IMPROVING IMAGING DIAGNOSIS OF RENAL MASS LESIONS

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Abstract. *Renal mass lesions are increasingly detected in daily clinical practice because ultrasonography, computed tomography, and magnetic resonance imaging are now widely used for abdominal evaluation. The main diagnostic challenge is not only detecting a renal lesion, but also accurately distinguishing benign from malignant masses, characterizing cystic versus solid lesions, defining local extent, and guiding further management. Contemporary imaging relies on a stepwise pathway in which ultrasound often serves as the first-line modality, while multiphasic contrast-enhanced CT remains the principal method for characterization and staging; MRI is particularly valuable when CT findings are equivocal or iodinated contrast is undesirable. Diagnostic performance can be improved through standardized imaging protocols, multiphasic enhancement assessment, consistent use of Bosniak 2019 criteria for cystic masses, careful integration of clinical data, and selective use of renal mass biopsy. Emerging tools such as contrast-enhanced ultrasound, radiomics, machine learning, and molecular imaging with sestamibi SPECT/CT or PSMA PET/CT may further refine noninvasive diagnosis. Although these innovations are promising, most remain adjuncts rather than replacements for conventional cross-sectional imaging. A structured multimodal strategy offers the best opportunity to improve accuracy, reduce unnecessary surgery, and optimize patient-specific management. (ACSearch)*

Keywords: *Renal mass; kidney tumor; imaging diagnosis; computed tomography; magnetic resonance imaging; contrast-enhanced ultrasound; Bosniak classification; radiomics.*

Introduction

Renal masses include a wide spectrum of entities, ranging from simple cysts and angiomyolipomas to oncocytomas and renal cell carcinoma. Because abdominal imaging is performed more frequently than before, many renal lesions are now found incidentally and at smaller sizes than in the past. This epidemiologic shift has increased the importance of precise imaging characterization, since not every detected mass requires the same

treatment. The central goal of imaging is therefore to identify lesions that are clearly benign, recognize features suggesting malignancy, assess stage, and support rational treatment planning. (Uroweb)

In modern practice, no single modality answers every question. Ultrasound is accessible and useful for screening, but multiphasic contrast-enhanced CT remains the reference standard for most indeterminate renal masses. MRI complements CT by improving tissue characterization, depicting enhancement when CT is inconclusive, and helping in patients with contraindications to iodinated contrast. Current guidelines emphasize enhancement analysis, lesion morphology, and staging information as the core of radiologic evaluation. On CT, enhancement of about 15 Hounsfield units or more in the solid component supports the presence of viable tumor tissue. (Uroweb)

Contemporary imaging pathway

The contemporary imaging pathway usually begins with conventional ultrasonography, especially when the lesion is found during evaluation of flank pain, hematuria, or a nonspecific abdominal complaint. Ultrasound can readily identify simple cysts and may detect a solid or complex mass, but it is less reliable for complete characterization of indeterminate lesions, particularly small masses or deeply located tumors. Therefore, lesions that are not definitively benign on ultrasound are commonly referred for contrast-enhanced CT or MRI. (PubMed)

For most patients, multiphasic contrast-enhanced CT is the main diagnostic examination. Guideline-based CT evaluation includes an unenhanced phase and post-contrast phases, typically including corticomedullary and nephrographic assessment, to demonstrate enhancement, internal architecture, necrosis, calcification, and vascular involvement. CT also provides key staging data such as perinephric extension, venous tumor thrombus, nodal enlargement, and distant abdominal spread. This comprehensive role explains why CT remains the backbone of renal mass workup. (Uroweb)

MRI is used when CT is indeterminate, when a lesion is small and difficult to characterize, or when iodinated contrast exposure should be avoided. MRI is particularly helpful for detecting enhancement in equivocal cystic masses, evaluating fat-poor angiomyolipoma, and clarifying complex anatomy. In cystic lesions, the Bosniak 2019 framework has become an important standardization tool, helping radiologists classify malignancy risk more consistently across CT and MRI. (Radiology Assistant)

How diagnostic performance can be improved

Diagnostic performance can be improved first by **standardizing protocols**. Nonoptimized studies are a common cause of uncertainty. A renal mass protocol should be designed specifically to assess enhancement, since enhancement is the main imaging sign separating solid tumor from a hyperdense cyst or pseudolesion. Incomplete phases, motion artifact, and inconsistent contrast timing reduce interpretive accuracy and may lead to both false reassurance and overcalling of benign lesions. (Uroweb)

Second, performance improves when radiologists use **structured classification systems** rather than subjective impressions alone. For cystic renal lesions, Bosniak 2019

helps reduce variability by defining imaging criteria in a more reproducible way. For solid masses, a structured report that comments on size, enhancement pattern, fat content, necrosis, collecting-system involvement, vascular invasion, and metastatic signs is more clinically useful than a purely descriptive narrative. (Radiology Assistant)

Third, diagnostic yield increases when imaging is interpreted together with **clinical and laboratory context**. Patient age, hereditary cancer syndromes, renal function, symptoms, and prior oncologic history can alter the probability of benign versus malignant disease. In selected cases, renal mass biopsy can be integrated when imaging remains equivocal and the result is likely to change management. Current guidelines support considering biopsy before ablative therapy and in selected patients who are candidates for active surveillance or systemic treatment decisions. (Uroweb)

Fourth, greater use of **contrast-enhanced ultrasound (CEUS)** may improve characterization, particularly for complex cystic lesions and in patients who should avoid CT or MRI contrast. According to ACR material, CEUS has shown high sensitivity for characterizing cystic renal masses and in some studies has been more sensitive than contrast-enhanced CT for this purpose. Recent reviews likewise describe CEUS as an increasingly valuable alternative for renal mass characterization, although availability and operator dependence still limit universal adoption. (ACSearch)

Emerging tools

Several emerging tools may further improve renal mass imaging. One important area is **radiomics and machine learning**, where quantitative features extracted from CT or MRI are used to distinguish benign from malignant tumors and even suggest subtype. Recent studies indicate that radiomics can achieve useful discrimination, especially for angiomyolipoma and some RCC subtypes, but reproducibility and external validation remain major concerns. A 2024 study on MRI-based radiomics reported only fair accuracy for differentiating RCC from benign renal masses, and another 2024 analysis showed that oncocytoma remains particularly difficult to classify accurately. These findings suggest promise, but not readiness for routine standalone use. (PubMed)

A second area is **molecular imaging**. Sestamibi SPECT/CT has attracted attention because benign oncocytic neoplasms, especially oncocytoma and hybrid oncocytic/chromophobe tumors, may show distinctive uptake patterns. A 2024 review concluded that sestamibi SPECT/CT demonstrates good sensitivity and specificity for differentiating these tumors from more aggressive lesions, although evidence is still insufficient for universal routine implementation outside specialist pathways. This technique may eventually reduce unnecessary surgery for selected small solid renal masses. (PubMed)

Another promising modality is **PSMA PET/CT**, especially in clear-cell RCC and advanced disease. Current evidence suggests that PSMA PET/CT may detect metastatic lesions better than conventional imaging in some settings and may influence treatment planning, but its role in primary characterization of localized renal masses is still evolving. Reviews from 2024 and 2025 describe encouraging diagnostic performance, particularly

in staging and restaging, while also emphasizing the need for larger prospective studies before broad guideline adoption. (PubMed)

Conclusion

Improvement of imaging diagnosis of renal mass lesions depends less on finding a single perfect test and more on building a **structured multimodal pathway**. Ultrasound remains useful for detection, multiphasic contrast-enhanced CT remains central for characterization and staging, and MRI serves as a critical problem-solving tool. Diagnostic accuracy can be increased through optimized protocols, standardized reporting, Bosniak-based assessment of cystic lesions, and selective integration of CEUS and biopsy. Emerging technologies such as radiomics, sestamibi SPECT/CT, and PSMA PET/CT are promising and may eventually reduce diagnostic uncertainty, but they currently function best as adjuncts to established cross-sectional imaging. Overall, the most effective strategy for renal mass evaluation is a patient-specific, evidence-based combination of conventional and innovative imaging methods. (ACSearch)

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