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Bosniak Classification Version 2019: A CT-Based Update for Radiologists

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Abstract
Purpose of Review To review the recent revision of the Bosniak classification: version 2019 (v2019), with emphasis on CT, comparing v2019 to the original Bosniak classification (last updated in 2005) and discuss why this revision was needed and is clinically useful. To present an approach to apply v2019 in practice, reviewing available validation studies evaluating inter- and intra-observer agreement, diagnostic test accuracy, and intermodality comparisons between CT (including dual-energy CT), MRI, and Ultrasound.
Recent Findings After the 2019 proposal revising the Bosniak classification of Cystic Renal masses, data have emerged, which support use of the revised system. These include higher prevalence of malignancy in class III and IV cystic masses and slightly improved interobserver agreement with less discrepancy between class assignment comparing CT and MRI. However, studies have shown limitations of v2019 which include high dispersion of agreement regarding wall or septa feature (e.g., irregularity versus nodule), a higher proportion of malignancy in class IIF and persistent upgrading of class comparing MRI to CT.
Summary Overall, the recent Bosniak v2019 revision has advanced the field of cystic renal mass imaging by achieving a consensus for terminologies and definitions, slightly improving interobserver agreement (with the opportunity for future iterations to improve upon these preliminary results) and increasing specificity of diagnosis of malignancy in higher Bosniak v2019 classes without impacting sensitivity. Future work is needed to simplify and potentially improve performance of the system and accommodate emerging techniques such as dual-energy CT and artificial intelligence.

Keywords Bosniak classification · Cystic renal masses · CT · MRI · Bosniak Version 2019

Introduction

In 1986, Dr. Bosniak published his approach to imaging of renal cysts with CT, proposing a 4-tiered system to differentiate simple cysts (which are benign and ubiquitous at imaging) from cystic renal cell carcinoma (RCC) [1]. The system, referred to as the Bosniak Classification, was adopted widely and remains, for the most part, the reference standard for classifying cystic masses in clinical practice [1]. Dr. Bosniak updated the system in 1993, adding a fifth tier (i.e., class IIF) due to a high percentage of resected benign cystic lesions [2]. Surveillance of class III cystic lesions was suggested as a second option to surgery [3]. Further revisions included lowering the importance of nodular calcifications in 2003 [4] and the last major update was in 2005, with an update to terminology regarding enhancement, replacing terms 'minimal and

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clear' enhancement to 'perceived and measurable' enhancement [5].

In 2019, a major proposed update was published revising the Bosniak Classification of Cystic Renal Masses. The Bosniak Classification of Cystic Renal Masses version 2019 (v2019) formally defines imaging terms and features, establishes which features are required to diagnose a particular class, formally incorporates MRI (and to some extent Ultrasound), and increases the number of cystic masses that are probably benign which can be assigned to Bosniak Class II without the need for a dedicated renal mass protocol CT or MRI [6••]. The overall aims of the revised system are to improve the radiologists' ability to classify cystic renal masses, reduce interobserver disagreement while increasing the specificity of diagnosis of malignancy and the precision for diagnosis of malignancy within each class. Bosniak v2019 acknowledges that cystic RCCs (i.e., RCC with cystic changes) are less aggressive than solid RCCs and are increasingly managed by active surveillance rather than surgery [7]. Moreover, v2019 aims to reduce the number of benign masses undergoing surgery and the number of follow-up exams performed for probably benign cysts. The purpose of this article is to review Bosniak v2019 with a particular emphasis on CT discussing the system in detail, how to apply the system, appraising recently published evidence supporting use of v2019 while highlighting limitations of the current system and last, to discuss the emerging use of Dual-Energy CT (DECT) for imaging cystic renal masses.

The Bosniak Classification of Cystic Renal Masses Version 2019 (v2019)

Bosniak v2019 aims to address the shortcomings of the current version, 2005. These limitations include high interobserver variability which may stem from lack of definitions of the terms used, highly variable reported malignancy rates in each class and high percentage of benign masses classified as Bosniak III (up to 50% in some studies) [3, 8]. One of the first concepts proposed is the definition of what constitutes a cystic renal mass, which is now defined as a renal mass with less than 25% enhancing tissue (Fig. 1). This threshold was chosen, in part based on available data and also to help differentiate solid lesions with necrosis (Fig. 2) from cystic masses with an enhancing component. The former is aggressive and requires definitive management, whereas the latter may be benign or indolent and generally have excellent prognosis (3). Hitherto, the definition of what constituted a cystic mass was never established, leading to erroneous classification of solid masses using the Bosniak Classification. Exceptions to applying Bosniak v2019 to a cystic mass occur: when benign lesions that may mimic malignancies (e.g., abscess, inflammatory disorders, vascular lesions, calyceal diverticulum) are suspected clinically and in and RCC syndromes (e.g., von Hipple-Lindau syndrome) where even benign appearing cysts on imaging may harbor malignancy [6••].

Terminologies and Definitions

A *cystic renal mass* is, therefore, a mass with $\leq 25\%$ enhancing tissue. *Enhancing* is defined as unequivocally perceived enhancement [clear enhancement comparing nonenhancing CT (NECT) to contrast-enhanced CT (CECT)] or measurable (an increase of ≥ 20 HU at CECT). Bosniak v2019 requires that a dedicated renal mass protocol CT is performed to fully classify a cystic mass as Bosniak I, II, IIF, III, or IV. However, there are an expanded number of Bosniak II cystic masses which have been added to v2019 enabling classification of commonly encountered masses that are almost certainly benign which are detected at CT performed without a dedicated renal mass protocol [6••].

The term *simple fluid density* is used for homogeneous attenuation (-9 to 20 HU). When wall and septa are described, the width can be *thin* (≤ 2 mm), *minimally thickened* (3 mm), or *thick* (≥ 4 mm). *Irregularity of the wall or septa* is defined as (≤ 3 mm) obtusely marginated convex protrusion. *Nodule* is defined as (≥ 4 mm) obtusely marginated convex protrusion or convex protrusion of any size with acute angle [6••]. The measurements should be performed perpendicular to the wall or septa and should exclude the wall or septa from which the protrusion

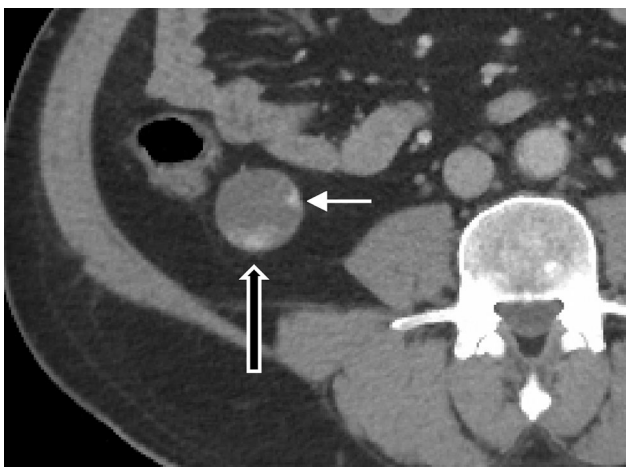


Fig. 1 Axial contrast-enhanced CT image obtained at the nephrographic phase in a 62-year-old man with a 2.7 cm cystic renal mass arising from the lower pole of the right kidney. The mass has < 25% enhancing tissue with an enhancing irregularity (white arrow) and an enhancing nodule (black arrow)

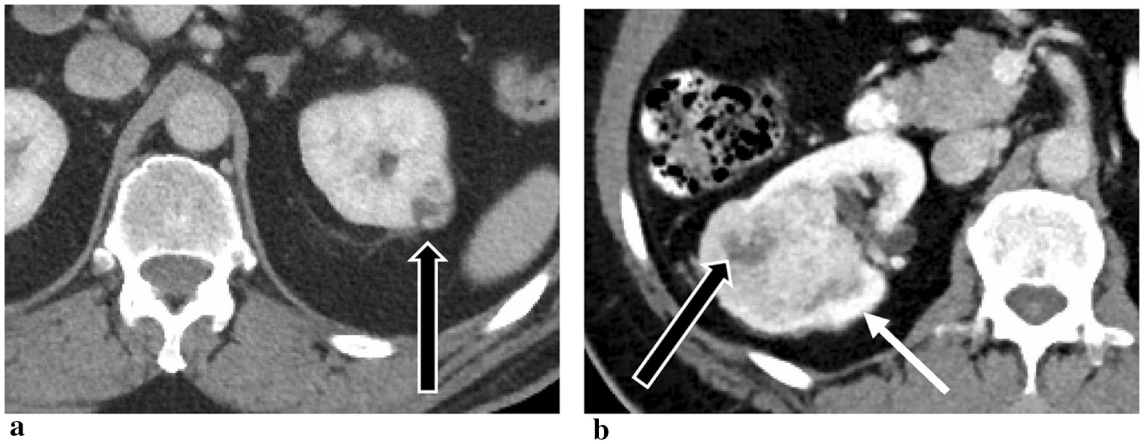


Fig. 2 **a** Axial contrast-enhanced CT image obtained at the nephrographic phase in a 60-year-old man with a 2.1 cm renal mass (black arrow) at the interpolar area of the left kidney. The mass has > 25% enhancing tissue. Therefore, the term cystic renal mass should not be applied using Bosniak v2019, and this lesion is considered a solid renal mass. **b** Axial contrast-enhanced CT image obtained at the corticomedullary phase in a 60-year-old man with a 5.2-cm solid renal mass (white arrow) at the interpolar area of the right kidney is mostly solid with central necrosis (black arrow). Necrosis can simulate cystic change on imaging; however, the former is aggressive and the latter can be associated with more indolent disease

originates (Fig. 3). When any measurement is performed, rounding down to the lower integer to maintain higher specificity for each class was suggested, e.g., 2.6 mm is 2 mm not 3 mm [9•]. Confluent septa should be evaluated in more than one plane to differentiate multiple septa from thickening, irregularity, or nodule [9•].

The term*Cyst* applies only to Bosniak I masses and to cystic masses in Bosniak II that are proven to be benign cysts [6••, 10•]. The terms complex or complicated cyst should be avoided, and all other lesions should be referred to as cystic masses [6••].

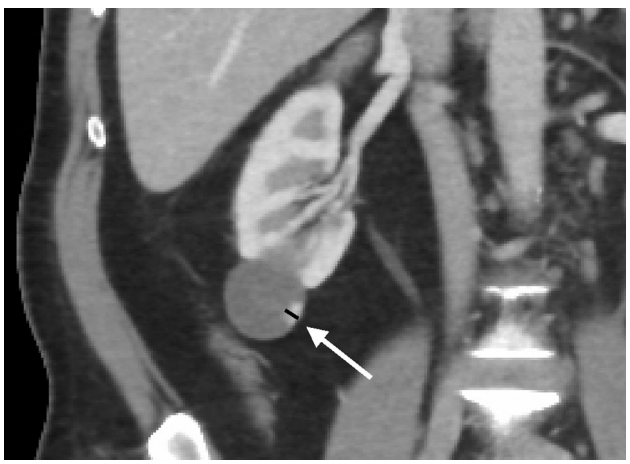


Fig. 3 Coronal contrast-enhanced CT image obtained at the corticomedullary phase in a 62-year-old man with a 2.7 cm cystic renal mass (white arrow) at the lower pole of the right kidney with an enhancing nodule along the medial wall. Black line depicts the correct method to measure a wall or septa feature. In this case, the feature is a convex protrusion measuring 4 mm with obtuse margins. Measurement of the nodule should be performed perpendicular to the wall

Calcifications

Initially, Dr. Bosniak considered the presence of calcification to be associated with malignancy [1]. However, small fine linear calcifications can occur in the wall of benign cysts. Therefore, the amount and pattern of calcifications were later considered important features.

In 2003, the role of classification was updated such that the presence of calcification in and of itself is not an important feature rather than the associated enhancing tissue [4]. A small amount of thin calcification is a feature of class II masses while more extensive calcifications without any enhancing tissue constitutes class IIF. In v2005, the presence of fine calcification or short slightly thick calcification in the wall or septa was moved to class II, While thick, nodular, or irregular calcifications without an associated enhancing soft tissue or thick wall/septa will place the cystic mass in class IIF [5].

The Bosniak v2019 further deemphasizes the significance of calcifications, which in and of itself is a feature of class II [2]. Calcification is not a stand-alone malignant feature. However, a mass with an abundant thick or nodular calcification should be evaluated by MRI, as suggested by v2019, before assigning a class by CT [6••].

CT Renal Mass Protocol

A standardized renal protocol CT, as suggested by the Society of Abdominal Radiology Disease Focused Panel on RCC, requires a pre-contrast and nephrographic phase (100–120 s) post-contrast imaging [11]. Other optional

additional series include corticomedullary (40–70 s delay) and excretory (7–10 min delay) phases.

All series should be axial acquisitions with 3 mm section thickness and a recommended additional coronal and sagittal reformats of all post-contrast series. The types of intravenous contrast media include low or iso-osmolar, and volume can be weight-based dosing or 35–52.5 g of iodine equivalent contrast with an injection rate of 2–5 cc/s.

Assigning the Bosniak v2019 Class by CT

Bosniak I

The CT features are well-defined thin smooth wall with homogeneous simple fluid density. No septa or calcification and the wall may enhance. The term *cysts* can be applied here [6••].

Bosniak II

The CT features include six types, all of which have a well-defined thin (≤ 2 mm) smooth wall [6••].

(Type 1) Cystic mass with (≤ 2 mm) thin and few [1–3] smooth septa. Septa and wall may enhance and may have calcifications of any type (noting that densely calcified masses should be further evaluated by MRI) [6••].

(Type 2) Cystic mass which is homogeneous and hyperattenuating (≥ 70 HU) at noncontrast CT (Fig. 4). These masses were included because they commonly represent hemorrhagic or proteinaceous cysts [12]. A mass with these features measuring > 3 cm, and nonenhancing should be further evaluated by MRI, as these are uncommon [6••].

(Type 3) Cystic mass which is homogeneous, measuring (≥ 20 HU) and nonenhancing at dedicated renal mass protocol CT, may have classification of any type. It is important to emphasize that a dedicated nephrographic phase CT is necessary to exclude enhancement, since papillary RCC may not enhance by CT attenuation criteria comparing pre-contrast to earlier phases (e.g., arterial, corticomedullary, portal venous) [13].

(Type 4) Homogeneous mass (-9 to 20 HU) at noncontrast CT. This differs from a Bosniak I cyst because there is no accompanying enhanced CT phase to confirm the absence of enhancement.

(Type 5) Homogeneous mass (21 to 30 HU) at portal-venous phase CT (Fig. 5). The inclusion of this type of cystic mass accounts for the presence of pseudoenhancement of benign cysts observed at single-phase-enhanced CT and has been shown to have a negligible risk of malignancy [6••, 12] even though papillary RCC may measure below 30 HU at enhanced CT [14].

Fig. 4 Axial non-contrast-enhanced CT image in a 60-year-old lady depicts a 0.9 cm homogeneously hyperattenuating mass (arrow) at the interpolar area of the left kidney. The attenuation is 71.3 HU. This is compatible with a benign hemorrhagic or proteinaceous cystic mass, Bosniak v2019 Class II

(Type 6) Homogeneous low-attenuation mass that are too small to characterize (TSTC) (Fig. 6). Inclusion of this type of cystic mass is consistent with American College of Radiology (ACR) recommendations for management of incidental renal masses and, however, is currently based on expert opinion [15].

Bosniak IIF

A Bosniak IIF cystic mass can only be assigned using renal mass protocol CT. Although the diagnosis can be inferred at single-phase-enhanced CT, a dedicated renal mass protocol is recommended for complete classification. The CT features are cystic masses with smooth minimally thickened (3 mm) wall or smooth minimal thickening (3 mm) of one of more septa, or many (≥ 4) smooth thin (≤ 2 mm) enhancing septa [6••].

Bosniak III

A Bosniak III cystic mass can only be assigned using renal mass protocol CT. Although the diagnosis can be inferred at single-phase-enhanced CT, a dedicated renal mass protocol is recommended for complete classification. The CT features are cystic masses with one or more enhancing thick (≥ 4 mm) or enhancing wall or septa showing enhancing protrusion measuring ≤ 3 mm with obtuse angulation to the underlying wall or septa, termed irregularity [6••].

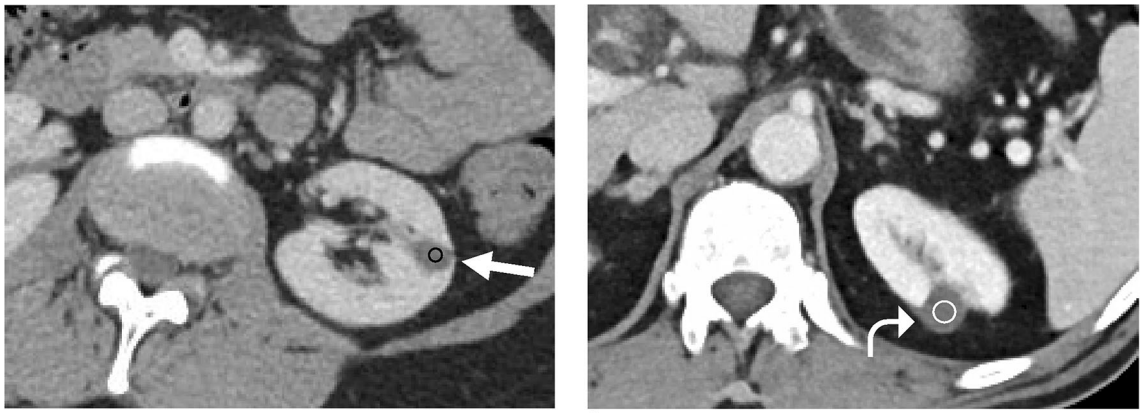


Fig. 5 **a** Axial contrast-enhanced CT image obtained at portal-venous phase in a 50-year-old lady depicts a homogeneous mass (white arrow) at the interpolar area of the left kidney measuring 1.2 cm and an attenuation of 26.9 HU. **b** Axial contrast-enhanced CT image obtained at portal-venous phase in a 62-year-old man with a homogeneous mass (curved white arrow) at the upper pole of the left kidney measuring 1.5 cm and an attenuation of 27 HU. In Bosniak v2019, both of these masses are classified as Bosniak II

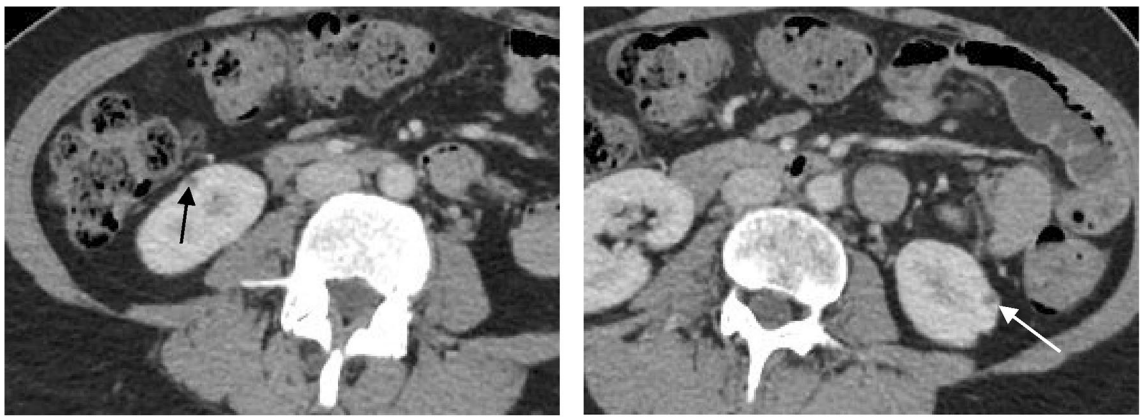


Fig. 6 Axial contrast-enhanced CT images obtained at portal-venous phase in a 50-year-old lady depict homogeneous low-attenuation masses that are too small to characterize in **a** the lower pole of the right kidney (black arrow) and **b** the lower pole of the left kidney (white arrow). In Bosniak v2019, these masses are considered Class II

Bosniak IV

A Bosniak IV cystic mass can only be assigned using renal mass protocol CT. Although the diagnosis can be inferred at single-phase-enhanced CT, a dedicated renal mass protocol is recommended for complete classification. The CT features are cystic masses with one or more enhancing nodules, defined as protrusions which enhance arising from a wall or septa that measure ≥ 4 mm with obtuse angulation to the underlying wall or septa, or that measure any size with acute angulation to the underlying wall or septa [6••].

The Approach to Apply the New Revision

After excluding solid renal masses, cystic masses encountered in RCC syndromes and cystic masses that could be from a benign cause, we suggest that the radiologist should begin by evaluating the individual features to assign the correct Bosniak Class. If a cystic mass has more than one feature from different classes, the feature associated with the highest Bosniak class determines the final class [6••, 10•]. For example, a cystic mass with a thick (≥ 4 mm) smooth septa and many (≥ 4) smooth thin (≤ 2 mm) septa is Class III due to the thick smooth septa. Of note, features are not cumulative. That is, a cystic mass with a minimally thickened (3 mm) septa and many (≥ 4) smooth thin (≤ 2 mm) septa is Class IIF, and the presence of both Class IIF features does not result in a higher Bosniak class.

We recommend using a top-down approach, starting with the most suspicious features first which determine Class IV and, then, moving down to the lower classes as described in a recently published flow diagram by Schieda et al. which demonstrates how to apply the Bosniak classification v2019 at CT [10•].

Bosniak v2019 Calculator and Flow Diagrams

Considering the extremely detailed description of Bosniak v2019, the use of an online calculator might aid assessment. Such a calculator was developed and is available at website (https://bosniak-calculator.herokuapp.com) and as a mobile application supporting evaluation of cystic masses using both CT and MRI.

As discussed above, flow diagrams have also been developed for both CT and MRI to aid in Bosniak v2019 assessment [10•].

Bosniak v2019: CT vs MRI

MRI was formally incorporated into Bosniak v2019 and a mass can be fully classified using Bosniak v2019 with CT or MRI. There are several scenarios when MRI is recommended after a dedicated CT renal mass protocol [6••, 10•, 16•]. These include (1) heterogenous masses that are too small to characterize (TSTC), (2) masses with abundant calcifications obscuring visualization of internal contents and enhancement (Fig. 7), (3) hyperattenuating, homogeneous, nonenhancing masses that measure > 3 cm and, (4) heterogeneous masses with nonenhancing ≥ 4 septa where the wall or septa is ≥ 3 mm. It should be noted that if a renal cystic mass does not definitively fall into one of the Bosniak v2019 classes by CT, MRI is suggested to further characterize and confirm or exclude enhancement [6••].

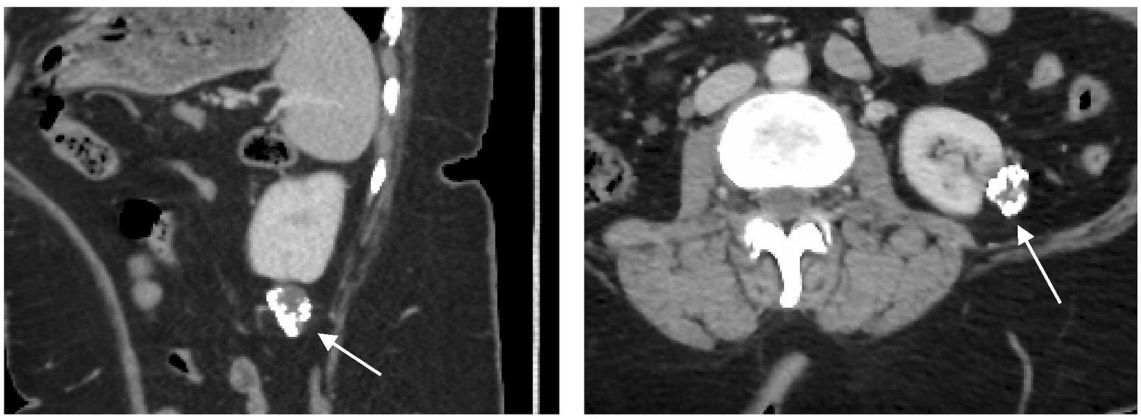
MRI is known to upgrade the Bosniak class of cystic masses compared to CT due to better soft tissue resolution and improved visualization of internal septa and wall and septa features [17–19]. Recent data evaluating Bosniak v2019 indicate that the absolute number of septa in a mass is not associated with malignancy, as suggested in the new revision (e.g., ≥ 4 smooth and thin septa is a feature of class IIF) [20]. Therefore, it is possible that differences in classification that occurred comparing masses evaluated by CT and MRI using the original classification have been reduced or eliminated.

In one study, there was no systematic difference comparing Bosniak v2019 class assigned by CT versus MRI in the same patient [21]; however, differences between the two modalities remained. Chan et al. showed discordant results, with a persistent trend towards upgrading cystic masses with MRI compared to CT in patients receiving both examinations [17]. Park et al. showed a similar intermodality agreement comparing class assignment using CT and MRI with Bosniak v2005 and v2019 [22].

Validation of the Bosniak v2019

Interobserver Agreement

The v2005 Bosniak had high interobserver variability [6••, 23, 24]. Most studies evaluating Bosniak v2019 with CT show similar to slightly higher interobserver agreement in compared to V2005, see Table 1 [8, 17, 20–22, 25–27]. In a study by Shampain et al., a source of disagreement among



a b

Fig. 7 Coronal **(a)** and axial **(b)** contrast-enhanced CT images obtained at portal-venous phase in a 65-year-old lady with a 1.8 cm renal mass (arrows) at the lower pole of the left kidney with abundant calcifications. The abundant calcifications obscures visualization of internal features and enhancement. In this case, MRI is recommended even after a dedicated CT renal mass protocol and before assigning a class according to Bosniak classification v2019

Table 1 Reported interobserver agreement in different studies evaluating Bosniak v2019 with CT

Study author, journal and year	Yan et al. European Radiology, 2021 [20]	Park et al., American Journal of Roentgenology, 2021 [22]	Osman et al. Canadian Urological Association Journal, 2021 [25]	Tse et al. American Journal of Roentgenology, 2021 [21]	Pacheco et al. European journal of Radiology, 2020 [41]	Chan et al. Abdominal Radiology, 2021 [17]	Shampain et al. Radiology, 2021 [26]
Original Bosniak (v2005)	Kappa	Weighted Kappa	Kappa	Weighted Kappa	Kappa	Kappa	Gwet agreement coefficient
	0.24–0.34 (CT + MRI)	0.67 (CT), 0.78 (MRI)	0.39 (CT + MRI)	0.70 (CT), 0.62 (MRI)	0.43 (CT), 0.42 (MRI)	0.35 (CT), 0.37 (MRI)	0.51 (CT), 0.43 (MRI)
V2019 Bosniak	Kappa	Weighted kappa	Kappa	Weighted Kappa	Kappa	Kappa	Gwet agreement coefficient
	0.26–0.47 (CT + MRI)	0.75 (MRI), 0.80 (CT)	0.44 (CT + MRI)	0.74 (CT), 0.65 (MRI)	0.40 (CT), 0.38 (MRI)	0.44 (CT), 0.39 (MRI)	0.56 (CT), 0.52 (MRI)

readers related to septa/wall quality (e.g., smooth versus irregular thickening, nodule) and these data suggest that these terms may need simplification in order to improve system performance [26].

In one study evaluating the use of an online Bosniak calculator, the interobserver agreement was unchanged; however, readers were already familiar with the v2019 system and the calculator may still be useful for inexperienced readers for which it was intended [25].

Prevalence of Malignancies in Each Class

Studies evaluating the prevalence of malignancy in Bosniak v2019 classes on CT are summarized in Table 2 [20, 22]. For both available studies, there is a higher proportion of malignant masses in Class IIF ($\sim$ 50–60%) compared to the far lower rate reported in the systematic review by Schoots et al. [23]. Conversely, a higher rate of malignancy was reported in Class III (80–90%) compared to the roughly 50:50 chance of malignancy in Class III when using Bosniak v2005 [23]. Similar results have been reported with MRI [8, 28]. These study results reflect an achieved goal of the Bosniak v2019, namely to emphasize specificity of diagnosis of malignancy which results in a higher proportion of malignant masses placed in higher Bosniak classes. The much higher prevalence of malignancy in Class IIF when applying Bosniak v2019 may reflect small and biased study samples (requiring histological verification) and this will require further study. This hypothesis would be supported by the results in Table 2 regarding proportion of malignancy in class II masses, where a reported rate of malignancy of 12–50% is noted. In a recent larger meta-analysis evaluating Bosniak v2019 class II lesions there were no reported cases of malignancy when imaging and pathological reference standards were used [12].

The Role of Dual-Energy CT

Dual-energy CT (DECT) is a technique with several advantages for renal mass evaluation. DECT is as accurate as conventional CT for renal mass diagnosis [29]. Other potential advantages of DECT include improved correction of beam-hardening artifacts reducing pseudoenhancement in benign cysts [30], production of material specific image sets such as iodine-only images (improving visual detection of enhancement [31] and virtual noncontrast-enhanced CT (vNECT) images (enabling derivation of pre-contrast attenuation when a dedicated NECT was not performed), and possible increased sensitivity to iodine which could improve detection of enhancement in low-enhancing renal masses such as papillary RCC [32].

To our knowledge, improvements in cystic mass diagnosis have not specifically been evaluated with DECT. In one study, using DECT readers were able to more confidently interpret CT in polycystic kidneys with reduced interpretation time [33]. There are several potential advantages of DECT for cystic renal mass characterization. First, when a dedicated renal mass protocol was not performed but rather only a single-phase contrast-enhanced CT (CECT) is available, vNECT and CECT image sets could be a surrogate for a dedicated renal mass protocol in many instances [34]. This could enable accurate characterization of a greater number of indeterminate renal masses as benign cystic masses (Class II) or enhancing

Table 2 Proportion of malignancies by CT comparing v2019 and v2005 in different studies

Study author, journal and year	Park et al., American Journal of Roentgenology, 2021 [22] (%)	Yan et al. European Radiology 2021 [20] (%)
Original		
Bosniak II	0–27.3	100
Bosnaik IIF	46.2–55	40
Bosniak III	80.4–82.1	75.6
Bosniak IV	82.8–83.8	81.9
V2019		
Bosniak II	12.5–22.2	50
Bosnaik IIF	53.1–53.3	60
Bosniak III	84.8–89.2	78.6
Bosniak IV	85.2–87.5	89

cystic or solid masses. For example, a homogeneous cystic mass measuring > 30 HU at single-phase CECT is indeterminate; however, if the vNECT is 30 HU and there is no iodine present on iodine-only images, it can be safely inferred the mass is not enhancing and a hyperdense cyst [35] (Fig. 8). Conversely, if the mass measures of low attenuation on vNECT and clearly enhance visually on iodine-only images and by comparing attenuation measurements to CECT, then it can be classified according to its' enhancement pattern without the need for a dedicated renal mass protocol. We do advise caution; however, because DECT evaluation of cystic renal masses has been not studied systematically. For instance, a papillary RCC imaged at arterial or portal-venous phase CECT may not appear enhancing comparing vNECT and CECT or iodine-only images due to improved detection of enhancement with dedicated nephrographic phase imaging [13]. Moreover, studies comparing vNECT and true NECT have shown a consistent trend towards overestimating attenuation values with vNECT [36], and these small differences may be significant when determining if a mass is enhancing or not. Reduction of elimination of pseudoenhancement is extremely important in CT evaluation of cystic renal masses and would theoretically enable a higher proportion of benign cysts to be accurately characterized by CT without the need for MRI.

Shortcomings and Opportunities for Improvement

Bosniak v2019 only partially includes ultrasound and future revisions might increase the emphasis of ultrasound for characterizing cystic renal masses, including through the use of contrast-enhanced ultrasound. For example, further evaluation of a hyperattenuating cystic mass (> 20 HU but < 70 HU or heterogeneous) identified at NECT or > 30 HU at CECT with a single-portal-venous phase) by ultrasound can be helpful in majority of cases [37]. Contrast-enhanced ultrasound could be useful to further evaluate masses which show indeterminate enhancement (10–20 HU) [38–40]. Caution must be taken when applying the new revision for cystic masses that do not fall into one of the defined classes when using CT or MRI, and in these situations, a cystic mass can be assigned to class IIF [6••]. Adaptation of the system to include established and emerging technologies such as dual-energy CT are required. Simplification may be an area of focus for future revisions, as a simplified system could be expected to

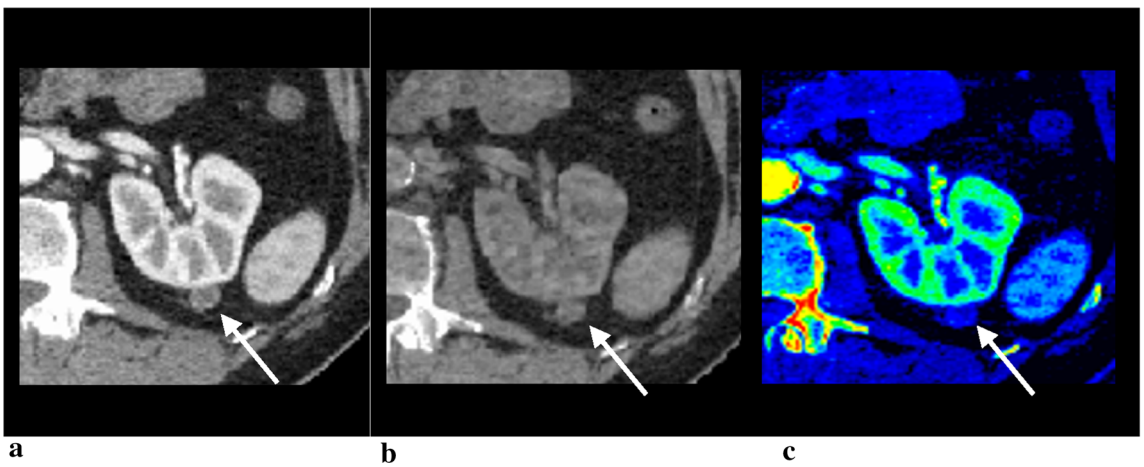


Fig. 8 Axial contrast-enhanced CT images obtained at corticomedullary phase in a 54-year-old patient using dual-energy CT technique depicts a cystic renal mass (white arrows). The attenuation of the mass is 49 HU on the corticomedullary phase **(a)**, 40 HU on the virtual non-enhanced CT **(b)** and on the iodine image **(c)** the mass shows no enhancement. In Bosniak v2019, the mass is considered indeterminate by a single-phase-enhanced CT. MRI (not shown) was performed and confirmed that the mass was a hemorrhagic cyst with no enhancement. The mass could have been classified as Bosniak II without the need for MRI using DECT

improve inter-observer agreement; however, this requires validation. Future iterations of the Bosniak classification may aim to differentiate aggressive cystic cancers requiring treatment from indolent cancers which can be surveilled safely. The current system focuses on diagnosis of cystic RCC, though many cystic RCC are indolent and can be surveilled safely.

Conclusions

In conclusion, studies evaluating Bosniak v2019 have shown increased specificity of diagnosis of malignancy and slightly improved interobserver agreement compared to the Original Classification. As data are published, opportunities to further study and improve v2019 emerge. Bosniak v2019 advances the imaging diagnosis of cystic renal masses and enables future research to meaningfully address knowledge gaps in management of cystic renal masses. Specific aims moving forward might be to simplify the system to potentially improve agreement, include emerging technologies such as dual-energy CT, and focus on diagnosis of aggressive cystic masses requiring treatment as opposed to any cancer including indolent disease.

Compliance with Ethical Guidelines

Conflict of interest All authors declare that they have no conflict of interest.

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- • Of importance
- •• Of major importance

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