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How I Do It: Evaluating Renal Masses[1]

With modern computed tomography (CT) and magnetic resonance (MR) imaging equipment, the diagnosis of most renal masses is usually straightforward and accurate. The major question to be answered is whether the mass represents a surgical or nonsurgical lesion or, in some cases, if follow-up studies are necessary. This evaluation usually can be accomplished if a high-quality examination is performed, if the clinical history of the patient is kept in mind, if conditions that mimic a renal neoplasm are considered and excluded, and if there is an awareness of the potential pitfalls and limitations of CT and MR imaging. In this article, the authors present their technique in the performance of CT and MR imaging examinations, summarize their approach to the diagnosis of renal masses, review the imaging findings in these lesions, and stress the limitations in renal mass diagnosis.
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The great majority of renal masses are found incidentally as a result of the use of computed tomography (CT), ultrasonography (US), and magnetic resonance (MR) imaging. Fortunately, most of these are simple renal cysts that can be easily diagnosed and do not require treatment. However, solid and complex cystic renal masses are also discovered, many of which are clearly malignant and need to be surgically removed, while others may not require surgical intervention. Therefore, the proper characterization of these masses is essential so that appropriate management is instituted. In this presentation, we summarize our current approach to the imaging evaluation of renal masses, review the pertinent imaging findings in these lesions, and discuss the limitations of CT and MR imaging as well as pitfalls in diagnosis.

TECHNIQUE AND QUALITY OF THE EXAMINATION

The accurate diagnosis of a renal mass is dependent on many factors, including the clinical history, the nature of the imaging findings, the experience of the radiologist, and the quality of the examination. A high-quality imaging examination, which is under the control of the radiologist, is essential. We present our technique in the performance of CT and MR imaging for the evaluation of a renal mass and acknowledge that other protocols work equally well. It is expected that these protocols will be modified over time as new equipment becomes available.

CT Scanning

When CT scanning is performed specifically to evaluate a known renal mass, the study must include an unenhanced examination prior to the administration of intravenous contrast material. By using a power injector, the authors routinely administer 150 mL of intravenous contrast material (75 mL for patients with a single kidney) injected at a minimum rate of 3 mL/sec to ensure that a high concentration of contrast material is present within the renal parenchyma during the postcontrast acquisition. By using a multi–detector row CT scanner, contrast material–enhanced imaging is routinely performed during the corticomedullary and nephrographic phases of enhancement by using scanning delays of 40 and 100 seconds, respectively. The corticomedullary phase of enhancement is used to perform three-dimensional (3D) reconstructions and to depict the renal vasculature for urologists who perform laparoscopic nephrectomy. This phase is also useful to help differentiate a renal pseudotumor from a renal neoplasm. However, the corticomedullary phase of enhancement, which results in a heterogeneous nephrogram, may hinder renal mass detection in some instances (Fig 1). During this phase of enhance-

ESSENTIALS

- *The accurate diagnosis of a renal mass is dependent on many factors, including the clinical history, the nature of the imaging findings, the experience of the radiologist, the quality of the examination, and the exclusion of conditions that can mimic a renal neoplasm.*

- *When characterizing a renal mass, the major question to be answered is whether the mass represents a surgical or nonsurgical lesion or, in some cases, if follow-up studies are necessary.*

- *The most important criterion used in differentiating surgical from nonsurgical renal masses is the determination of enhancement.*

- *The inconsistencies of CT Hounsfield unit measurements, pseudoenhancement of simple renal cysts at CT, and the lack of a standardized approach for evaluating renal mass enhancement with MR imaging all contribute to the potential pitfalls of characterizing renal masses.*

ment, a small renal mass may have attenuation similar to that of the renal medulla, and differentiating the mass from normal renal parenchyma may be difficult. Furthermore, enhancement in hypovascular renal neoplasms (papillary neoplasms) may not be evident during this early phase of enhancement (1–3). Therefore, obtaining contrast-enhanced images during the nephrographic phase of enhancement, which results in a homogeneous nephrogram, is necessary because renal mass detection and the ability to demonstrate enhancement in hypovascular neoplasms is maximized (1). For examinations performed with a single–detector row helical CT scanner, contrast-enhanced imaging only during the nephrographic phase (by using a scanning delay of 90 seconds) is performed.

The section collimation is partly dependent on the size of the mass to be characterized. With a single–detector row scanner, we routinely use a section collimation of 5 mm but may also perform imaging with dedicated thinner sections (3 mm or thinner) through the mass (particularly small masses) or a portion of the mass, if necessary. With multi–detector row CT, the unenhanced and contrast-enhanced nephrographic phase

datasets are acquired by using a 4 × 2.5-mm or a 16 × 1.5-mm collimator and are reconstructed to 4-mm sections. If necessary, it is possible to then reconstruct thinner images from the same dataset without rescanning the patient. The scanning parameters (pitch, tube current, peak voltage) of the unenhanced and contrast-enhanced examinations should be held constant, which will ensure that the most accurate Hounsfield unit readings are compared. The corticomedullary phase dataset is acquired by using a 4 × 1.0-mm or 16 × 0.75-mm collimator with images reconstructed to 4-mm sections as well as 1.0–1.25-mm sections incorporating a 50% overlap of adjacent sections. This dataset is manipulated by using a 3D workstation to produce volume-rendered and 3D images when necessary. It is becoming increasingly important for radiologists to produce 3D reconstructed images as more laparoscopic surgery is being performed for the treatment of renal cancer, and these images are helpful in such procedures.

MR Imaging

High-quality renal MR imaging is dependent on multiple factors, including patient cooperation. Therefore, the MR examination should start with educating the patient about the examination to help minimize anxiety and to ensure a complete understanding of what is expected of him or her. All renal MR examinations at our institution are performed by using a torso phased-array coil, which will increase the signal-to-noise ratio and will also allow the use of smaller fields of view, resulting in better spatial resolution. All sequences are performed during an end-expiratory breath hold, and, for those patients who cannot hold their breath for a sufficient period of time (approximately 20 seconds), 2 L/min oxygen is given via a nasal cannula. Finally, by using cushions, the patients' arms are elevated anterior to the level of their kidneys to avoid a wraparound artifact in the phase-encoding direction while coronal acquisitions are performed.

Prior to contrast material administration, a transverse dual-echo two-dimensional T1-weighted gradient-echo sequence (repetition time msec/echo time msec, 200/2.2–4.4 for opposed- and in-phase imaging, respectively) and a transverse or coronal T2-weighted half-Fourier single-shot turbo spin-echo (∞/65) sequence are performed.

In all patients referred for evaluation of

a renal mass, MR angiography, MR venography, and MR urography are performed by using an oblique coronal breath-hold 3D fat-suppressed T1-weighted spoiled gradient-echo sequence (3.4/1.2; flip angle, 25°–40°) before and at multiple time points after administration of 19 mL of a gadolinium-based contrast material. The 3D slab should be kept as thin as possible, without excluding any of the structures that need to be evaluated, to maximize through-plane spatial resolution. The matrix should also be adjusted to maximize in-plane spatial resolution without increasing the length of the sequence to greater than the breath-hold capability of the patient. The typical voxel size should be no greater than 1.5 × 1.5 × 2 mm. The imaging delay for MR angiography is based on a timing run with a power injector and 1 mL of gadolinium-based contrast material followed by a 20-mL saline flush (4). MR venography and MR urography are performed at approximately 30 seconds and 5 minutes after MR angiography, respectively. These sequences are used to depict the renal arteries and veins and the relationship of a renal tumor to the hilar vessels and collecting system, which is helpful to the urologist in surgical planning.

To evaluate the renal parenchyma and a renal mass, a separate 3D breath-hold fat-suppressed T1-weighted fat-saturated spoiled gradient-echo sequence (4.4/1.8; flip angle, 12°) (5), designed to improve visualization of parenchymal structures, is performed in the transverse plane before and after contrast material administration. The postcontrast acquisition is performed between MR venography and MR urography. For the characterization of renal masses and to determine the presence or absence of enhancement, we recommend an imaging delay of 3–5 minutes.

When asked to specifically evaluate a known renal mass at MR imaging, the imaging planes of the sequences may be modified to best depict the mass. For masses at the poles of the kidney, the coronal and sagittal planes are advantageous because the relationship of the mass to the kidney is not optimally demonstrated in the transverse plane. Similarly, the transverse and sagittal planes best depict a mass in the anterior or posterior aspect of the kidney, and the transverse and coronal planes best depict a mass in the medial or lateral aspect of the kidney. This approach is most important when evaluating a patient with a solitary kidney that contains a renal neoplasm that is amenable to partial nephrectomy.
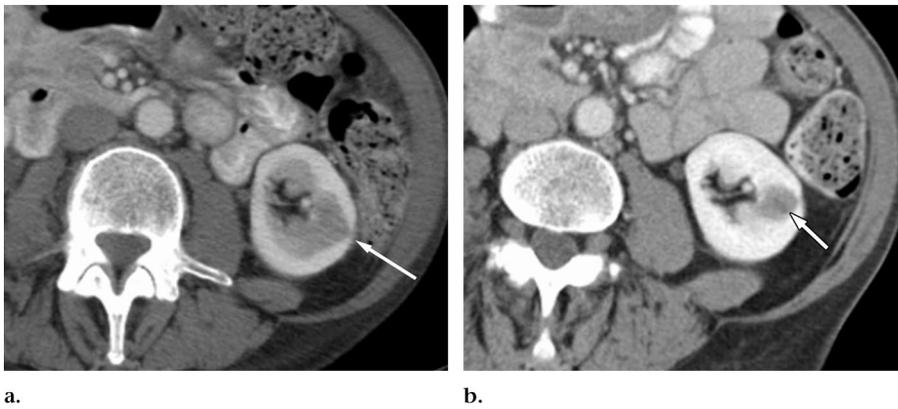
Figure 1. Transverse contrast-enhanced CT scans in a 54-year-old woman with a renal cell carcinoma. **(a)** Corticomedullary phase scan shows focal thinning (arrow) of the renal cortex, but a definite renal mass is not identified in this early phase of renal enhancement. **(b)** Nephrographic phase scan shows a 1.5-cm intrarenal mass (arrow), which was surgically proved to be renal cell carcinoma.

A clear depiction of the relationship of the tumor to the kidney, renal vasculature, and collecting system is necessary for the surgeon to perform a successful partial nephrectomy and preserve as much remaining normal renal parenchyma as possible.

DIFFERENTIATING ENHANCING FROM NONENHANCING RENAL MASSES

Enhancement

The most important criterion used in differentiating surgical from nonsurgical renal masses is the determination of enhancement. Renal mass enhancement is dependent on multiple factors, including the amount and rate of the contrast material injection, the imaging delay, and the nature of the tissue within the mass. Obviously, tumors that are very vascular will enhance considerably, while hypovascular tumors will enhance to a lesser degree (benign cystic renal masses will not measurably enhance). Some tumors will enhance heterogeneously. By using proper technique with current CT technology, enhancement should be detected in all vascularized masses.

When there is a question of whether a mass enhances at CT, Hounsfield unit measurements should be obtained and compared on the unenhanced and contrast-enhanced images. In the past, with conventional (nonhelical) CT scanners, a difference of 10 HU was suggested as evidence of enhancement (6). With the evolution and introduction of helical CT, it was realized that there was more variability in the Hounsfield unit readings

and that 10 HU was no longer an acceptable threshold with this equipment (7). At present, there is no universally agreed upon specific number that can be used as definitive and unequivocal evidence of enhancement within a renal mass, and it has been proposed by many authors that the previously used threshold of 10 HU should be increased to 15–20 HU (8–12), while others believe that a 10-HU threshold is still valid (13,14). In our opinion, a renal mass that enhances 10–20 HU is indeterminate and needs further evaluation for definitive characterization. In characterizing a renal mass, it is important to be aware of the potential unreliability of Hounsfield unit readings, and, therefore, it must be emphasized that no matter what number is used to determine enhancement, any enhancement that is identified must be unequivocal. In some cases, use of the gallbladder or an obvious simple renal cyst as an internal reference standard and comparison of the Hounsfield unit measurements of that reference standard (on the unenhanced and contrast-enhanced images) with the Hounsfield unit measurements of the renal mass can be helpful. However, if there is any question as to whether or not a lesion enhances, another examination (better optimized CT, US in some cases, or MR imaging) should be performed.

There is no unanimously accepted way of determining renal mass enhancement with MR imaging. With our equipment, we have found image subtraction (gadolinium-enhanced fat-suppressed T1-weighted image minus unenhanced fat-suppressed T1-weighted image) to be an easy, reliable, and repro-

ducible method of demonstrating the presence or absence of enhancement within a renal mass. However, to be successful using subtraction, it is necessary to have accurate image coregistration of the unenhanced and contrast-enhanced sequences. Therefore, we perform all MR imaging sequences during an end-expiratory breath hold, which has been shown to be more reproducible than end-inspiratory breath holding (15,16). However, if subtraction is not available, calculating the percentage enhancement with signal intensity units may be performed and has showed promising results (17,18). Finally, it is often possible to subjectively identify enhancement within a renal mass with a side-by-side comparison of the unenhanced and contrast-enhanced images, particularly in hypervascular masses. However, in hypovascular masses and those masses that are hyperintense on unenhanced T1-weighted images, we have found that a side-by-side comparison is usually not reliable and have found subtraction particularly helpful in these cases (Fig 2).

Pitfalls of Enhancement

Whether obtaining Hounsfield unit readings at CT or signal intensity readings at MR imaging, the comparison of corresponding region-of-interest (ROI) measurements on the unenhanced and contrast-enhanced images must be performed. Larger ROI measurements can be used in homogeneous solid masses. However, cystic, complex, or necrotic masses require multiple small ROI measurements to be obtained from all portions of the mass, similarly placed on both the unenhanced and contrast-enhanced images. When analyzing a renal mass that is high in attenuation at unenhanced CT or has increased signal intensity at unenhanced T1-weighted MR imaging, it is important that multiple large and small ROI measurements be made, since any enhancing soft-tissue components within the lesion may be obscured by the increased attenuation of the mass. In addition, small intrarenal masses that do not alter the renal contour may be hard to identify on an unenhanced CT scan, making it difficult to obtain accurate Hounsfield unit measurements. In these cases, the use of narrow window settings and morphologic landmarks such as hilar vessels help in identifying these masses. Finally, when obtaining readings near the interface of the mass and kidney or perirenal fat, it is of course necessary to be careful to avoid incorporating pixels
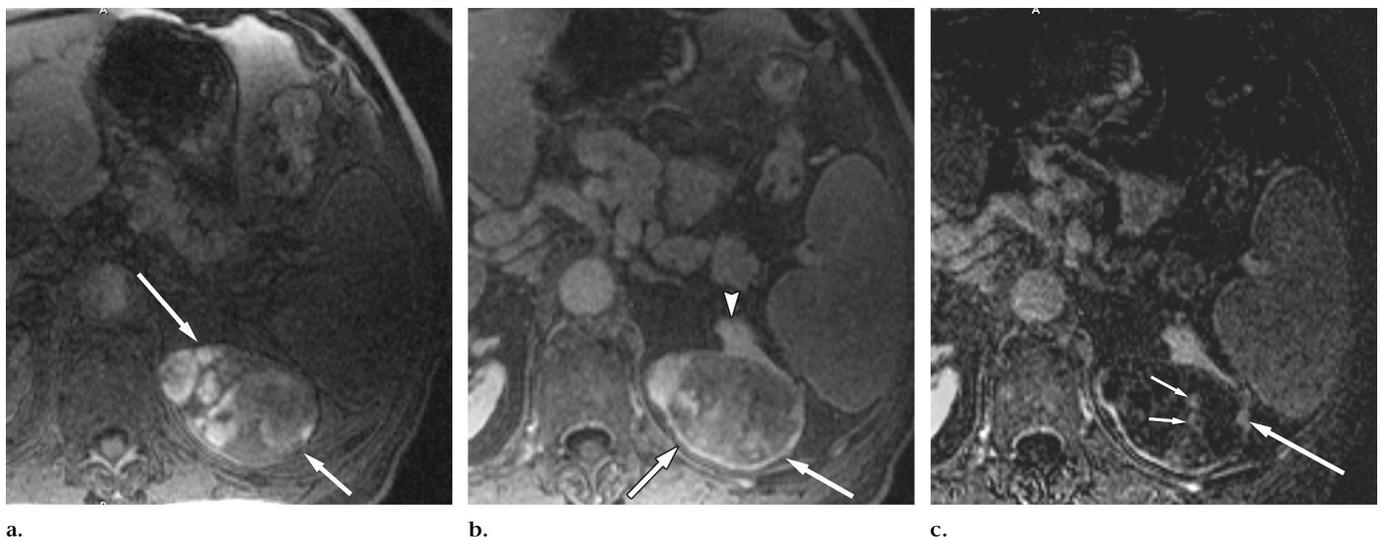
a.   **b.**   **c.**

Figure 2. Transverse fat-suppressed T1-weighted MR images (3.6/1.6; 12° flip angle) in a 68-year-old man with a complex renal mass. **(a)** Unenhanced image shows a hemorrhagic mass (arrows) at the upper pole of the left kidney. **(b)** Gadolinium-enhanced image shows enhancement of a thickened wall (arrows), but it is difficult to determine if there is any internal enhancement within the mass because of its heterogeneous signal intensity on **a**. A small portion of enhancing renal parenchyma (arrowhead) is present anterior to the mass. **(c)** Subtracted image (gadolinium-enhanced image minus unenhanced image) shows nodular enhancement (large arrow) along the wall of the mass and internal enhancement (small arrows), confirming the diagnosis of a renal cancer. A papillary renal cell carcinoma was diagnosed at surgical pathologic evaluation.

from outside of the mass into the ROI, which will lead to erroneous measurements.

It has been shown that renal cysts on occasion may show artificial apparent enhancement of 10 HU or more (pseudoenhancement) at contrast-enhanced CT, and this may potentially lead to the mischaracterization of a renal cyst as a renal neoplasm. The phenomenon of pseudoenhancement at CT is thought to be secondary to the image reconstruction algorithm used in helical scanners to adjust for beam-hardening effects (8,10,12,19,20). Beam-hardening artifacts may also help explain why Hounsfield unit readings are not as reliable today (in our opinion), leading to the difficulty in determining renal mass enhancement in some cases. It is important to be aware of the possibility of pseudoenhancement and to know when to suspect it. Pseudoenhancement most often occurs when the cyst is surrounded by renal tissue during the peak level of renal parenchymal enhancement. Many of these cysts are small (<2 cm) and completely intrarenal (Fig 3). Pseudoenhancement is relatively easy to suspect when a mass appears as a simple cyst and measures 10 HU or less on the unenhanced CT scan. However, when a mass measures greater than 10 HU on an unenhanced CT scan and "enhances" approximately 10–15 HU after contrast material administration, it is difficult to know if this represents pseudoenhance-

ment of a benign cyst or true enhancement within a renal neoplasm. When we encounter such a mass, we suggest another modality (US or MR imaging) (Fig 3). If the mass measures less than 20 HU at the unenhanced examination, US frequently can be used to characterize the mass as a simple cyst. When the mass measures 20 HU or greater at the unenhanced CT examination, it may represent a high-attenuating cyst or a solid renal neoplasm. In the case of a high-attenuating cyst, one may be able to use US to characterize the mass as a benign cyst—but not if it contains blood or debris. In these cases, we believe MR imaging should be used as the problem-solving modality.

DIFFERENTIATING SURGICAL FROM NONSURGICAL RENAL MASSES

Solid Renal Masses

In general, any enhancing solid mass in the kidney should be considered a renal neoplasm. However, it should also be kept in mind that all enhancing solid renal masses do not represent a renal neoplasm. In most cases, it is possible to preoperatively differentiate those renal masses that require surgery (renal cell carcinoma, invasive transitional cell carcinoma, and oncocytoma) from those that do not. Renal cell carcinoma and

oncocytoma are indistinguishable from each other at imaging. However, angiomyolipoma, lymphoma, metastatic disease, renal anomalies, and other pseudotumors can all mimic renal cell carcinoma. Frequently it is possible to make this differentiation by using the imaging findings alone, but often the clinical history can be very important in making the correct diagnosis. In fact, before making a diagnosis of renal cell carcinoma, one should be satisfied that none of these possible mimickers of renal cell carcinoma are potentially present.

The imaging characteristics of renal cell carcinoma are extremely varied, with masses ranging from cystic to solid, from homogeneous to heterogeneous and necrotic, from small to large, and from localized to extensive (Fig 4). Renal cell carcinomas can range from small, slow-growing, incidentally discovered lesions to aggressive neoplasms that may metastasize. The radiologist's role is to be certain that renal cell carcinomas are correctly diagnosed and to differentiate them from those lesions that do not require surgery.

The differentiation of an angiomyolipoma from a renal cell carcinoma is important because, in most cases (excluding very large lesions or those that are bleeding), angiomyolipomas do not need to be surgically removed. The diagnosis of an angiomyolipoma is made by demonstrating fat within a solid renal mass (21).

a.

b.

c.

d.

Figure 3. Images in a 28-year-old man with a right renal mass. **(a)** Transverse unenhanced CT scan shows 1.4-cm low-attenuating mass (arrow) that measures 15 HU in the upper pole of the right kidney. **(b)** On the transverse contrast-enhanced CT scan, renal mass measures 32 HU. Although it could represent a hypovascular neoplasm, this intrarenal mass is small and associated with a dense nephrogram, and pseudoenhancement of a renal cyst was suspected. **(c)** Coronal T2-weighted MR image (∞/65; 180° flip angle) shows the mass to be uniformly hyperintense, suggesting a simple cyst. **(d)** Transverse subtracted MR image (gadolinium-enhanced fat-suppressed T1-weighted image minus unenhanced fat-suppressed T1-weighted image) shows no enhancement within the mass, confirming the diagnosis of a simple cyst.

Figure 4. Transverse contrast-enhanced CT scan in a 32-year-old man with bilateral renal cell carcinomas shows a 6-cm well-defined solid enhancing mass (long arrow) in the right kidney. Left kidney contains a poorly defined infiltrating enhancing mass that has grown into and expands the left renal vein (short arrow) and inferior vena cava (arrowhead). The patient underwent left nephrectomy (and removal of the tumor thrombus from the left renal vein and inferior vena cava) and partial right nephrectomy. At surgical pathologic evaluation, bilateral renal cell carcinomas of different histologic subtypes were diagnosed, a well-differentiated clear cell carcinoma in the right kidney and infiltrating carcinoma in the left kidney.

Many times, angiomyolipomas contain large amounts of fat and the diagnosis is obvious. However, in some cases, they may contain very small quantities of fat that can be overlooked if the mass is not carefully evaluated (Fig 5) (22,23). It is therefore imperative to meticulously evaluate all solid renal masses for the presence of fat to avoid recommending surgical excision of an angiomyolipoma. When a small amount of fat is suspected in a renal mass, an unenhanced CT examination with thin sections combined with a pixel analysis is the most sensitive test to confirm this (9,22–24). A small number of angiomyolipomas (hamartomas) do not contain macroscopic fat (angiomyomas), and the imaging differentiation from a renal neoplasm is impossible. These lesions often have a higher attenuation than that of renal tissue (on the unenhanced CT scan) (22,23) or may demonstrate homogeneous and prolonged enhancement (25), but these findings are not specific enough to make a confident diagnosis of a non–fat-containing hamartoma. The term "minimal fat" angiomyolipoma has been used in the literature to describe angiomyolipomas with microscopic fat and without demonstrable macroscopic fat (23,25). It should be emphasized that there are some imaging findings suggestive of an angiomyolipoma containing only microscopic fat, but this diagnosis cannot be made definitively prior to surgery (or perhaps biopsy in appropriate cases) unless macroscopic fat is present, and every attempt should be made to detect it.

There have been a few case reports of fat occurring in renal cell carcinomas that also contain calcification (26,27). Angiomyolipomas rarely contain calcification (28), and, therefore, a diagnosis of angiomyolipoma should not be made if a lesion contains fat and calcium. In such cases, a renal cell carcinoma must be considered likely. Rarely, a large renal cell carcinoma may contain a small amount of fat, and differentiating this from an angiomyolipoma is impossible (29,30). Finally, it is also possible that a large renal cell carcinoma may engulf a small portion of fat in the renal sinus or perinephric fat, or even a small adjacent angiomyolipoma, giving the appearance of a larger angiomyolipoma containing a small amount of fat. It may not be possible to distinguish these types of masses from each other.

Infiltrating Renal Masses

Infiltrating neoplasms of the kidney include some cases of lymphoma, inva-

sive transitional cell carcinoma, metastatic disease (particularly from lung cancer), and renal cell carcinoma (especially the sarcomatoid subtype) (31,32). These malignancies infiltrate into the renal parenchyma, which results in a region of diminished nephrogram with indistinct margins. The kidney may enlarge but retains its reniform shape. The entire kidney or only a portion of it may be involved. Superficially, these masses resemble one another on images but are quite different histologically and clinically. The clinical history associated with other imaging findings (and in some cases, biopsy) usually will allow the differentiation of these masses, which is particularly important since the treatment of each is different.

Lymphoma can have a variable appearance and may on occasion resemble renal cell carcinoma. Most frequently, it manifests as bilateral solid renal masses, and in a patient with systemic lymphoma the proper diagnosis is not difficult (33). Characteristically, lymphoma often infiltrates into the kidney via the renal sinus or surrounds the kidney (Fig 6). However, on rare occasion, lymphoma may manifest as a solitary renal mass or a homogeneous infiltrating renal mass (this can enlarge the kidney, which usually maintains a reniform shape) (32–34).

In a patient with known systemic lymphoma in whom a renal mass with imaging characteristics of lymphoma is detected, systemic treatment for lymphoma should be instituted. If the patient's systemic disease responds to treatment and the renal mass does not respond accordingly, biopsy of the mass is indicated. On the other hand, in a patient with systemic lymphoma and a renal mass that does not have the imaging characteristics of lymphoma, biopsy of the mass is indicated prior to systemic therapy (35). In the rare case of a patient without known systemic lymphoma in whom a renal mass with imaging characteristics of lymphoma is detected, percutaneous biopsy might be indicated to avoid surgery and nephrectomy (Fig 6).

Transitional cell carcinoma of the kidney is usually diagnosed by detecting a filling defect in the collecting system that enhances on a CT or MR image. However, a small percentage of transitional cell carcinomas are anaplastic and infiltrate into the renal sinus and kidney parenchyma (36) (Fig 7). These masses are very aggressive and have a poor prognosis, often manifesting with lymph node metastases. Infiltrative transitional cell carcinoma can be diagnosed by showing
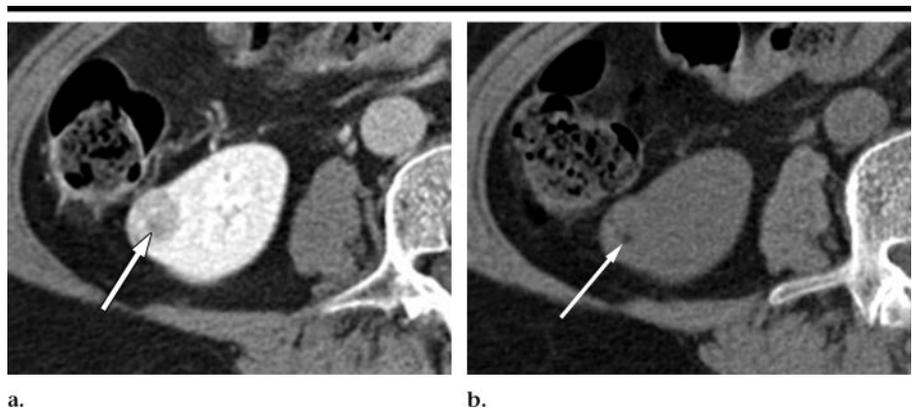

Figure 5. Transverse CT scans in a 45-year-old woman with a renal mass incidentally found on an abdominal CT scan. **(a)** Contrast-enhanced scan shows a 1.8-cm enhancing mass in the right kidney. The lesion was thought to represent a renal cell carcinoma. However, because of a relatively low-attenuating region (arrow) in the central portion of the mass and because we generally perform unenhanced CT (in addition to contrast-enhanced CT) before surgery to be certain of the diagnosis, dedicated renal CT (before and after intravenous contrast agent administration) was performed. **(b)** Unenhanced scan shows a minimal amount of fat (arrow) (−30 HU), diagnostic of an angiomyolipoma. The small amount of fat within this mass is obscured on **a**. Also, the mass is slightly higher in attenuation than the adjacent renal parenchyma, a finding typical of the myomatous component of the angiomyolipoma (23).

that the mass arises from the collecting system with urography (CT, MR, or conventional intravenous), retrograde pyelography, or endoscopy. The differentiation from other infiltrative lesions (which may also involve the renal sinus) is critical because transitional cell carcinoma is treated by means of nephroureterectomy, while lymphoma is treated by means of systemic chemotherapy and infiltrative renal cell carcinoma by means of nephrectomy. Biopsy of infiltrative transitional cell carcinoma should be avoided if possible because of the propensity for seeding (37).

Metastatic disease to the kidney typically manifests as multiple bilateral renal masses, often associated with metastatic disease to other organs (32,38,39). Often they are poorly defined and infiltrate the renal parenchyma (Fig 8). With the appropriate clinical history, the diagnosis is straightforward. However, in a patient with a solitary renal mass (especially an infiltrating mass) and history of previous malignancy (especially carcinoma of the lung), percutaneous renal biopsy is indicated for a definitive diagnosis.

Pseudotumors and Renal Mass Mimickers

There are a group of renal "masses" that superficially may be difficult to differentiate from a renal neoplasm. This group includes congenital anomalies and inflammatory masses, as well as vascular structures. A careful evaluation with a
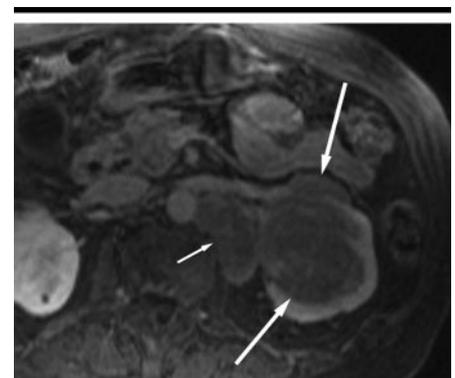

Figure 6. Transverse gadolinium-enhanced fat-suppressed T1-weighted MR image (3.6/1.6; 12° flip angle) in an 84-year-old woman with a renal mass shows a solid enhancing mass (long arrows) in the left renal sinus, infiltrating into the kidney. Large left periaortic lymph nodes (short arrow) are also present. Results at biopsy of the lymphadenopathy confirmed lymphoma.

high-quality CT or MR examination combined with the clinical context of the case and a familiarity with this group of "lesions" should reveal the true nature of these in virtually every case.

A renal pseudotumor represents normal renal tissue that may mimic a renal neoplasm. Congenital pseudotumors are normal variants which include prominent renal columns of Bertin, renal dysmorphism, and dromedary humps, while acquired pseudotumors represent hypertrophied normal renal parenchyma assuming a tumorlike appearance adjacent

Figure 7. Transverse contrast-enhanced CT scan in a 73-year-old man with transitional cell carcinoma in the right kidney shows a tumor that arises from the right renal collecting system and infiltrates into the renal sinus and kidney parenchyma. Findings are consistent with invasive transitional cell carcinoma. Note large lymph node metastases (arrow) posterior to the inferior vena cava.

a.   b.

Figure 9. Transverse contrast-enhanced CT scans in a 63-year-old man with a left renal pseudo-tumor. **(a)** Nephrographic phase scan shows a focal "mass" (large arrow) adjacent to a scar (small arrow) in the left kidney. The left kidney is smaller than the right kidney, and the mass enhances identically to the renal parenchyma. **(b)** Corticomedullary phase scan shows corticomedullary differentiation in the renal "mass," diagnostic of localized hypertrophy of normal renal parenchyma.

Figure 8. Transverse contrast-enhanced CT scan in a 48-year-old man with metastatic lung cancer to the left kidney shows an infiltrative tumor within the left kidney consistent with metastatic disease (in view of the history of lung cancer).

to parenchymal scarring (Fig 9). The key in their proper diagnosis is to observe that the "mass" enhances identically to the normal renal parenchyma. In these situations, it is advantageous to scan not only during the nephrographic phase of enhancement but also during the corticomedullary phase to demonstrate the normal corticomedullary differentiation in the suspect "mass." In addition, reconstructing images in planes different than those originally acquired is sometimes helpful in characterizing pseudotumors.

Inflammatory masses, including focal pyelonephritis and renal abscess, may also mimic the appearance of a renal neoplasm. However, with the appropriate clinical history the correct diagnosis usually becomes apparent. On the other hand, the differentiation of a cystic renal neoplasm from a subacute or chronic renal abscess can be difficult when the typical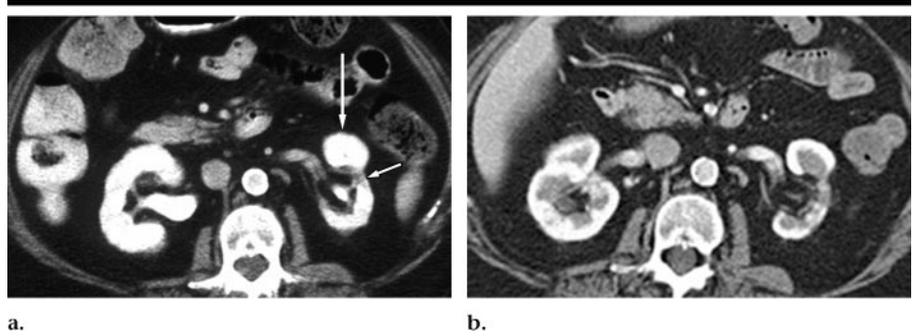 clinical findings of infection are not present. If a remote history of fever, leukocytosis, or urinary tract infection is obtained, needle aspiration should be performed, and if pus is recovered, percutaneous drainage can be instituted. However, if blood or necrotic debris is recovered, surgical removal is indicated.

Vascular anomalies, including renal artery aneurysm or arteriovenous fistula, may manifest as an enhancing renal mass when the contrast-enhanced portion of the examination is performed after a poor bolus of contrast material or during the excretory phase of renal enhancement. These lesions are usually centrally located, and the observation that the mass is associated with and has the same attenuation of the vasculature is the clue to the diagnosis. Also, enlargement of the feeding renal artery or draining renal vein may be apparent. In such cases, a repeat CT or MR examination performed with an adequate bolus of contrast material will clearly demonstrate the vascular nature of the lesion.

Cystic Renal Masses

The Bosniak renal cyst classification (Table) is a system used worldwide in evaluating cystic renal masses (6,40–43). It is based on CT findings and enables a cystic mass to be classified into one of five groups (categories I, II, IIF, III, and IV) (43–47). As can be seen in the Table, it is not a pathologic classification of cystic renal masses but rather an imaging and clinical management system. Originally described in 1986 (6), it has been updated and further defined. Category I (simple cysts), category II (mildly complicated benign cysts), and category IV (cystic neoplasms) are easy to diagnose. Their clinical management is straightforward, with surgery indicated for category IV masses while category I and II masses can be dismissed as benign. However, category IIF ("F" for follow-up; moderately complicated cystic masses that require follow-up imaging to demonstrate stability and therefore benignity) and category III masses (indeterminate masses that require surgery in most cases) can be difficult to differentiate and are subject to interobserver variability. This distinction is essential, however, because their treatment is different (47).

Although not specifically addressed in the Bosniak renal cyst classification system, decisions as to management in any individual case are dependent on the combination of imaging findings, clinical factors, and available treatment options. For example, a category IIF mass (which traditionally requires follow-up examination) may now be treated with laparoscopic partial nephrectomy. This surgical approach might be appropriate in a young patient with a small exophytic category IIF cyst to alleviate the need for long-term follow-up examinations and in some cases to alleviate patient anxiety while ruling out the possibility (albeit small) of malignancy. This same lesion in an elderly patient would be managed with follow-up imaging. In another example, a complex cystic renal mass with a thick irregular enhancing wall would be placed in category III, and surgery would be indicated. However, if a patient with this lesion had a history of or findings suggestive of infection (even remotely), needle biopsy of the lesion would be indicated. If pus was obtained, catheter drainage would be instituted. In another instance, a category III lesion in an el-

derly debilitated patient who is a poor surgical risk might be followed up, in lieu of surgery.

Although the Bosniak renal cyst classification was developed and based on only CT findings, it is commonly applied to other imaging modalities, including US and MR imaging. Although some complex cystic renal masses may be initially detected with US, in our experience they cannot be accurately characterized by using US alone. Therefore, we do not use US in the evaluation of cystic renal masses, with the exception of proving that a renal mass is a simple cyst (such as in a case of suspected CT pseudoenhancement). On the other hand, MR imaging does have a role in evaluating cystic renal masses, and it is often used when contrast-enhanced CT is contraindicated, such as in patients with renal failure and those with an allergy to iodinated contrast material. In addition, many cystic renal masses are incidentally discovered when MR imaging is performed for another reason. Therefore, it is necessary to be able to accurately characterize these cystic masses by using MR imaging. Our experience suggests that MR imaging can be used reliably to evaluate most cystic renal masses with the Bosniak classification system (48) (Figs 10, 11). MR images may demonstrate some septa that are not depicted at CT and may also show additional thickness of the septa and wall of some lesions, particularly on T2-weighted images. Also, the superior contrast resolution of gadolinium-enhanced T1-weighted MR images compared with that of CT scans may demonstrate definitive enhancement in renal lesions that show only equivocal enhancement at CT. Therefore, it is possible that a cystic renal mass will be placed in a higher Bosniak category with MR imaging than with CT in some cases. This is not a problem in most cases. However, it can create uncertainty in management of masses that appear as category IIF on CT scans but as category III on MR images. Further experience is needed to determine the proper management of these cases in which CT and MR imaging differ, especially those cases that are borderline between categories IIF and III.

As noted in the previous paragraph, the complex internal appearance of some cystic renal masses is more graphically seen on T2-weighted MR images (Figs 10, 11). Often, this complexity within the mass cannot be appreciated on the CT or T1-weighted images, which might show the mass to have a homogeneous appearance. In such cases, a careful evaluation

The Bosniak Renal Cyst Classification System	
Category	Criteria and Management
I	A benign simple cyst with a hairline-thin wall that does not contain septa, calcifications, or solid components; it has water attenuation and does not enhance; no intervention is needed
II	A benign cystic lesion that may contain a few hairline-thin septa in which perceived (not measurable) enhancement may be appreciated; fine calcification or a short segment of slightly thickened calcification may be present in the wall or septa; uniformly high-attenuating lesions (<3 cm) that are sharply marginated and do not enhance are included in this group; no intervention is needed*
IIF†	Cysts may contain multiple hairline-thin septa; perceived (not measurable) enhancement of a hairline-thin smooth septum or wall can be identified; there may be minimal thickening of wall or septa, which may contain calcification that may be thick and nodular, but no measurable contrast enhancement is present (45); there are no enhancing soft-tissue components; totally intrarenal nonenhancing high-attenuating renal lesions (>3 cm) are also included in this category; these lesions are generally well marginated; they are thought to be benign but need follow-up to prove their benignity by showing stability (46)*
III	Cystic masses with thickened irregular or smooth walls or septa and in which measurable enhancement is present; these masses need surgical intervention in most cases, as neoplasm cannot be excluded; this category includes complicated hemorrhagic or infected cysts, multilocular cystic nephroma, and cystic neoplasms; these lesions need histologic diagnosis, as even gross observation by the urologist at surgery or the pathologist at gross pathologic evaluation is frequently indeterminate
IV	Clearly malignant cystic masses that can have all of the criteria of category III but also contain distinct enhancing soft-tissue components independent of the wall or septa; these masses are clearly malignant and need to be removed

*Perceived enhancement refers to enhancement of hairline-thin or minimally thickened walls or septa that can be visually appreciated when comparing unenhanced and contrast-enhanced CT images side-by-side and on subtracted MR imaging datasets. This "enhancement" occurs in hairline-thin or smooth minimally thickened septa/walls and, therefore, cannot be measured or quantified. The authors believe tiny capillaries supply blood (and contrast material) to these septa/walls, which are appreciated because of higher doses of intravenous contrast material and thinner CT and MR imaging sections.

†"F" indicates follow-up needed.

of the unenhanced and contrast-enhanced images at CT or MR imaging is necessary to determine if any of the internal structures depicted on the T2-weighted images enhance with contrast material. If enhancement cannot be demonstrated within these structures, they likely represent a combination of hemorrhage and debris within the lesion. Only if enhancement is present can a surgical mass be diagnosed.

THE ROLE OF RENAL BIOPSY

Renal biopsy for the diagnosis of renal cancer has a limited but defined role. As discussed, it is clearly indicated to diagnose a renal abscess and to differentiate a primary renal cancer from a metastatic neoplasm or lymphoma (35,49). It also has use for tissue diagnosis in patients with unresectable tumors and in patients prior to ablative therapy to be certain a malignancy is present (50).

There are some who believe that renal mass biopsy is useful in evaluating the indeterminate cystic renal mass (51,52). Others, however, believe that biopsy is

unreliable, particularly in indeterminate cystic masses (35,53,54). Truly indeterminate cystic masses (category III) require surgery whether the biopsy specimen is positive or negative for malignant cells. A positive biopsy result merely confirms the need for surgery, and a biopsy result that is negative for malignancy does not alter patient care because there will be uncertainty as to whether or not a sampling error is present. The patient may still have a malignancy, and, therefore, surgical exploration of the lesion is necessary. In some cystic renal carcinomas, the cystic architecture dominates the morphologic appearance of the tumor, there is less solid tissue to sample, and the total population of malignant cells is small in these lesions (35). In addition, once biopsy is performed in a cystic renal mass, the natural history of the mass could be changed. If a decision to perform follow-up examinations is made on the basis of a negative biopsy result, we have found that it can be difficult to know if the change in the mass is secondary to change in its nature or a response to the instrumentation. We believe that a
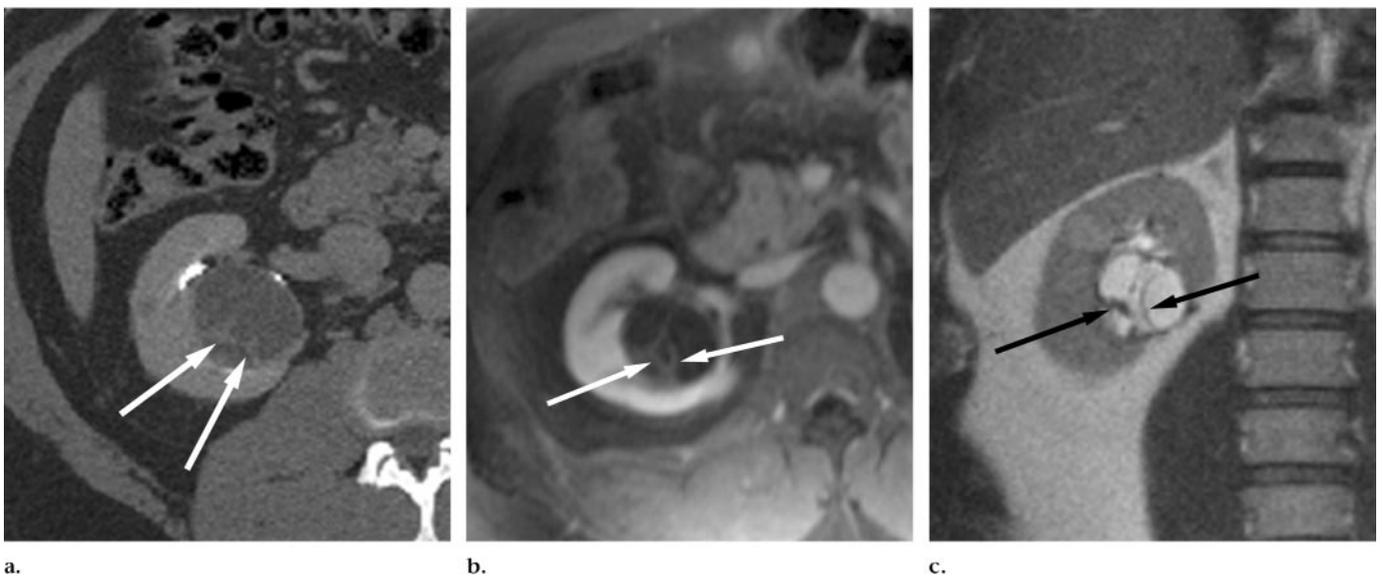
Figure 10. Images in a 56-year-old man with a category III cystic right renal mass. **(a)** Transverse contrast-enhanced CT scan shows a cystic right renal mass that contains enhancing thickened and irregular septa (arrows) consistent with a category III mass. **(b)** Transverse gadolinium-enhanced fat-suppressed T1-weighted MR image (3.6/1.6; 12° flip angle) also shows enhancing thickened and irregular septa (arrows) within the mass, similar to those depicted on **a**. **(c)** Coronal T2-weighted MR image (∞/65; 180° flip angle) better delineates the septa (arrows) within the mass. A multiloculated cystic renal cell carcinoma was diagnosed at surgical pathologic evaluation.
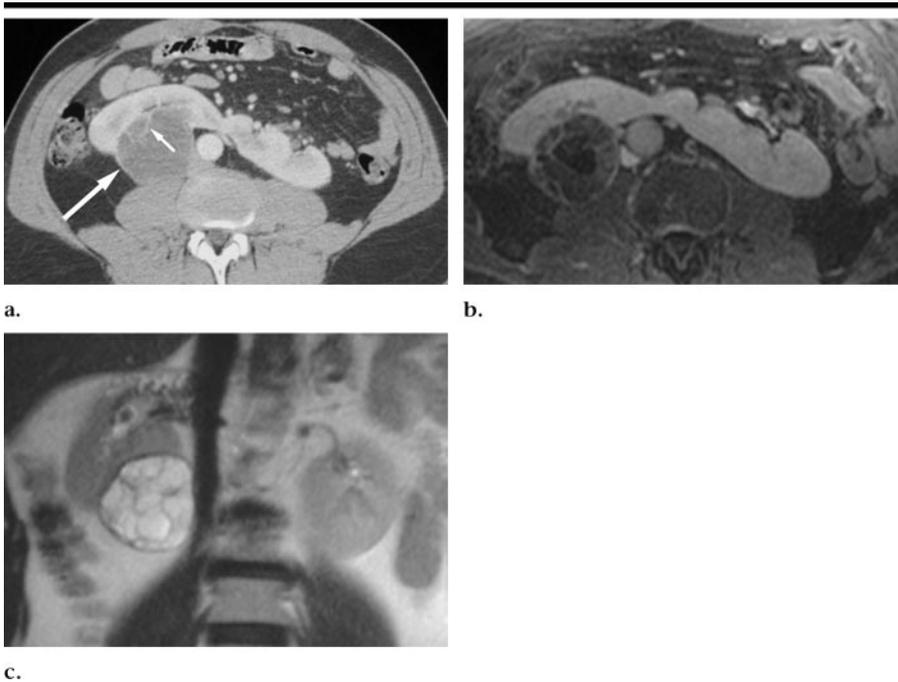

Figure 11. Images in a 61-year-old man with a category III cystic renal mass in the right portion of a horseshoe kidney. **(a)** Transverse contrast-enhanced CT scan shows a cystic renal mass with a thickened wall (large arrow) and thick enhancing septa (small arrow). **(b)** Transverse gadolinium-enhanced fat-suppressed T1-weighted MR image (3.6/1.6; 12° flip angle) shows enhancement within the thickened wall of the mass and within the septa. **(c)** Coronal T2-weighted MR image (∞/65; 180° flip angle) shows the thickened wall of the mass, as well as multiple thickened and slightly nodular septa within the mass. The right portion of the horseshoe kidney was removed and a cystic renal cell carcinoma was diagnosed at surgical pathologic evaluation.

careful evaluation of high-quality imaging studies (combined with follow-up studies in some cases) will allow diagnosis of the overwhelming majority of these cases and that biopsy is an unnecessary and invasive procedure. Finally, as radiologists, we all can agree that the performance of renal biopsy for the diagnosis of an "indeterminate" renal mass, in which the imaging studies are not adequate, is not justified.

CONCLUSION

We have outlined our approach in evaluation of renal masses as of this time. However, with the continuing advances being made in state-of-the-art CT and MR imaging equipment, it is expected that imaging techniques will change and the effect of some imaging findings on patient care will need to be redefined as we gain further experience with these modalities. In any event, accurate imaging diagnosis will still be dependent on the radiologist to perform high-quality imaging examinations, to correlate these imaging findings with clinical and pathologic results, and to be aware of the potential pitfalls in renal mass diagnosis so that the proper management options can be instituted.

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