

**American College of Radiology
ACR Appropriateness Criteria®**

Clinical Condition: **Indeterminate Renal Masses**

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen without and with contrast	9	Either CT or MRI is appropriate. Thin-section CT.	☼☼☼☼
MRI abdomen without and with contrast	8	Either CT or MRI is appropriate. See statement regarding contrast in text under “Anticipated Exceptions.”	O
US kidney retroperitoneal with Doppler	8	To clarify mass that is probably a hyperdense or simple cyst.	O
Biopsy and aspiration kidney	5	Depends on clinical scenario. The appearance and size of mass. US, CT, or MRI may be used for image guidance.	NS
MRI abdomen without contrast	3	Can be useful to characterize simple cysts.	O
Tc-99m DMSA scan kidney	1	May be useful to rule out pseudomass of functioning renal tissue.	☼☼☼
Arteriography kidney	1	To rule out arteriovenous malformation, arteriovenous fistula, or renal artery aneurysm.	☼☼☼
X-ray intravenous urography	1	May be helpful to differentiate parenchymal masses from collecting system masses.	☼☼☼
CT abdomen with contrast	1		☼☼☼
CT abdomen without contrast	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

INDETERMINATE RENAL MASSES

Expert Panel on Urologic Imaging: Gary M. Israel, MD¹; David D. Casalino, MD²; Erick M. Remer, MD³; Ronald S. Arellano, MD⁴; Jay T. Bishoff, MD⁵; Courtney A. Coursey, MD⁶; Manjiri Dighe, MD⁷; Douglas F. Eggli, MD⁸; Pat Fulgham, MD⁹; Stanley Goldfarb, MD¹⁰; Elizabeth Lazarus, MD¹¹; John R. Leyendecker, MD¹²; Paul Nikolaidis, MD¹³; Nicholas Papanicolaou, MD¹⁴; Srinivasa Prasad, MD¹⁵; Parvati Ramchandani, MD¹⁶; Sheila Sheth, MD¹⁷; Raghunandan Vikram, MD.¹⁸

Summary of Literature Review

An indeterminate renal mass is one that cannot be diagnosed confidently as benign or malignant at the time it is discovered. Lesions or masses whose character and type are clearly defined by the first imaging test will not be discussed in this review.

In years past, discovery of a renal mass by excretory urography led to angiography, needle aspiration, or even exploratory surgery to characterize it accurately. The advent of ultrasonography (US) helped resolve many masses found at urography by identifying them clearly as simple cysts. Computed tomography (CT) has eliminated the need for angiographic evaluation of renal mass lesions. Magnetic resonance imaging (MRI) of renal masses with fast scan techniques and intravenous (IV) gadolinium now provides imaging comparable to CT scanning. Radionuclide scintigraphy has in the past been helpful in identifying lobulated functioning renal tissue resembling a more ominous mass, but it has limited applications now. The use of needle aspiration has declined as imaging techniques have improved.

Intravenous Urography

Abdominal radiographs have very poor sensitivity and specificity for evaluating a renal mass. Intravenous urography (IVU) with nephrotomography has only 67% sensitivity in detecting renal masses ≤ 3 cm in diameter [1], and without tomography the sensitivity is even less. In a small series by Curry et al [2] over half of small tumors were not visualized or were missed on the initial IVU. IVU also lacks specificity in separating benign from malignant cystic masses [3]. However, the IVU continues to be an effective single test for imaging renal function and renal anatomy, and in collecting system integrity. It has value in imaging the upper urinary collecting tracts, particularly in a patient with lower-tract transitional neoplasm. CT urography is being used in many centers to evaluate patients with hematuria, as it provides a comprehensive evaluation of the urinary tract and not only can detect renal calculi and masses but also can evaluate the urothelial tract for causes of hematuria [4-5].

Ultrasonography

The most common renal mass is a cyst, and US provides the most cost-effective method of defining and confirming a benign cyst [3]. Factors limiting US include the patient's body habitus, lesion location, multiple lesions, calcification in the wall of a cystic mass, and hemorrhagic fluid in a cystic mass. Early studies have suggested that US may have a problem in detecting small (< 3 cm) renal masses [2-3]. A study of von Hippel-Lindau patients using grayscale US detected only 70% of renal masses < 2 cm, in contrast to CT which showed 95% of the lesions [6]. However, more recent studies using color and power Doppler imaging have shown improved and promising results [7-8]. In one study of 114 patients, phase-inversion harmonic imaging when combined with B-mode sonography improved lesion conspicuity as well as accuracy in tissue characterization [9].

Contrast-enhanced Doppler US using intravenously administered contrast agents has also been shown to have the potential to improve the detection and characterization of renal cell carcinomas, but it is not widely available in the United States [10]. In a small series, US failed to find or accurately characterize 40% of small (≤ 3 cm) renal cell carcinomas [2]. Conversely, in a report of a much larger series by Amendola et al [1] sonography had a sensitivity of 79% in detecting small (≤ 3 cm) renal cell carcinomas. In the future, color Doppler flow imaging with an IV contrast agent may improve sensitivity in detecting tumor vessels and evaluating the renal vein [11].

Previously, sonographic findings of a small hyperechoic mass were considered diagnostic of angiomyolipoma; however, a large series by Yamashita et al [12] showed that 61% of small (≤ 3 cm) solid renal cell carcinomas were hyperechoic relative to normal renal echogenicity, and therefore US cannot be used to make a definitive diagnosis of angiomyolipoma. One finding suggestive of a small-renal-cell carcinoma is a hypoechoic rim about

¹Principal Author, Yale University School of Medicine, New Haven, Connecticut.

²Panel Chair, Northwestern University, Chicago, Illinois.

³Panel Vice-chair, Cleveland Clinic, Cleveland, Ohio.

⁴Massachusetts General Hospital, Boston, Massachusetts.

⁵Intermountain Urological Institute, Murray, Utah, American Urological Association.

⁶Emory University Hospital, Atlanta, Georgia.

⁷University of Washington Medical Center, Seattle, Washington.

⁸Pennsylvania State University, Hershey, Pennsylvania, Society of Nuclear Medicine.

⁹Presbyterian Hospital of Dallas, Dallas, Texas, American Urological Association.

¹⁰University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, American Society of Nephrology.

¹¹Alpert Medical School of Brown University, Providence, Rhode Island.

¹²Wake Forest University School of Medicine, Winston Salem, North Carolina.

¹³Northwestern University, Chicago, Illinois.

¹⁴Hospital of University of Pennsylvania, Philadelphia, Pennsylvania.

¹⁵University of Texas Health Science Center, San Antonio, Texas.

¹⁶University of Pennsylvania Hospital, Philadelphia, Pennsylvania.

¹⁷Johns Hopkins Hospital, Baltimore, Maryland.

¹⁸University of Texas MD Anderson Cancer Center, Houston, Texas.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

the solid tumor [12-13]. Doppler US has been suggested as a way to further characterize solid masses; in the absence of clinical evidence of infection, a Doppler frequency shift >2.5 kHz is advocated by some as a reliable indicator of malignancy [14-15]. However, US can be falsely negative with avascular tumor masses and falsely positive with inflammatory masses.

Renal cysts are the most commonly discovered renal masses, and the criteria for US diagnosis of renal cysts are well defined. These criteria include that the mass is sonolucent, demonstrates good through-transmission of the sound waves with posterior enhancement, and has a thin, well-defined wall. Complex masses not fulfilling the criteria of cysts are considered indeterminate and require further evaluation, usually by CT.

Computed Tomography

The accepted criteria of a benign simple cyst are well-defined [16]. Bosniak has developed a CT classification system for cystic renal masses, encompassing the spectrum from simple renal cyst to obvious cystic malignancy [17-18]. A cyst that contains simple fluid, has a hairline-thin wall, does not contain septa or calcification, and does not enhance with IV contrast is category I, a benign cyst. Category II cysts have a hairline-thin wall and may contain a few hairline-thin septa. Hairline-thin calcification or a short segment of slightly thickened but smooth calcification may be seen in category II lesions. These lesions do not show measurable enhancement with IV contrast. High-attenuation cysts are also included in category II. Initial reports indicated that category II cysts are invariably benign [19-21]. The hyperdense cyst can also present a diagnostic problem in that its initial attenuation coefficients are high (>20 Hounsfield units [HU]) which can theoretically obscure tiny papillary projections along its wall. US may be useful in characterizing some of these high-attenuation lesions, as approximately 50% of them will be anechoic and can be characterized as benign [22].

While US is superior to CT in depicting the internal features of cystic renal masses, the presence of calcium can obscure other features. In these instances, CT can be useful to characterize these lesions, as the presence of a small amount of calcium does not hinder characterization [20-21].

Category IIF cysts are those cystic renal masses that are felt to be benign but are too complex to be diagnosed with absolute certainty. They have one or more of the following abnormalities: increased number of hairline septa; minimal thickening of cyst wall or septa, which may demonstrate perceived (not measurable) enhancement of septa or cyst wall; calcification, which may be thick and nodular [23]; no enhancing soft-tissue components; and totally intrarenal high-attenuation lesions ≥ 3 cm in size. These lesions, in view of their complexity when compared to category II lesions, warrant follow-up (usually at 6-month intervals for the first year, and then annually for a minimum of 5 years), to assure stability [16]. Israel and Bosniak [24] reported a series of

42 category IIF lesions with a minimum of 2-year follow-up and showed that most of them were stable (>5-year mean follow-up) and only in two cases did the lesion become more complex and subsequently prove to be renal cell carcinoma.

Category III lesions have grossly thickened walls or septa in which measurable enhancement can be demonstrated. Category III lesions are indeterminate and include diagnoses such as multilocular cystic renal cell carcinoma, multilocular cystic nephroma, multilocular hemorrhagic cyst, and chronic renal abscess. In general, malignancy cannot be excluded in these cases, and surgery is usually suggested (with the exception of a chronic renal abscess).

Initially, it was felt that about half of category III cystic lesions will be malignant, but reported percentages vary from 25%-100% [19-20]. However, with the introduction of category IIF, some lesions that were initially felt to be category III are now considered category IIF and are followed, in lieu of surgery. Therefore, the overall percentage of malignancy within category III is felt to have increased.

Identification of enhancement after IV contrast is a key determinant in characterizing a renal mass as potentially malignant. CT is the most important imaging technique for evaluating the indeterminate renal mass. Images acquired before and after contrast are critical to define the lesion; enhancement indicates a vascularized mass and therefore a possible malignancy. Initially, enhancement of more than 10 HU was considered by Bosniak and others [22,25-26] to be significant. However, with the introduction of helical CT scanners, others suggest an increase of 20 HU to be indicative of enhancement [27-28]. Sensitivity of CT in identifying small renal masses is greater than 90% [1]. Analysis of enhancement for neoplasm is best done in the nephrographic phase of helical CT imaging of the kidneys [25]. False negatives may occur in the corticomedullary phase.

Although the Bosniak classification scheme is very useful for the clinical management of cystic renal masses, interobserver variation in distinguishing between category II, IIF, and III lesions does exist and may present problems in recommending surgical versus conservative management in some cases. In a study by Siegel et al [29] 11 (16%) of 70 cystic lesions classified as category I or II by one reader were upgraded to category III or IV by another reader.

CT enables detection of small amounts of fat that identifies the lesion as a benign angiomyolipoma [30]. Fat related to other malignant neoplasms has been reported, but these masses are generally large tumors that have engulfed perinephric or renal sinus fat, or renal carcinomas that have areas of osseous metaplasia and small amounts of fat. Macroscopic fat within a noncalcified mass remains specific for benign angiomyolipoma [20,31]. For angiomyolipomas that do not contain macroscopic fat, chemical shift MRI may suggest the diagnosis by demonstrating loss of signal on

the opposed-phase images [32]. However, clear-cell renal cell carcinoma may also lose signal on opposed-phase MRI images, and therefore the diagnosis of an angiomyolipoma that does not contain macroscopic fat cannot be made with absolute certainty with CT or MRI. Approximately 5% of angiomyolipomas contain little or no fat and have the appearance of small hyperattenuating (at unenhanced CT) homogeneously enhancing masses [33-34]. These angiomyolipomas are also hypointense on T2-weighted MR images secondary to their smooth muscle content [35]. However, other solid renal masses may have a similar imaging appearance [35]. Therefore, when a mass has a typical appearance of an angiomyolipoma with minimal fat, it is suggested that the mass be biopsied for definitive diagnosis.

Oncocytomas cannot be diagnosed based on their imaging appearance. The CT finding of a central scar, previously felt to be specific for oncocytoma, has been found with renal cell carcinomas, and the finding is not specific [36-37]. As reported by Davidson et al [36] CT findings of homogeneity or a central stellate “scar” are poor discriminators in predicting oncocytoma or renal cell carcinoma, regardless of size.

The small (≤ 1.5 cm in diameter) renal mass poses a more complex problem for CT imaging, in that volume-averaging effects occur, making it difficult to assess accurately the density on noncontrast images and to evaluate for enhancement after IV contrast administration [22,26-27]. Among the more difficult entities to differentiate from a small renal cell carcinoma are a small dense cyst containing blood or proteinaceous material [1] and a simple cyst that demonstrates pseudo enhancement. Multidetector CT using thin overlapping reconstructions may help improve characterization of small renal masses. In a multidetector CT study of 37 patients with 175 small (< 3 cm) renal masses, thin overlapping reconstructions were performed and compared to routine 5-mm-thick sections to determine if the thin overlapping reconstructions could improve detection and characterization of small renal masses. Lesion characterization for cysts improved from 29%-84% when thin overlapping reconstructions were used, and the overall percentage of indeterminate lesions was reduced from 69% to 53% [38].

Very small solid renal nodules are common; in one study more than 50% of patients had some type of very small renal nodule at necropsy, and about one-third of these were termed “adenomas” [39]. The small renal adenoma is currently considered to be a “renal adenocarcinoma of low metastatic potential” [40-41]. The low metastatic potential of small renal cell carcinomas (≤ 3 cm in diameter) is supported by many series [1,26,40,42-45]. In the elderly or in a patient who is a poor surgical risk, some advocate following small solid masses in lieu of surgery [26,46]. In the general population, a solid lesion should be considered and treated as a malignancy [31,47]. If the patient’s clinical condition militates against surgery or if there is surgical risk of causing the patient to become dialysis-dependent, such lesions, because of their low

metastatic potential when small, can be followed with CT or MRI [46]. Surgery is reconsidered if the mass shows rapid growth [26-27].

The effect of early detection of a very small renal mass by current technology operates insidiously to alter our perception of how radiological tests affect patient care, especially the detection and management data affected by “length bias” and “lead bias” [48]. Therefore, a “wait and see” approach is especially appropriate for managing the very small, asymptomatic, indeterminate renal mass in an elderly patient [48]. For a younger, healthy patient, a solid mass > 1 cm is usually surgically treated (except for angiomyolipoma) [46]. Although there are no data to suggest how to manage very small (< 1 cm) renal masses, some feel that if the lesion in question appears to be a simple cyst — that is, a low-attenuation (0-20 HU) mass containing no septations, nodularity, calcifications, or enhancement — it can be presumed to be benign and need not be further pursued [46].

Magnetic Resonance Imaging

With the exception of angiomyolipomas and simple renal cysts, unenhanced MRI cannot characterize renal masses. However, MRI using IV gadolinium contrast agents now provides sensitivity and specificity similar to those of CT in detecting contrast enhancement and identifying a mass requiring surgery [49-53]. Previously it was felt that MRI with gadolinium was particularly applicable to patients with renal insufficiency for whom conventional contrast would be significantly nephrotoxic [51]. However, it has been suggested recently that the development of nephrogenic systemic fibrosis is associated with the administration of gadolinium in patients with renal failure, and further studies are necessary to determine this exact relationship [54]. Gadolinium is still felt to be safe in patients with a history of allergy to conventional contrast agents.

Ho et al [55] demonstrated that it is possible to calculate percentage of enhancement of renal masses at MRI and that this can be used to characterize renal masses. In another study, 73 patients with 93 renal masses underwent contrast-enhanced MRI, and quantitative enhancement with signal intensity measurement analysis (percentage enhancement) was compared to qualitative analysis of enhancement with image subtraction to determine which was superior for detecting malignancy. Sensitivity and specificity for diagnosing malignancy based on enhancement were 95% and 53%, respectively, for quantitative analysis and 99% and 58%, respectively, for qualitative analysis. Three of four malignant lesions incorrectly assigned as benign by quantitative method were hyperintense on unenhanced MRI. All were accurately diagnosed as being malignant by qualitative method [56].

In a study [57] of 69 cystic renal masses evaluated using the Bosniak classification with CT and MRI, there was CT and MRI agreement in 56 of 69 lesions (81%) and disagreement in 13 of 69 lesions (19%). CT and MRI were felt to be similar in evaluation of most renal cystic

mass lesions. However, MRI may depict additional findings such as an increase in number of septa, septal and/or wall thickness, and enhancement. Such findings would result in MRI upgrading cystic lesions and thus might alter patient management. The authors recommend caution in interpreting MRI of complex cystic renal masses, and more specifically those that are borderline between categories IIF and III, without additional correlative imaging.

Nuclear Medicine

Radionuclide scintigraphy with a cortical imaging agent (eg, DMSA) has a limited role in evaluating the indeterminate renal mass, being used primarily to identify the so-called column of Bertin or junctional zone, which may be causing a pseudotumor effect on IVU or US [20]. Fluorine-18-2-fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET) may prove to be useful in detecting renal tumors and characterizing indeterminate renal cysts. Although there were false negatives in both the tumor group and the indeterminate cyst group, there were no false positives [58]. Others have reported varying accuracies for detecting renal cell carcinoma, but in general the low sensitivity of FDG-PET for renal cell carcinoma detection and characterization has limited its use for this purpose [59-60].

Angiography

Although two-thirds of renal tumors have enough vascularity to allow identification of tumor neovascularity, one-third will be of such a hypovascular or “avascular” state that angiography will not help identify the lesion as benign or malignant [27]. This is even true of renal carcinomas presenting with acute perirenal hemorrhage. For some applications of nephron-sparing surgery for small renal neoplasms, the urologic surgeon uses aortography or selective angiography to provide a road map to assist in resection.

Aspiration and Biopsy

Biopsy of the indeterminate renal mass has a limited role in the current era of high-quality imaging. In a survey by the Society of Uroradiology [61] reporting on approximately 16,000 cases, 92% of uroradiologists accepted the US findings of a cyst as being sufficient for diagnosis, and 100% accepted the CT criteria of a simple or category II cyst as being sufficiently diagnostic. If cyst aspiration is done, cytologic evaluation is considered the laboratory study of choice. Although aspiration of clear fluid usually indicates a benign cyst, clear fluid was found in 19 cystic renal cell carcinomas, only 11 of which had positive cytologic evaluation. Therefore, the gross and laboratory analysis of aspirated fluid is not conclusive, and CT is considered the gold standard in evaluating cystic masses [61]. However, aspiration or biopsy does have certain indications: confirmation of an infected cyst or abscess, and identification of lymphoma or a metastasis in a kidney when either diagnosis would affect clinical management.

In the last few years, in part due to the development of new techniques in histological and molecular analysis, the

indications for renal mass biopsy have increased and now include the following: confirmation of renal cell carcinoma when the surgical risk is high, when disease is either locally advanced or metastatic, when a solid mass is present in a solitary or transplant kidney, and prior to ablative therapies [62-65].

Summary

- CT is the modality of choice for evaluating indeterminate renal lesions that are suspicious for malignancy.
- For those patients who cannot tolerate iodinated IV contrast material due to allergy, MRI with gadolinium contrast is advised.
- US may be useful to clarify a mass seen on CT that is probably a hyperdense cyst.
- Newer techniques have shown that MRI is also capable of characterizing indeterminate renal masses.
- When CT and MRI are compared in the evaluation of cystic renal masses, MRI appears to be more sensitive and tends to upgrade cystic lesions. Thus caution is advised when using MRI findings to direct clinical management at this time.
- Radionuclide scintigraphy has a role limited to confirming normal renal tissue.
- Angiography is used primarily to define vascular anatomy before nephron-sparing surgery.
- Renal aspiration or biopsy has few but emerging indications: confirming an infected cyst, identifying lymphoma or a metastasis as the cause of the indeterminate renal mass, and confirming renal cell carcinoma in certain circumstances, including prior to ablative therapies.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, $<30 \text{ mL/min/1.73m}^2$), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates $<30 \text{ mL/min/1.73m}^2$. For more information, please see the [ACR Manual on Contrast Media](#) [66].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated

with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
⊕	<0.1 mSv	<0.03 mSv
⊕⊕	0.1-1 mSv	0.03-0.3 mSv
⊕⊕⊕	1-10 mSv	0.3-3 mSv
⊕⊕⊕⊕	10-30 mSv	3-10 mSv
⊕⊕⊕⊕⊕	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).

Supporting Document(s)

- [ACR Appropriateness Criteria® Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

References

1. Amendola MA, Bree RL, Pollack HM, et al. Small renal cell carcinomas: resolving a diagnostic dilemma. *Radiology* 1988; 166(3):637-641.
2. Curry NS, Schabel SI, Betsill WL, Jr. Small renal neoplasms: diagnostic imaging, pathologic features, and clinical course. *Radiology* 1986; 158(1):113-117.
3. Einstein DM, Herts BR, Weaver R, Obuchowski N, Zepp R, Singer A. Evaluation of renal masses detected by excretory urography: cost-effectiveness of sonography versus CT. *AJR* 1995; 164(2):371-375.
4. Caoili EM, Cohan RH, Korobkin M, et al. Urinary tract abnormalities: initial experience with multi-detector row CT urography. *Radiology* 2002; 222(2):353-360.
5. Joffe SA, Servaes S, Okon S, Horowitz M. Multi-detector row CT urography in the evaluation of hematuria. *Radiographics* 2003; 23(6):1441-1455; discussion 1455-1446.
6. Jamis-Dow CA, Choyke PL, Jennings SB, Linehan WM, Thakore KN, Walther MM. Small (< or = 3-cm) renal masses: detection with CT versus US and pathologic correlation. *Radiology* 1996; 198(3):785-788.

7. Helenon O, Correas JM, Balleyguier C, Ghouadni M, Cornud F. Ultrasound of renal tumors. *Eur Radiol* 2001; 11(10):1890-1901.
8. Riccabona M, Szolar D, Preidler K, et al. Renal masses--evaluation by amplitude coded colour Doppler sonography and multiphasic contrast-enhanced CT. *Acta Radiol* 1999; 40(4):457-461.
9. Schmidt T, Hohl C, Haage P, et al. Diagnostic accuracy of phase-inversion tissue harmonic imaging versus fundamental B-mode sonography in the evaluation of focal lesions of the kidney. *AJR* 2003; 180(6):1639-1647.
10. Reichelt O, Wunderlich H, Weirich T, Schlichter A, Schubert J. Computerized contrast angiosonography: a new diagnostic tool for the urologist? *BJU Int* 2001; 88(1):9-14.
11. Filippone A, Muzi M, Basilio R, Di Giandomenico V, Trapani AR, Bonomo L. Color Doppler flow imaging of renal disease. Value of a new intravenous contrast agent: SH U 508 A (Levovist). *Radiol Med (Torino)* 1994; 87(5 Suppl 1):50-58.
12. Yamashita Y, Takahashi M, Watanabe O, et al. Small renal cell carcinoma: pathologic and radiologic correlation. *Radiology* 1992; 184(2):493-498.
13. Siegel CL, Middleton WD, Teefey SA, McClennan BL. Angiomyolipoma and renal cell carcinoma: US differentiation. *Radiology* 1996; 198(3):789-793.
14. Jinzaki M, Ohkuma K, Tanimoto A, et al. Small solid renal lesions: usefulness of power Doppler US. *Radiology* 1998; 209(2):543-550.
15. Kier R, Taylor KJ, Feyock AL, Ramos IM. Renal masses: characterization with Doppler US. *Radiology* 1990; 176(3):703-707.
16. McClennan BL, Stanley RJ, Melson GL, Levitt RG, Sagel SS. CT of the renal cyst: is cyst aspiration necessary? *AJR* 1979; 133(4):671-675.
17. Bosniak MA. The current radiological approach to renal cysts. *Radiology* 1986; 158(1):1-10.
18. Bosniak MA. Difficulties in classifying cystic lesions of the kidney. *Urol Radiol* 1991; 13(2):91-93.
19. Amis ES, Jr., Newhouse J. Essentials of Uroradiology. Boston: Little, Brown & Co. 1991:146-147.
20. Aronson S, Frazier HA, Baluch JD, Hartman DS, Christenson PJ. Cystic renal masses: usefulness of the Bosniak classification. *Urol Radiol* 1991; 13(2):83-90.
21. Bosniak MA. How does one deal with a renal cyst that appears to be Bosniak class II on a CT scan but that has sonographic features suggestive of malignancy (e.g., nodularity of wall or a nodular, irregular septum)? *AJR* 1994; 163(1):216.
22. Silverman SG, Lee BY, Seltzer SE, Bloom DA, Corless CL, Adams DF. Small (< or = 3 cm) renal masses: correlation of spiral CT features and pathologic findings. *AJR* 1994; 163(3):597-605.
23. Israel GM, Bosniak MA. Calcification in cystic renal masses: is it important in diagnosis? *Radiology* 2003; 226(1):47-52.
24. Israel GM, Bosniak MA. Follow-up CT of moderately complex cystic lesions of the kidney (Bosniak category IIF). *AJR* 2003; 181(3):627-633.
25. Birnbaum BA, Jacobs JE, Ramchandani P. Multiphasic renal CT: comparison of renal mass enhancement during the corticomedullary and nephrographic phases. *Radiology* 1996; 200(3):753-758.
26. Bosniak MA. The small (less than or equal to 3.0 cm) renal parenchymal tumor: detection, diagnosis, and controversies. *Radiology* 1991; 179(2):307-317.
27. Curry NS. Small renal masses (lesions smaller than 3 cm): imaging evaluation and management. *AJR* 1995; 164(2):355-362.
28. Helenon O, Chretien Y, Paraf F, Melki P, Denys A, Moreau JF. Renal cell carcinoma containing fat: demonstration with CT. *Radiology* 1993; 188(2):429-430.
29. Siegel CL, McFarland EG, Brink JA, Fisher AJ, Humphrey P, Heiken JP. CT of cystic renal masses: analysis of diagnostic performance and interobserver variation. *AJR* 1997; 169(3):813-818.
30. Bosniak MA, Megibow AJ, Hulnick DH, Horii S, Raghavendra BN. CT diagnosis of renal angiomyolipoma: the importance of detecting small amounts of fat. *AJR* 1988; 151(3):497-501.
31. Licht MR, Novick AC. Nephron sparing surgery for renal cell carcinoma. *J Urol* 1993; 149(1):1-7.
32. Kim JK, Kim SH, Jang YJ, et al. Renal angiomyolipoma with minimal fat: differentiation from other neoplasms at double-echo

- chemical shift FLASH MR imaging. *Radiology* 2006; 239(1):174-180.
33. Jinzaki M, Tanimoto A, Narimatsu Y, et al. Angiomyolipoma: imaging findings in lesions with minimal fat. *Radiology* 1997; 205(2):497-502.
 34. Kim JK, Park SY, Shon JH, Cho KS. Angiomyolipoma with minimal fat: differentiation from renal cell carcinoma at biphasic helical CT. *Radiology* 2004; 230(3):677-684.
 35. Silverman SG, Morteale KJ, Tuncali K, Jinzaki M, Cibas ES. Hyperattenuating renal masses: etiologies, pathogenesis, and imaging evaluation. *Radiographics* 2007; 27(4):1131-1143.
 36. Davidson AJ, Hayes WS, Hartman DS, McCarthy WF, Davis CJ, Jr. Renal oncocytoma and carcinoma: failure of differentiation with CT. *Radiology* 1993; 186(3):693-696.
 37. Wildberger JE, Adam G, Boeckmann W, et al. Computed tomography characterization of renal cell tumors in correlation with histopathology. *Invest Radiol* 1997; 32(10):596-601.
 38. Jinzaki M, McTavish JD, Zou KH, Judy PF, Silverman SG. Evaluation of small (≤ 3 cm) renal masses with MDCT: benefits of thin overlapping reconstructions. *AJR* 2004; 183(1):223-228.
 39. Xipell JM. The incidence of benign renal nodules (a clinicopathologic study). *J Urol* 1971; 106(4):503-506.
 40. Birnbaum BA, Bosniak MA, Megibow AJ, Lubat E, Gordon RB. Observations on the growth of renal neoplasms. *Radiology* 1990; 176(3):695-701.
 41. Peterson RO, Sesterhenn IA, Davis DJ. *Urologic Pathology*. 3rd ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 1986.
 42. Evins SC, Varner W. Renal adenoma -- a misnomer. *Urology* 1979; 13(1):85-86.
 43. Levine E, Huntrakoon M, Wetzel LH. Small renal neoplasms: clinical, pathologic, and imaging features. *AJR* 1989; 153(1):69-73.
 44. Smith SJ, Bosniak MA, Megibow AJ, Hulnick DH, Horii SC, Raghavendra BN. Renal cell carcinoma: earlier discovery and increased detection. *Radiology* 1989; 170(3 Pt 1):699-703.
 45. Bennington JL. Renal adenoma. *World Journal of Urology* 1987; 5(2):66-70.
 46. Silverman SG, Israel GM, Herts BR, Richie JP. Management of the incidental renal mass. *Radiology* 2008; 249(1):16-31.
 47. Novick AC. Partial nephrectomy for renal cell carcinoma. *Urol Clin North Am* 1987; 14(2):419-433.
 48. Black WC, Ling A. Is earlier diagnosis really better? The misleading effects of lead time and length biases. *AJR* 1990; 155(3):625-630.
 49. Eilenberg SS, Lee JK, Brown J, Mirowitz SA, Tartar VM. Renal masses: evaluation with gradient-echo Gd-DTPA-enhanced dynamic MR imaging. *Radiology* 1990; 176(2):333-338.
 50. Kreft BP, Muller-Miny H, Sommer T, et al. Diagnostic value of MR imaging in comparison to CT in the detection and differential diagnosis of renal masses: ROC analysis. *Eur Radiol* 1997; 7(4):542-547.
 51. Rofsky NM, Weinreb JC, Bosniak MA, Libes RB, Birnbaum BA. Renal lesion characterization with gadolinium-enhanced MR imaging: efficacy and safety in patients with renal insufficiency. *Radiology* 1991; 180(1):85-89.
 52. Semelka RC, Hricak H, Stevens SK, Finegold R, Tomei E, Carroll PR. Combined gadolinium-enhanced and fat-saturation MR imaging of renal masses. *Radiology* 1991; 178(3):803-809.
 53. Yamashita Y, Miyazaki T, Hatanaka Y, Takahashi M. Dynamic MRI of small renal cell carcinoma. *J Comput Assist Tomogr* 1995; 19(5):759-765.
 54. Grobner T. Gadolinium--a specific trigger for the development of nephrogenic fibrosing dermopathy and nephrogenic systemic fibrosis? *Nephrol Dial Transplant* 2006; 21(4):1104-1108.
 55. Ho VB, Allen SF, Hood MN, Choyke PL. Renal masses: quantitative assessment of enhancement with dynamic MR imaging. *Radiology* 2002; 224(3):695-700.
 56. Hecht EM, Israel GM, Krinsky GA, et al. Renal masses: quantitative analysis of enhancement with signal intensity measurements versus qualitative analysis of enhancement with image subtraction for diagnosing malignancy at MR imaging. *Radiology* 2004; 232(2):373-378.
 57. Israel GM, Hindman N, Bosniak MA. Evaluation of cystic renal masses: comparison of CT and MR imaging by using the Bosniak classification system. *Radiology* 2004; 231(2):365-371.
 58. Goldberg MA, Mayo-Smith WW, Papanicolaou N, Fischman AJ, Lee MJ. FDG PET characterization of renal masses: preliminary experience. *Clin Radiol* 1997; 52(7):510-515.
 59. Aide N, Cappele O, Bottet P, et al. Efficiency of [(18)F]FDG PET in characterising renal cancer and detecting distant metastases: a comparison with CT. *Eur J Nucl Med Mol Imaging* 2003; 30(9):1236-1245.
 60. Kang DE, White RL, Jr., Zuger JH, Sasser HC, Teigland CM. Clinical use of fluorodeoxyglucose F 18 positron emission tomography for detection of renal cell carcinoma. *J Urol* 2004; 171(5):1806-1809.
 61. Amis ES, Jr., Cronan JJ, Pfister RC. Needle puncture of cystic renal masses: a survey of the Society of Uroradiology. *AJR* 1987; 148(2):297-299.
 62. Lechevallier E, Andre M, Barriol D, et al. Fine-needle percutaneous biopsy of renal masses with helical CT guidance. *Radiology* 2000; 216(2):506-510.
 63. Maturen KE, Nghiem HV, Caoili EM, Higgins EG, Wolf JS, Jr., Wood DP, Jr. Renal mass core biopsy: accuracy and impact on clinical management. *AJR* 2007; 188(2):563-570.
 64. Rybicki FJ, Shu KM, Cibas ES, Fielding JR, vanSonnenberg E, Silverman SG. Percutaneous biopsy of renal masses: sensitivity and negative predictive value stratified by clinical setting and size of masses. *AJR* 2003; 180(5):1281-1287.
 65. Silverman SG, Gan YU, Morteale KJ, Tuncali K, Cibas ES. Renal masses in the adult patient: the role of percutaneous biopsy. *Radiology* 2006; 240(1):6-22.
 66. American College of Radiology. *Manual on Contrast Media*. Available at: http://www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.