imaging terms and features contributed to a third shortcoming: widely variable reported malignancy rates for each of the Bosniak classes (4–7). A fourth shortcoming of the original classification was that MRI and US were not fully incorporated. The Bosniak Classification, version 2019 now includes MRI and to some extent US. MRI is an important clinical tool for diagnosing cystic masses (in addition to solid renal masses) and is particularly valuable for characterizing cystic masses that are indeterminate at CT and US. For example, the revised classification explicitly recommends performing MRI to further evaluate indeterminate masses at CT that *(a)* show abundant thick or nodular calcifications, *(b)* are homogeneously hyperattenuating and larger than 3 cm, or *(c)* are heterogeneous and nonenhancing (1). MRI is recommended for each of these three types of masses because enhancement can be better identified on MR images than on CT images (16,17).

The role of US in rendering a definitive diagnosis has been historically reserved for Bosniak I and to some extent Bosniak II masses. However, recent data indicate that contrast-enhanced US may be useful to diagnose other Bosniak classes (18–20), a topic that is actively being studied. Finally, the original Bosniak classification required that cystic masses be "completely characterized" with renal mass protocol CT or MRI (ie, thin-section images acquired before and after contrast material injection) and thus did not allow many cystic renal masses encountered in clinical practice to be fully classified (1,21). The Bosniak Classification, version 2019 can be applied to more cystic masses imaged at CT, MRI, and to some extent US, with an expanded number of cystic masses that can be characterized as Bosniak II masses. Therefore, many previously "incompletely characterized" renal masses can now be classified as benign Bosniak II masses (1,22–28). However, renal mass protocol CT and MRI remain a requirement for diagnosis of Bosniak III and IV masses.

With the introduction of Bosniak Classification, version 2019, there is the need to explain when and how to apply the classification in clinical practice. This can be accomplished by showing both common and challenging clinical examples that illustrate key concepts and changes. Summary tables, flow diagrams, and a suggested reporting template are provided to assist the radiologist in applying the new classification. The purpose of this article is to present an image-rich summary of the Bosniak Classification, version 2019 to enhance readers' understanding of the key concepts and changes, to help radiologists better apply the classifications, and to ultimately improve the management of cystic renal masses in clinical practice.

When to Use the Bosniak Classification, Version 2019

Before the revision, a definition of what constituted a cystic mass had not been formally defined; as a result, many authors used variable imaging criteria (29). The Bosniak Classification, version 2019 defines a cystic renal mass as a mass that, based on subjective visual inspection, is composed of less than approximately 25% enhancing components (1,9). Therefore, masses with approximately 25% or more enhancing components are considered solid and not classifiable by the Bosniak Classification, version 2019. The distinction between cystic and solid renal masses is important. Solid masses behave more aggressively and have a higher propensity for local recurrence and metastatic disease than cystic masses. Therefore, their management and prognosis differ (30,31). As a corollary, it is important not to mistake a necrotic RCC for a cystic RCC (and vice versa), as the former is aggressive and the latter is typically indolent (10,26–28) (Fig 1).

Differentiating necrosis from cystic change at imaging is important, although challenging (32). The subjective 25% enhancing component threshold was chosen, in part, to minimize the likelihood of mistaking a necrotic RCC as a cystic RCC (1). However, other imaging findings may also be useful. For example, necrosis is usually central with ill-defined borders and a thick wall, while cystic change is usually peripheral with well-defined borders and a thin wall (1,33).

Imaging Techniques for Evaluation of Cystic Renal Masses

General Imaging Technique

The original Bosniak classification of cystic masses was CT based, but it has been applied to some extent to MRI (21,34,35). US (other than for the evaluation of simple cysts) was not

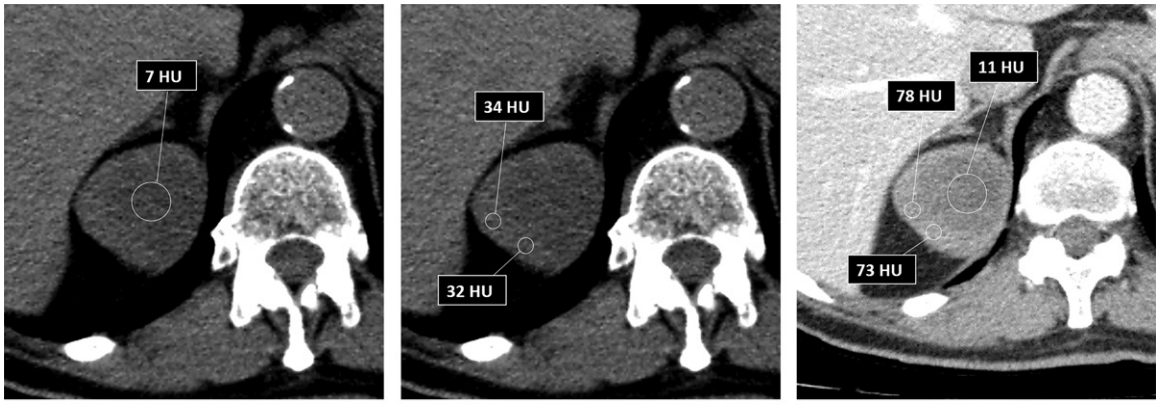


Figure 1. Example of a necrotic RCC mimicking a cystic renal mass. Necrotic papillary RCC, type 2 in a 73-year-old man. **(a)** Axial noncontrast CT image shows a 5.1-cm mass in the upper pole of the right kidney, with a central circular region of interest (ROI) measurement with low attenuation (7 HU). **(b)** Axial noncontrast CT image obtained at the same level as **a** shows that the mass is heterogeneous and, by placing multiple smaller ROIs in the peripheral region of the mass, higher-attenuation (32–34 HU) measurements were obtained. **(c)** Axial contrast-enhanced CT image obtained during the portal venous phase (obtained at the same level as **a** and **b**) shows that the peripheral region is a thick (11 mm) enhancing wall (attenuation 73–78 HU). Histopathologic analysis results confirmed that the low-attenuation region contained necrosis. This mass was thought to be a cystic mass but was found to be a solid necrotic RCC at surgery. Such masses in general are more aggressive than cystic RCCs. Recognizing heterogeneity and placing multiple appropriately sized ROIs help identify solid tissue.

considered valuable in the original classification owing to a tendency to overestimate the Bosniak class and to the inability of conventional gray-scale or color Doppler US to reliably help in the evaluation for the presence of blood flow (36). Renal mass protocol CT must include noncontrast images and enhanced images (obtained during the nephrographic phase, ~100–120 seconds after injection) with the same acquisition parameters and about 3-mm reconstructed sections to enable accurate comparison of attenuation values (37–39). The corticomedullary phase (~30–40 seconds after injection) and urographic phase (~5 minutes after injection) are also important phases in a renal mass protocol, which may assist in detection and characterization of renal masses and relevant anatomy (37–39). However, many renal masses visualized at CT are imaged in the portal venous phase (eg, at 70–75 seconds) during examinations performed for unrelated reasons.

Renal mass protocol MRI includes obtaining T1- and T2-weighted images, dual-echo T1-weighted chemical shift images, and fat-suppressed T1-weighted images obtained dynamically before and after intravenous gadolinium-based contrast material injection (40–42). Renal US includes scanning in the supine or decubitus position, typically with a curvilinear array transducer (1–5 MHz). Prone imaging with higher-frequency linear transducers, a technique commonly used in the pediatric population, is generally impractical in adults owing to larger patient size.

Bosniak Classification, Version 2019 Definition and Significance of Enhancement

Enhancement signifies the presence of blood flow and remains a crucial element for classification of cystic renal masses. The Bosniak Classification, version 2019 defines *enhancement* as present when there is an unequivocal increase in attenuation (CT) or signal intensity (MRI) after intravenous contrast material administration that is perceived visually or when there is a quantitative change that fulfills one of the following criteria: *(a)* a 20 HU or greater rise in attenuation within the mass at comparison of CT images obtained before and after intravenous iodinated contrast material is administered; or *(b)* a 15% or greater signal intensity increase at MRI on gadolinium-enhanced T1-weighted images compared with that on precontrast (obtained before the administration of contrast material) images when both images are obtained with identical acquisition parameters (1,43,44). If the feature being evaluated is too small to be measured accurately and is not visually enhancing, it is considered nonenhancing (1).

Application of color or power Doppler US may depict blood flow within a renal mass at US. Although the positive predictive value of unequivocal detection of blood flow within the mass with these techniques is high for neoplasm, color and power Doppler US are insensitive for blood flow compared with contrast-enhanced CT or MRI (45). Contrast-enhanced US increases the sensitivity of US in the detection of blood flow

and has shown promise in renal mass imaging. Its potential value in Bosniak Classification, version 2019 is being explored for possible incorporation into any future revisions of the Bosniak classification (46). However, at present, data remain limited compared with those for CT and MRI.

It is important to recognize that some RCCs (eg, papillary RCC) may not enhance by using an attenuation change threshold of 20 HU at CT, typically showing indeterminate range enhancement (10–20 HU) and less frequently no enhancement (<10 HU) (16,47). Subtraction images at MRI, which coregister precontrast and postcontrast (obtained after the administration of contrast material) gadolinium-enhanced images, are helpful in the detection (or exclusion) of enhancement (36,37), particularly in the evaluation of masses that are intrinsically T1 hyperintense. Misregistration artifacts can confound interpretation of subtraction images and are important to recognize.

Quantitative determination of enhancement for both CT and MRI should be as standardized as possible. Region of interest (ROI) size, location, and number are particularly important when evaluating masses at CT because obtaining subtraction images is not typically feasible (48). When quantitatively assessing a homogeneous renal mass at CT for the presence of enhancement, the ROI should encompass approximately two-thirds of the mass (on both noncontrast and enhanced images), avoiding the edges of the mass to prevent spurious measurements, which average imaging voxels containing other structures (47). When assessing for enhancement in a heterogeneous renal mass, multiple ROIs should be placed, typically starting with the highest attenuating portions on the enhanced images (as these are the portions most likely to be enhancing) and then comparing the resulting attenuation value to the attenuation value obtained with an ROI placed by using the same size and location on the noncontrast image. The ROI should be large enough to be representative but should include a homogeneous sample of tissues, so as not to include nonenhancing portions (Fig 1).

The size, number, and location of ROIs are also important at nonenhanced CT alone, particularly when encountering a low-attenuation mass that looks like a cyst. A single ROI that is too small or placed in an incorrect location may fail in helping to detect a solid portion of a cystic RCC (44). A single ROI that is too large may fail in helping to detect portions that measure higher than 20 HU in a cystic RCC because of volume averaging cystic and solid components (49). If the mass is homogeneous at noncontrast CT, a single ROI encompassing the majority of the mass and depicting an attenuation between −9 and 20 HU can be used to diagnose a Bosniak classification, version 2019 class II cyst. A minority of RCCs, most commonly the clear cell type, can be depicted as low-attenuation masses at noncontrast CT (50). Such masses typically appear heterogeneous (50) but rarely can appear homogeneous on the basis of visual inspection alone (Fig 1). Therefore, to be sure that such cancers are not misdiagnosed as benign cysts, subjectively evaluating cystic masses with a smaller window width and placing multiple small ROIs throughout the mass help ensure that a region measuring 20 HU or greater is not overlooked (49,50).

The meaning of enhancement with respect to classifying renal masses was changed in the Bosniak classification, version 2019 (1). As opposed to the original classification, enhancement can now be a feature of both Bosniak I and II masses. It is recognized that the thin wall of a Bosniak I cyst and the wall and thin septa of a Bosniak II cyst may enhance. On the other hand, for a renal mass to be characterized as Bosniak IIF or higher, there must be enhancement. The only exception is nonenhancing masses with heterogeneously hyperintense signal on fat-suppressed T1-weighted images (1).

A *septum* is defined as a linear or curvilinear structure that connects two surfaces. The number of septa is quantified in the Bosniak Classification, version 2019. The term *few* is defined as one to three septa, and *many* is defined as four or more septa. Septal thickness is also defined: *thin* is defined as less than or equal to 2 mm, *minimally thickened* as 3 mm, and *thick* as greater than or equal to 4 mm. *Wall* or *septal irregularity* is defined as an obtusely margined enhancing convex protrusion less than or equal to 3 mm. A *nodule* is defined as an enhancing convex protrusion that can be any size if it has acute margins with the adjoining wall or septa or is at least greater than or equal to 4 mm if it has obtuse margins. A nodule or irregularity is measured perpendicular to the wall or septa and does not include the wall or septa. Measurements of cystic mass structures should be obtained on contrast-enhanced CT or MR images. They should not be measured on T2-weighted images because debris or blood products can exaggerate the size or thickness of a structure.

Applying the Bosniak Classification of Cystic Renal Masses, Version 2019

A summary of the Bosniak version 2019 classification of cystic renal masses is provided in Table 1 (1) and in flow diagrams for CT and MRI (Figs 2, 3). A suggested radiologist reporting template

Table 1: Update to Bosniak Classification of Cystic Renal Masses, Version 2019

Class	CT: Proposed Bosniak Classification, Version 2019*	MRI: Proposed Bosniak Classification, Version 2019*
I	Well-defined, *thin (≤2 mm)* smooth wall; homogeneous simple fluid *(−9 to 20 HU)*; no septa or calcifications; *the wall may enhance*	Well-defined, *thin (≤2 mm)* smooth wall; homogeneous simple fluid *(signal intensity similar to CSF)*; no septa or calcifications; *the wall may enhance*
II	Six types, *all well-defined with thin (≤2 mm) smooth walls:* 1. Cystic masses with thin *(≤2 mm)* and few *(one to three)* septa; septa and wall *may* enhance; may have *calcification of any type*† 2. *Homogeneous hyperattenuating (≥70 HU) masses at noncontrast CT* 3. Homogeneous nonenhancing masses >20 HU at renal mass protocol CT, may have *calcification of any type*† 4. *Homogeneous masses −9 to 20 HU at noncontrast CT* 5. *Homogeneous masses 21 to 30 HU at portal venous phase CT* 6. *Homogeneous low-attenuation masses that are too small to characterize*	Three types, *all well-defined with thin (≤2 mm) smooth walls:* 1. Cystic masses with thin *(≤2 mm)* and few *(one to three) enhancing septa; any nonenhancing septa;* may have *calcification of any type*† 2. *Homogeneous masses markedly hyperintense at T2-weighted imaging (similar to CSF) at noncontrast MRI* 3. *Homogeneous masses markedly hyperintense on T1-weighted imaging (approximately ×2.5 normal parenchymal signal intensity) at noncontrast MRI*
IIF	Cystic masses with a smooth minimally thickened *(3 mm)* enhancing wall, or smooth minimal thickening *(3 mm)* of one or more enhancing septa, or *many (≥4)* smooth thin *(≤2 mm) enhancing septa*	Two types: 1. Cystic masses with a smooth minimally thickened *(3 mm)* enhancing wall, or smooth minimal thickening *(3 mm)* of one or more enhancing septa, or *many (≥4)* smooth thin *(≤2 mm) enhancing septa* 2. *Cystic masses that are heterogeneously hyperintense at noncontrast fat saturated T1-weighted imaging*
III	One or more enhancing thick *(≥4 mm width)* or enhancing irregular *(displaying ≤3 mm obtusely margined convex protrusion[s])* walls or septa	One or more enhancing thick *(≥4 mm width)* or enhancing irregular *(displaying ≤3 mm obtusely margined convex protrusion[s])* walls or septa
IV	One or more *enhancing nodule(s) (≥4 mm convex protrusion with obtuse margins, or a convex protrusion of any size that has acute margins)*	*One or more enhancing nodule(s) (≥4 mm convex protrusion with obtuse margins, or a convex protrusion of any size that has acute margins)*

Source.—Adapted and reprinted, with permission, from reference 1.

Note.—Italicized elements emphasize changes from the previous Bosniak classification. CSF = cerebrospinal fluid.

*The Bosniak classification is intended for cystic renal masses after infectious, inflammatory, or vascular etiologies, and necrotic solid masses are excluded. If a cystic mass has features described in more than one Bosniak class, the highest Bosniak class is assigned. In rare cases, a mass may have an unusual combination of features (undefined, not fitting a specific Bosniak class) that may warrant inclusion in Bosniak IIF. Other than for the diagnosis of Bosniak I simple cysts, the role of US with or without contrast material in assigning a Bosniak class is uncertain.

†Renal masses that at CT have abundant thick or nodular calcifications; are hyperattenuating, homogeneous, nonenhancing, and larger than 3 cm; or are heterogeneous (including but not limited to many [four or more] nonenhancing septa or 3-mm or larger nonenhancing septa or wall) may be best visualized at MRI before assigning a Bosniak class to determine if there are occult enhancing elements that might affect classification.

is presented in Table 2. A website *(https://bosniak-calculator.herokuapp.com)* and mobile application (Bosniak Calculator; Deepa Sajani Jeyaraj) are now available to aid users when assigning classes by using the Bosniak classification of cystic Thank masses, version 2019. In the remaining sections, we review, with clinical examples, the various imaging features, terms, and definitions as they apply to each Bosniak class. If a cystic mass meets criteria for more than one Bosniak class, the highest class is assigned.

Bosniak Classification of Cystic Renal Masses, Version 2019: Class I

Bosniak Classification, version 2019 class I cystic masses are benign simple cysts, with no risk of malignancy (1). The term *cyst* can be used to describe class 1 cystic masses.

Bosniak I Masses at US

At US (51), Bosniak I cysts are anechoic, have a thin (≤2 mm) smooth wall, and have posterior acoustic enhancement (45, 52).

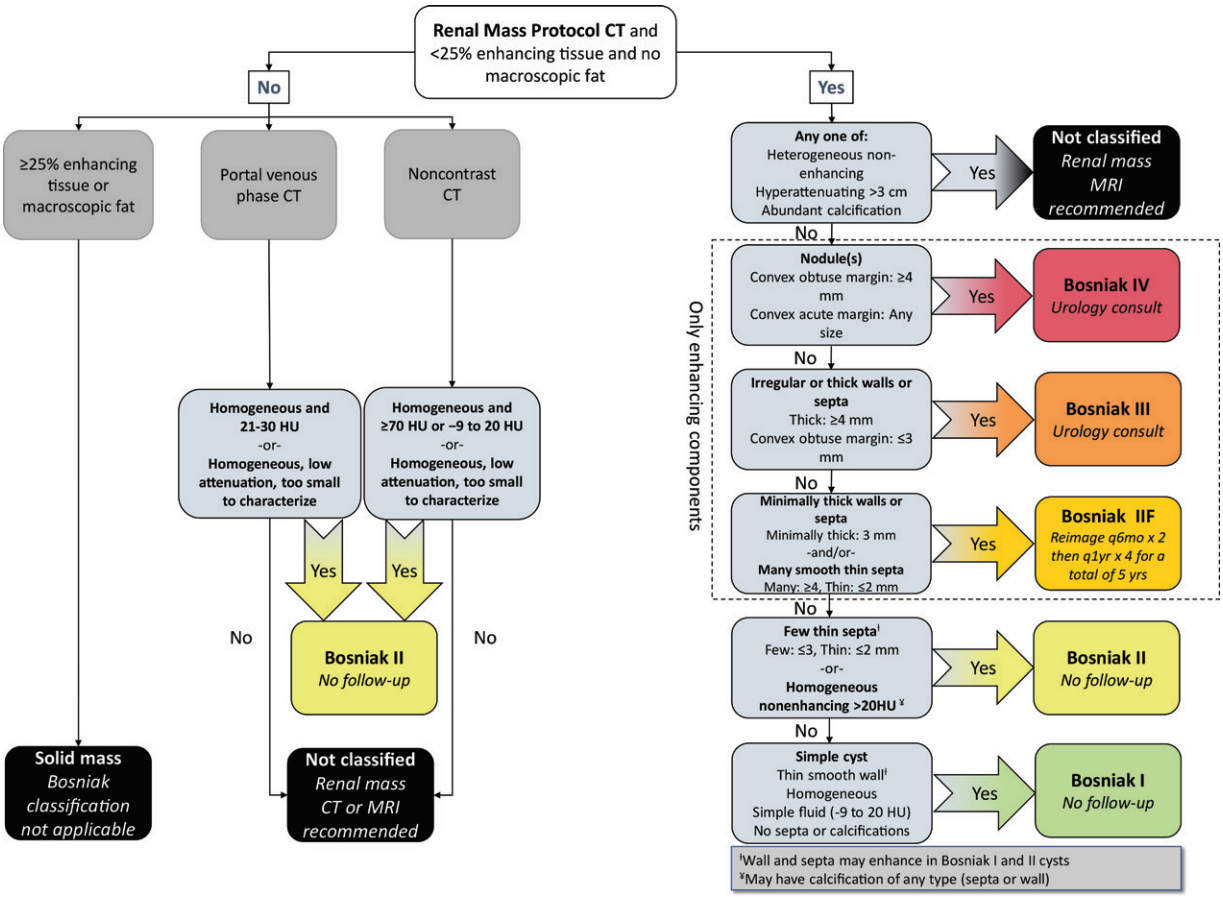


Figure 2. Flow diagram shows how to apply the Bosniak classification of cystic masses, version 2019 at CT. *q1yr* = every year thereafter, *q6mo* = every 6 months.

Bosniak I Masses at CT

At CT, Bosniak I cysts are well defined, with a thin (≤2 mm) smooth wall, homogeneous simple fluid (−9 to 20 HU), and no septa or calcifications (Table 1). The wall may enhance (Fig 4).

Bosniak I Masses at MRI

At MRI, Bosniak I cysts are well defined, with a thin (≤2 mm) smooth wall, homogeneous simple fluid (signal intensity similar to that of cerebrospinal fluid (CSF), and no septa or calcifications (Table 1). The wall may enhance.

Bosniak Classification of Cystic Renal Masses, Version 2019: Class II

Bosniak Classification, version 2019 has expanded the number of renal masses that can be characterized as Bosniak class II (reliably benign) (Table 1) (1). For Bosniak class II cystic masses that are proven to represent benign cysts, the term *cyst* can be used. However, for all other Bosniak class II or higher masses, the term *cystic mass* should be used. These masses are common in clinical practice. Although malignances have rarely been reported in masses with Bosniak II features, the proportion of malignancy among all Bosniak II masses is close to zero (6,53). Therefore, evaluating these masses further is not practical. The exception is in patients with hereditary renal cancer syndromes, in which a greater proportion of Bosniak class II cystic masses are malignant (54). Bosniak Classification, version 2019 cannot be applied to masses in patients with a hereditary renal cancer syndrome.

Bosniak II Masses at CT

At CT, there are six types of Bosniak II masses, all of which are well defined, with thin (≤2 mm) smooth walls. The first type includes cystic masses with thin (≤2 mm) and few (one to three) septa. The septa may enhance and may have calcification of any type (Fig 5). However, masses with abundant, thick, or nodular calcification can obscure visualization and characterization of enhancing components. Therefore, these may require evaluation at MRI before class assignment (Fig 6). The second type of Bosniak II mass includes homogeneous hyperattenuating (≥70 HU) masses at noncontrast CT (Fig 7). Inclusion of this mass type is based on the results of studies that show few to no cases of RCC in homogeneously hyperattenuating masses 70 HU

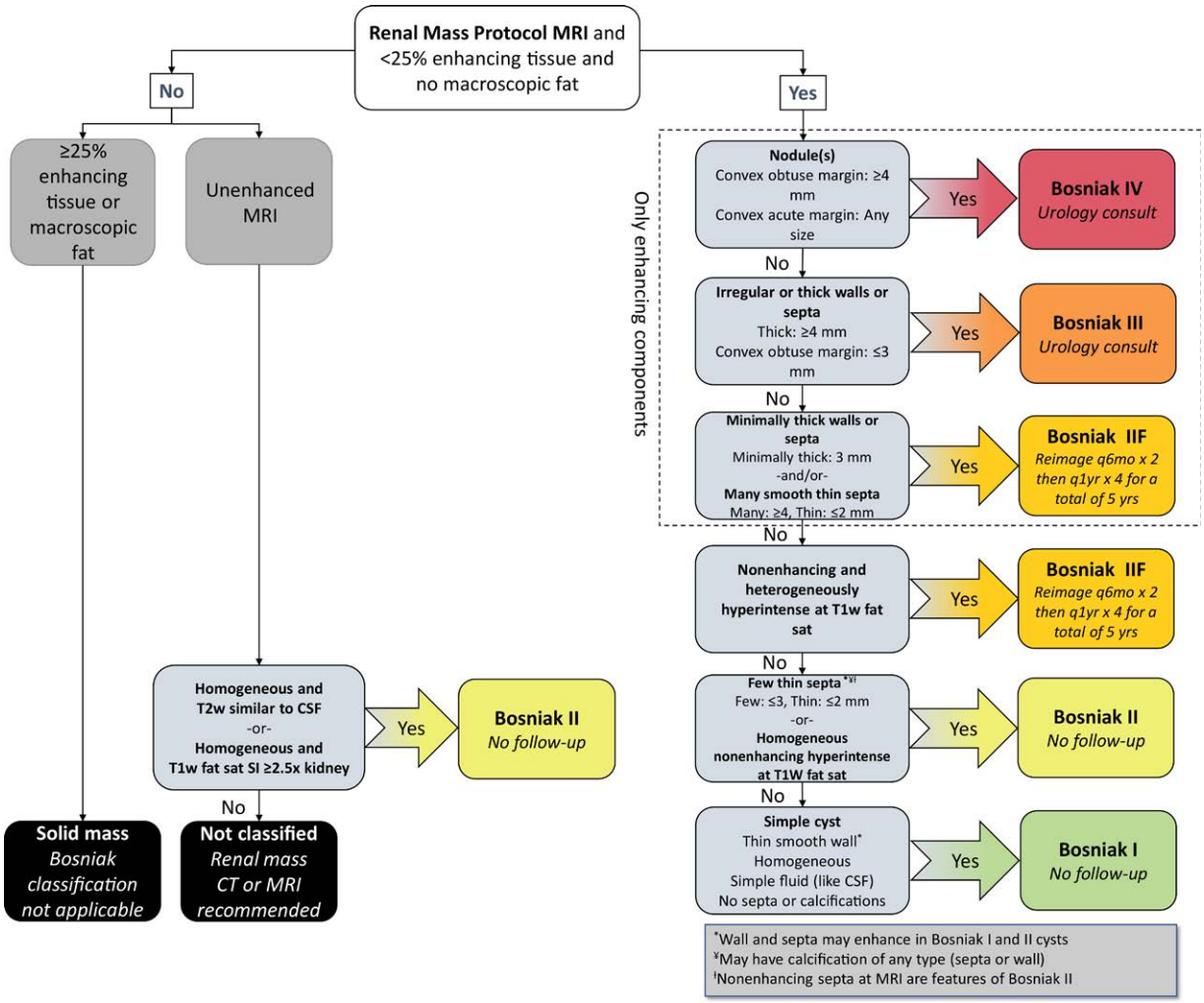


Figure 3. Flow diagram shows how to apply the Bosniak classification of cystic masses, version 2019 at MRI. *CSF* = cerebrospinal fluid, *fat sat* = fat saturated, *q1yr* = every year thereafter, *q6mo* = every 6 months, *SI* = signal intensity, *T1w* = T1=weighted, *T2w* = T2-weighted.

Table 2: Structured Reporting Template for Bosniak Classification, Version 2019 at CT or MRI

Findings:	
[Right/left] cystic renal mass	
Location: [anterior/posterior] [upper pole/interpolar/lower pole]	
Size: ( ) cm	
Bosniak Class: [ ]	
Impression:	
(Size) cm [Bosniak class] cystic renal mass in the [right/left] kidney.	
Recommendation:	
I	Benign simple renal cyst requiring no follow-up.
II	Likely a benign renal mass requiring no follow-up.
IIF	The large majority of Bosniak IIF masses are benign. When malignant, nearly all are indolent. Generally, Bosniak IIF masses are followed by imaging at 6 months and 12 months, then annually for a total of 5 years to assess for morphologic change.
III	Bosniak III masses have an intermediate probability of being malignant. If not already obtained, consider seeking urology consultation.
IV	The largest majority of Bosniak IV masses are malignant. If not already obtained, consider seeking urology consultation.

Source.—Reference 1.
Note.—The gray rows are mandatory reporting headings. Items in round brackets (size) are areas intended for the radiologist to provide the necessary information. Items in square brackets are intended to be pick-list choices when used with reporting software.

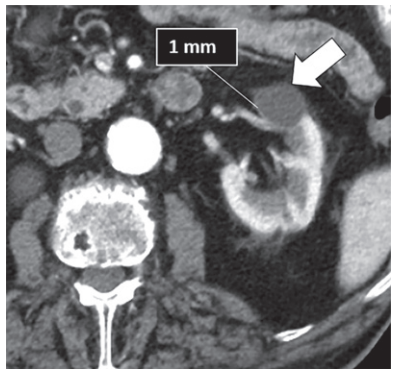
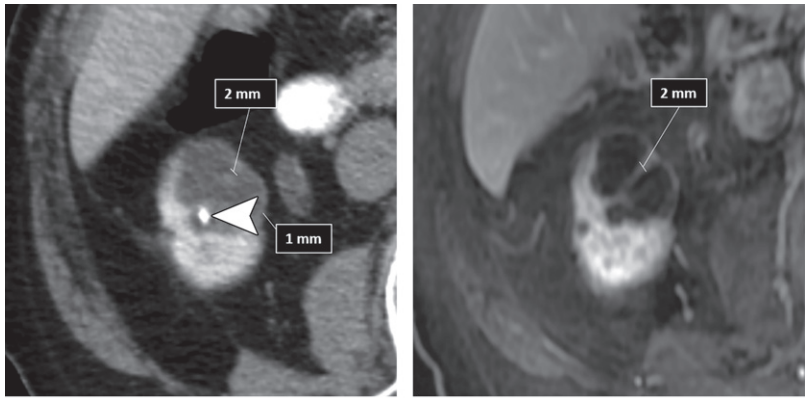
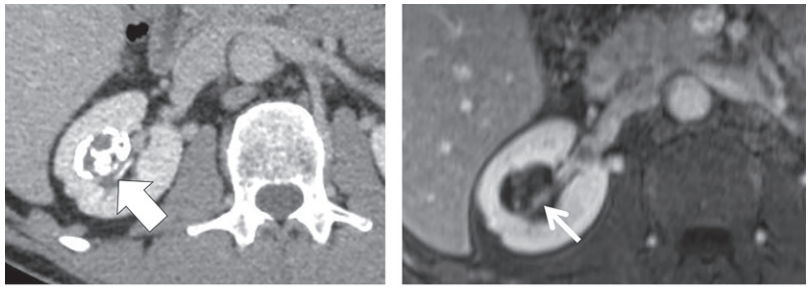


Figure 4. Bosniak Classification, version 2019 class I cyst. Left renal cystic mass in a 65-year-old man. Axial contrast-enhanced CT image obtained during the portal venous phase shows a left-sided 2.7-cm well-defined homogeneous low-attenuation (2 HU) mass (arrow), with a smooth thin (1 mm) enhancing wall and no septa or calcifications. Wall enhancement is permissible in Bosniak Classification, version 2019 class I cysts when it is smooth and thin (≤2 mm).



a. **b.**

Figure 5. Bosniak Classification, version 2019 class II mass. Right renal cystic mass in a 45-year-old woman. **(a)** Axial contrast-enhanced CT image obtained during the nephrographic phase shows a 3.4-cm cystic renal mass, with an enhancing smooth thin (1 mm) wall, two thin (2 mm) septa, and a nodular calcification (arrowhead). **(b)** Axial T1-weighted fat-suppressed MR image obtained during the nephrographic phase shows an enhancing smooth thin wall and two thin (2 mm) enhancing septa. The mass showed no change at 5-year follow-up. A cystic mass with thin (≤2 mm) and few (one to three) septa and that may have calcification of any type is classified as a Bosniak II mass.



a. **b.**

Figure 6. Renal mass with abundant calcification requiring MRI for full classification. Calcified right renal mass in a 56-year-old man. **(a)** Axial contrast-enhanced CT image obtained during the nephrographic phase shows a 2.6-cm renal mass near the hilum of the right kidney, with abundant calcification (arrow). **(b)** Axial T1-weighted fat-suppressed subtraction MR image obtained during the nephrographic phase shows two enhancing septa. The posterior septum is minimally thick (3 mm) and irregular (arrow), rendering the mass Bosniak Classification, version 2019 class III. There was no change at 2-year follow-up. Because calcifications can obscure enhancing structures, MRI is needed to help classify masses with abundant calcification. Wall or septal irregularity, defined as less than or equal to 3-mm focal or diffuse enhancing convex protrusion(s) that have obtuse margins with the underlying wall or septa, are features of a Bosniak III mass.

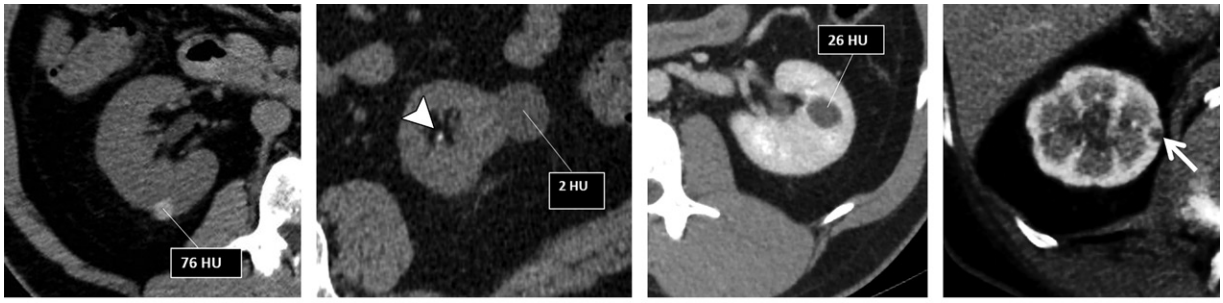


Figure 7. Bosniak Classification, version 2019 class II mass in four patients. **(a)** Incidental hyperattenuating renal mass in a 43-year-old man. Axial noncontrast CT image shows a well-defined 13-mm homogeneously hyperattenuating mass (76 HU) in the upper pole of the left kidney, with smooth walls. Masses on nonenhanced CT images that are homogeneous and measure 70 HU or higher are Bosniak Classification, version 2019 class II masses and are typically proteinaceous or hemorrhagic cysts. **(b)** Incidental simple cyst-appearing renal mass in a 22-year-old man. Axial noncontrast CT image shows a left-sided 3.2-cm homogeneous hypoattenuating (2 HU) mass. Masses with smooth thin walls and that are homogeneously hypoattenuating (−9 to 20 HU) are Bosniak Classification, version 2019 class II masses and are almost certainly benign cysts. These differ from Bosniak class I simple cysts because they are being characterized on the basis of incomplete information (nonenhanced CT only), without dedicate−d renal mass protocol CT. Note the incidental 2-mm calyceal calculus (arrowhead). **(c)** Incidental hypoattenuating renal mass in a 34-year-old woman. Axial contrast-enhanced CT image obtained during the portal venous phase shows a left-sided well-defined homogeneous 14-mm mass (26 HU) with smooth walls. Masses that are homogeneous and measure 21–30 HU at portal venous phase contrast-enhanced CT are Bosniak Classification, version 2019 II cystic masses and are almost certainly benign cysts. **(d)** Incidental renal mass that is too small to characterize in a 55-year-old man. Axial contrast-enhanced CT image obtained during the corticomedullary phase shows a left-sided homogeneous low-attenuation 6-mm mass (arrow) that is too small to characterize. Masses with these features are Bosniak Classification, version 2019 class II masses and are almost certainly cysts or benign neoplasms.

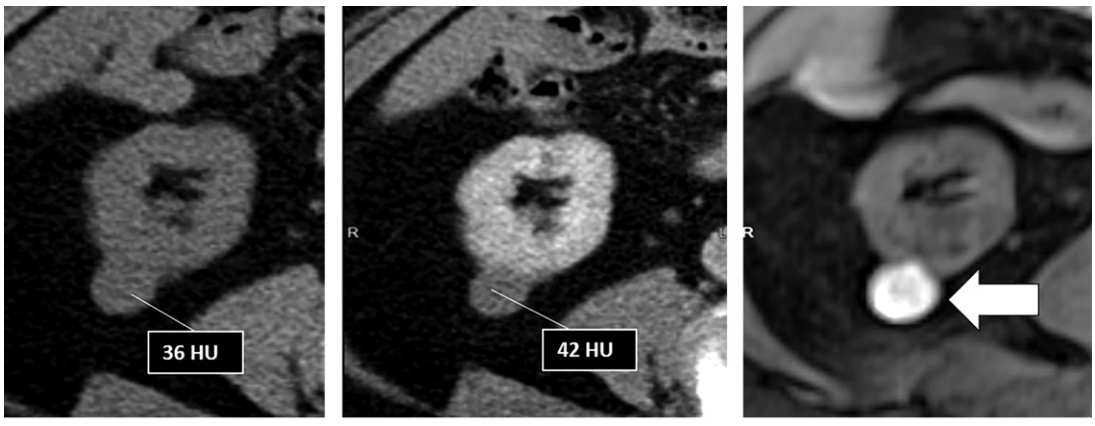
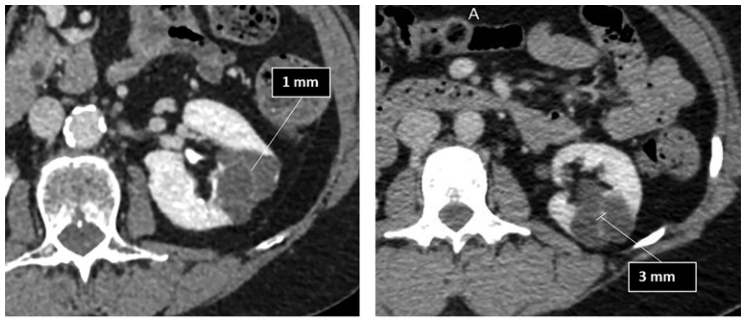


Figure 8. Bosniak Classification, version 2019 class II cystic mass. Right renal mass in a 39-year-old woman. **(a)** Axial noncontrast CT image shows a right-sided well-defined 2.1-cm mass measuring 36 HU. **(b)** Axial contrast-enhanced CT image obtained during the nephrographic phase shows an attenuation of 42 HU. Therefore, the mass is not enhancing (ΔHU < 10 HU). **(c)** Axial noncontrast T1-weighted fat-suppressed MR image obtained 2 years later shows the same cystic renal mass (arrow) with homogeneous marked hyperintensity. Masses that are homogeneous, hyperattenuating (>20 HU), and nonenhancing at renal mass protocol CT or that are homogeneous and T1 hyperintense (signal intensity > 2.5 × the adjacent normal renal cortical parenchyma) are likely proteinaceous or hemorrhagic cysts and are classified as Bosniak Classification, version 2019 class II.

or greater (2,23,55,56). One of the first studies to describe this imaging finding suggested that virtually all homogeneously hyperattenuating (≥70 HU) masses could be considered reliably benign, regardless of size (23). However, masses with these features are rarely larger than 3 cm. Therefore, homogeneous hyperattenuating (≥70 HU) masses larger than 3 cm may require MRI before class assignment. The third type of Bosniak II mass is nonenhancing, homogeneous, and greater than 20 HU at noncontrast CT (Fig 8). The absence of enhancement is defined as a less than 10 HU change in attenuation when comparing noncontrast CT images to nephrographic phase CT images (16). Any heterogenous nonenhancing mass requires assessment with MRI before class assignment (1).

The fourth type of Bosniak II mass is homogeneous and −9 to 20 HU at noncontrast CT (Fig 7). This type of mass differs from a simple cyst in a Bosniak class I because evaluation is based on incomplete information (ie, noncontrast CT



a. **b.**

Figure 9. Bosniak Classification, version 2019 class IIF mass in two patients. **(a)** Axial contrast-enhanced CT image obtained during the nephrographic phase in a 43-year-old man shows a left-sided 3.3-cm cystic mass with many (≥4) smooth thin (≤2 mm) enhancing septa. No change 7 years later prompted a final diagnosis of a benign cyst. **(b)** Axial contrast-enhanced CT image obtained during the nephrographic phase in a 47-year-old woman shows a left-sided 3.9-cm cystic mass, with one smooth minimally thickened (3 mm) enhancing septum. No morphologic change 5 years later prompted a final diagnosis of a benign cyst. Bosniak IIF cystic masses are those with a smooth minimally thickened (3 mm) enhancing wall, a smooth minimal thickening (3 mm) of one or more enhancing septa, or many (≥4 mm) smooth thin (≤2 mm) enhancing septa.

only) and not dedicated renal mass protocol CT. In a study by O'Connor et al (24) evaluating simple cyst-appearing masses at noncontrast CT in over 2500 patients, no patients developed cancer within or at the site of the simple cyst–appearing renal mass. It is important to stress that such masses must be homogeneous. Heterogeneous masses with −9 to 20 HU could be RCC (Fig 1).

The fifth type of Bosniak II mass is homogeneous, with 21–30 HU at portal venous phase CT (Fig 7). Multiple studies have shown that these masses are most likely benign and are probably proteinaceous cysts or simple cysts affected by pseudoenhancement (the artifactual increase in attenuation of a cyst by >10 HU comparing noncontrast to contrast-enhanced images related primarily to beam hardening effects from iodinated contrast material) (25,57–59). Investigators have evaluated accepting a 40 HU upper threshold to diagnose benign cysts at portal venous phase CT (25,58,59), but more data are needed.

The sixth type of Bosniak II mass is homogeneous, has low attenuation, and is too small to characterize (Fig 5). The phrase "too small to characterize" refers mainly to masses that are imaged at CT, with imaging data reconstructed with a section thickness that is less than twice the cross-sectional size of a mass (eg, an 8-mm mass on a CT reconstructed image with 5-mm sections). However, pseudoenhancement may render larger masses (eg, endophytic and <15 mm) also too small to characterize at CT. With the advent of multidetector CT, the traditional definition of *masses that are too small to characterize* has been challenged (47).

Bosniak II Masses at MRI

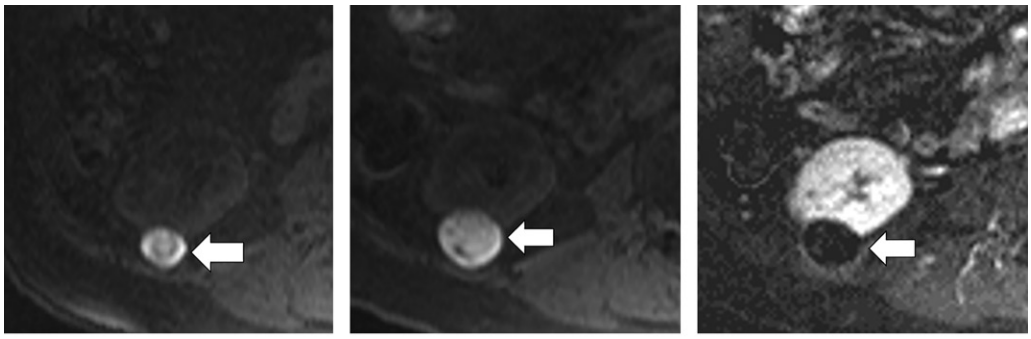
At MRI, there are three types of Bosniak II masses, all of which are well defined, with thin (≤2 mm) smooth walls. The first type includes masses with thin (≤2 mm) and few (one to three) septa (Fig 5). The septa may enhance and may have calcification of any type. Calcification is less well depicted at MRI than at CT. This is advantageous in situations in which there is abundant calcification at CT. The second type of Bosniak II mass is homogeneous and markedly hyperintense at T2-weighted imaging (ie, similar to that of cerebrospinal fluid) at noncontrast MRI. The third type of Bosniak II mass is homogeneous and markedly hyperintense at unenhanced fat-saturated T1-weighted imaging (ie, signal intensity ≥2.5 times more intense than the adjacent renal cortical parenchyma) (Fig 8). This third type of Bosniak II mass is usually a benign hemorrhagic or proteinaceous cyst (22,28,60).

Bosniak Classification of Cystic Renal Masses Version 2019: Class IIF

Bosniak Classification, version 2019 class IIF cystic masses are likely benign but warrant follow-up (1). For a feature to be considered part of a Bosniak IIF mass, it must enhance, with the only exception occurring at MRI in nonenhancing masses that demonstrate heterogeneously increased signal intensity at fat-suppressed T1-weighted imaging.

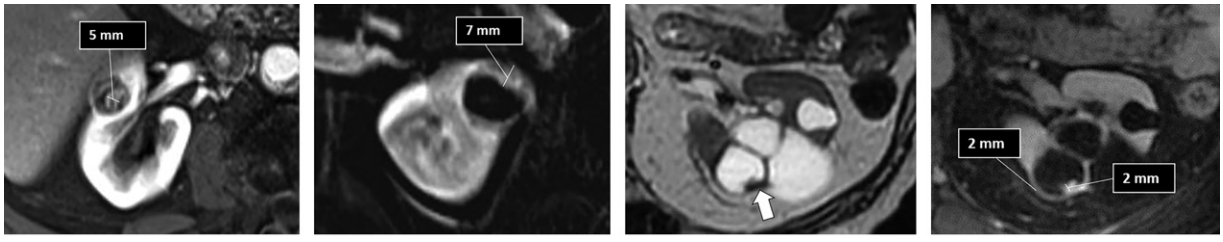
Bosniak IIF Masses at CT

At CT, Bosniak IIF masses contain either a smooth minimally thickened (3 mm) enhancing wall, one or more smooth minimally thickened (3 mm) enhancing septa, or many (≥4) smooth thin (≤2 mm) enhancing septa (Fig 9).



a. b. c.

Figure 10. Example of Bosniak Classification, version 2019 class IIF mass in a 46-year-old man with a right renal mass that was a papillary RCC, type 1 at partial nephrectomy. **(a)** Axial noncontrast T1-weighted fat-suppressed MR image shows a 1.3-cm mass (arrow) in the interpolar region of the right kidney, which is heterogeneously hyperintense. The subtraction images (not shown) were equivocal for enhancement owing to motion artifact. **(b)** Axial noncontrast T1-weighted fat-suppressed MR image obtained 17 months later shows interval growth of the mass (arrow) to 2.5 cm. **(c)** Axial T1-weighted fat-suppressed subtraction MR image obtained during the nephrographic phase shows no internal enhancement (arrow). Cystic masses that are heterogeneously hyperintense at noncontrast fat-suppressed T1-weighted imaging and nonenhancing are classified as Bosniak IIF masses.



a. b. c. d.

Figure 11. Bosniak Classification, version 2019 class III mass in three patients. **(a)** Right renal cystic mass that was a cystic ISUP grade 2 clear cell RCC at partial nephrectomy in a 73-year-old woman. Axial T1-weighted fat-suppressed MR image obtained during the portal venous phase shows a right-sided 2.1-cm cystic renal mass, with enhancing thick (5 mm) septa. **(b)** Left renal cystic mass that was an ISUP grade 2 cystic clear cell RCC at partial nephrectomy in a 62-year-old woman. Axial T1-weighted fat-suppressed MR image obtained during the portal venous phase shows a right-sided 2.9-cm cystic renal mass with an enhancing thick (7 mm) wall. **(c, d)** Left cystic renal mass that was an ISUP grade 2 cystic clear cell RCC at partial nephrectomy in a 64-year-old woman. Axial T2-weighted MR image **(c)** shows a 5.8-cm cyst with an irregular wall (arrow). Axial T1-weighted fat-suppressed MR image obtained during the nephrographic phase **(d)** shows an enhancing irregularly thickened wall (defined as an obtusely margined convex protrusion ≤3 mm). Bosniak III cystic masses show one or more enhancing thick (≥4 mm width) or enhancing irregular thickened (displaying ≤3 mm obtusely margined convex protrusion[s]) walls or septa.

Bosniak IIF Masses at MRI

At MRI, Bosniak IIF masses contain a smooth minimally thickened (3 mm) enhancing wall or one or more smooth minimally thickened (3 mm) enhancing septa, or many (≥4) smooth thin (≤2 mm) enhancing septa. An additional type of Bosniak IIF mass is nonenhancing and heterogeneously hyperintense at noncontrast fat-suppressed T1-weighted imaging (Fig 10). This type of mass is important because some RCCs (typically papillary RCC) are hemorrhagic and may show little to no enhancement (61–63). A heterogeneous nonenhancing T1-weighted hyperintense renal mass is classified as Bosniak IIF.

Bosniak Classification of Cystic Renal Masses Version 2019: Class III

At CT and MRI, a Bosniak III mass has thick (≥4 mm) or irregular (≤3 mm obtusely margined convex protrusion[s]) wall or septa (Figs 11, 12). For a feature to be considered part of a Bosniak III mass, it must enhance. Thick enhancing or irregularly enhancing walls or septa are features of Bosniak III cystic masses.

Bosniak Classification of Cystic Renal Masses Version 2019: Class IV

At CT and MRI, a Bosniak IV mass has one or more enhancing nodule(s). A *nodule* is defined as a focal enhancing convex protrusion that can be any size if it has acute margins with the adjoining wall or septa but must be greater than or equal to 4 mm if it has obtuse margins with the adjoining wall or septa (Fig 13). An enhancing convex protrusion with obtuse margins that is less than or equal 3 mm is an irregularity, not a nodule, and is a feature of a Bosniak III mass. In order for a structure to be considered a nodule, it must enhance.

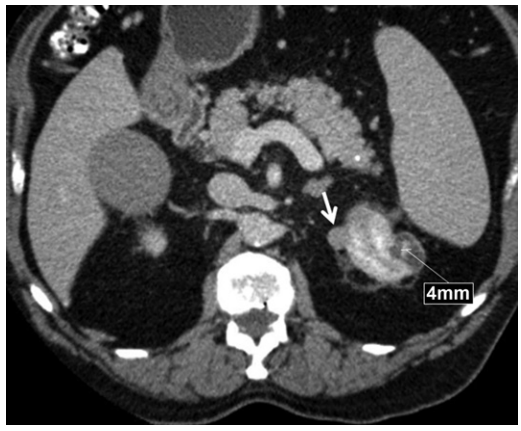


Figure 12. Bosniak Classification, version 2019 class III mass. Left renal cystic mass that was a mixed epithelial and stromal tumor at partial nephrectomy in a 63-year-old woman. Axial contrast-enhanced CT image obtained during the nephrographic phase shows a left-sided 2.4-cm cystic renal mass, with enhancing thick (4 mm) septa. The homogeneous hyperattenuating nodule in the medial anterior left kidney (arrow) was not enhancing compared with that on the noncontrast CT (not shown) and was consistent with a hemorrhagic or proteinaceous cyst (Bosniak Classification, version 2019 class II cystic mass).

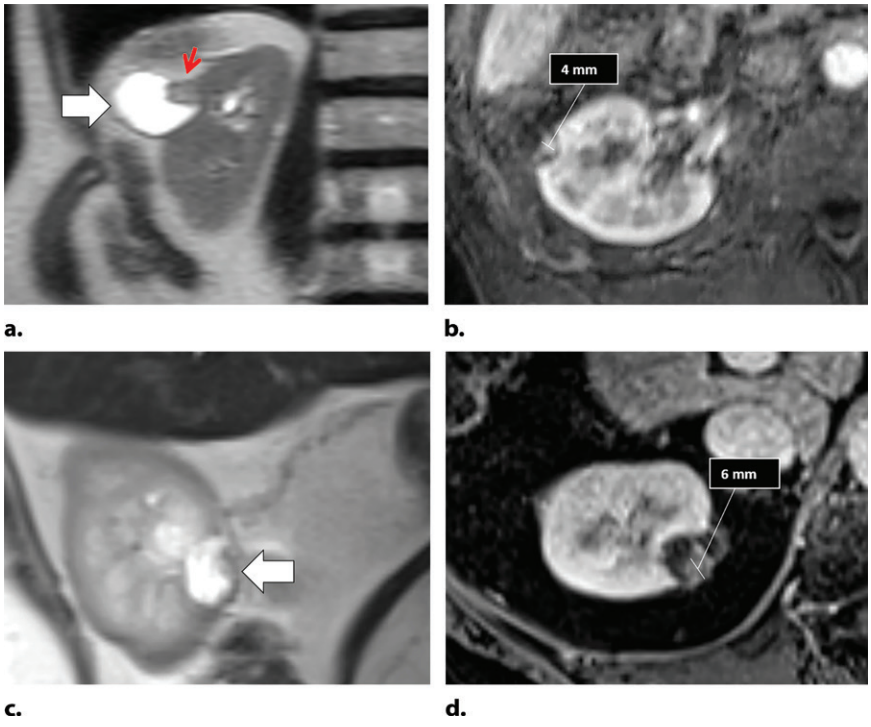


Figure 13. Bosniak Classification, version 2019 class IV mass in two patients. **(a, b)** Right cystic renal mass that was an ISUP grade 2 clear cell RCC at partial nephrectomy in a 44-year-old woman. Coronal single-shot fast spin-echo (SSFSE) T2-weighted MR image **(a)** shows a right-sided 3.3-cm cystic mass (white arrow) with a 4-mm nodule (red arrow) that manifests as a focal protrusion forming an acute margin with the wall. Axial T1-weighted fat-suppressed MR image **(b)** obtained during the portal venous phase shows that the nodule is enhancing. **(c, d)** Right cystic renal mass that was an ISUP grade 3 clear cell RCC at partial nephrectomy in a 59-year-old woman. Coronal oblique SSFSE T2-weighted MR image **(c)** shows a right-sided 2.7-cm cystic mass, with a nodular portion that manifests as a convex protrusion (arrow) with an obtuse margin to the wall. Axial T1-weighted fat-suppressed MR image **(d)** obtained during the nephrographic phase shows the nodule is enhancing and measures 10 mm. Enhancing nodules are features of a Bosniak IV cystic mass and may have obtuse margins (nodule $\geq$ 4 mm) or acute margins (nodule of any size) with the wall or septa. Nodules are measured on contrast-enhanced images and not on T2-weighted images.

Conclusion

This pictorial review illustrates key definitions, terms, and updates of the Bosniak Classification of cystic renal masses, version 2019. We hope that the revised Bosniak Classification will be applied in clinical practice. However, as the authors of the revision have acknowledged, further study will be needed to determine if the revised classification meets its goals, addresses the shortcomings of the original classification system, and better discriminates benign from malignant renal masses. In addition, work will be needed to more fully incorporate contrast-enhanced US and perhaps identify other methods such as texture analysis and radiomics that could be added to the classification.

***Disclosures of Conflicts of Interest.*—N.S.** *Activities related to the present article:* disclosed no relevant relationships. *Activities not related to the present article:* editorial board member and section editor of genitourinary imaging for the *American Journal of Roentgenology. Other activities:* disclosed no relevant relationships. **M.S.D.** *Activities related to the present article:* disclosed no relevant relationships. *Activities not related to the present article:* royalties from Wolters Kluwer and UpToDate.com. *Other activities:* disclosed no relevant relationships. **I.P.** *Activities related to the present article:* disclosed no relevant relationships. *Activities not related to the present article:* honorarium for the Scientific Advisory Board from Bayer Healthcare; stock options in Health Tech International; travel and meeting expenses paid by Siemens Healthcare; Institutional Research Agreement and coinventor of patents (no royalties received) from Philips Healthcare. *Other activities:* disclosed no relevant relationships. **A.S.** *Activities related to the present article:* disclosed no relevant relationships. *Activities not related to the present article:* consultant to Arog Pharmaceuticals. *Other activities:* disclosed no relevant relationships.

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RadioGraphics
Errata
January-February 2022 • Volume 42 • Number 1

Originally published in:

RadioGraphics 2021; 41(3):814–828 • https://doi.org/10.1148/rg.2021200160

Bosniak Classification of Cystic Renal Masses, Version 2019: A Pictorial Guide to Clinical Use

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Erratum in:

RadioGraphics 2022:42(1):E33 • https://doi.org/10.1148/rg.219016

Page 821, Figure 3: The gray-shaded labels at the top left of the diagram were reversed. Figure 3 and its legend are reprinted correctly here.

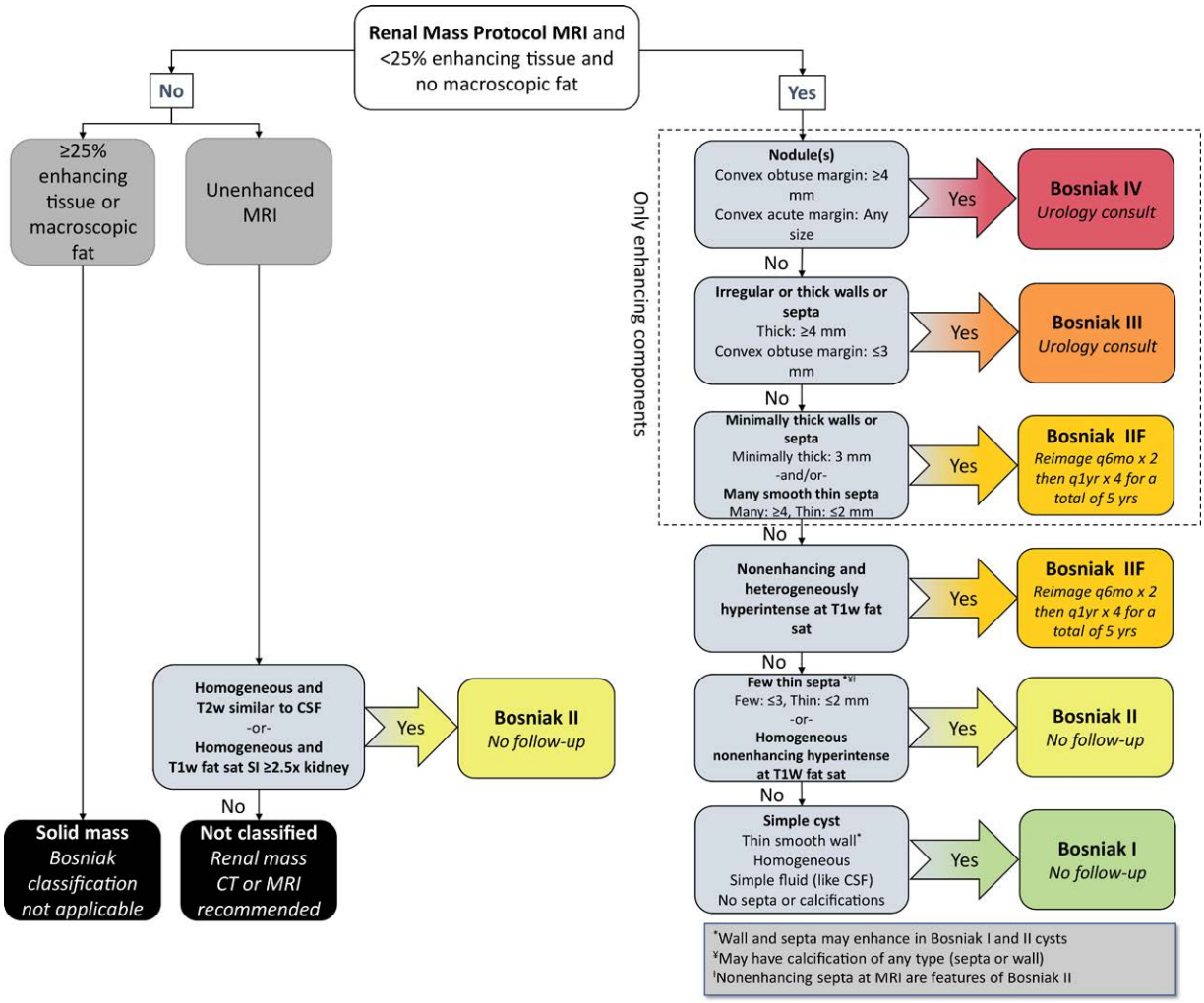

Figure 3. Flow diagram shows how to apply the Bosniak classification of cystic masses, version 2019 at MRI. *CSF* = cerebrospinal fluid, *fat sat* = fat saturated, *q1yr* = every year thereafter, *q6mo* = every 6 months, *SI* = signal intensity, *T1w* = T1=weighted, *T2w* = T2-weighted.