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SOLICITED REVIEW / *Genitourinary imaging*

Characterization of small (<4 cm) solid renal masses by computed tomography and magnetic resonance imaging: Current evidence and further development

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Abstract Diagnosis of renal cell carcinomas (RCC) subtypes on computed tomography (CT) and magnetic resonance imaging (MRI) is clinically important. There is increased evidence that confident imaging diagnosis is now possible while standardization of the protocols is still required. Fat-poor angiomyolipoma show homogeneously increased unenhanced attenuation, homogeneously low signal on T2-weighted MRI and apparent diffusion coefficient (ADC) map, may contain microscopic fat and are classically avidly enhancing. Papillary RCC are also typically hyperattenuating and of low signal on T2-weighted MRI and ADC map; however, their gradual progressive enhancement after intravenous administration of contrast material is a differentiating feature. Clear cell RCC are avidly enhancing and may show intracellular lipid; however, these tumors are heterogeneous and are of characteristically increased signal on T2-weighted MRI. Oncocytomas and chromophobe tumors (collectively oncocytic neoplasms) show intermediate imaging findings on CT and MRI and are the most difficult subtype to characterize accurately; however, both show intermediately increased signal on T2-weighted with more gradual enhancement compared to clear cell RCC. Chromophobe tumors tend to be more homogeneous compared to oncocytomas, which can be heterogeneous, but other described features (e.g. scar, segmental enhancement inversion) overlap considerably between tumors. Tumor

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grade is another important consideration in small solid renal masses with emerging studies on both CT and MRI suggesting that high grade tumors may be separated from lower grade disease based upon imaging features.

Introduction

Small renal masses are commonly incidentally discovered on computed tomography (CT) and magnetic resonance imaging (MRI) examinations [1]. Once a small renal mass is characterized as enhancing (i.e. shown to be solid instead of cystic), the presumptive diagnosis becomes renal cell carcinoma (RCC). Those malignant tumors represent 80% of <4 cm solid renal masses in large surgical series [2,3]. Approximately 20% of <4 cm solid renal masses are benign, namely renal oncocytomas and fat-poor angiomyolipomas (AML) [3—5]. Differentiating between RCC and benign <4 cm solid renal masses is thus highly desirable to optimize treatment. Moreover, RCC show variable behavior depending on their subtype with clear cell RCC being the most aggressive compared to papillary RCC and the least aggressive variant chromophobe RCC [6—8]. Surveillance of small renal masses is now becoming a popular option in clinical practice since the risk of metastatic disease from renal masses <4 cm is low [8—12]. However, surveillance of clear cell and potentially other high grade small RCCs may occasionally yield unfavorable outcomes. Therefore, subtyping of RCCs and potentially providing information on anticipated grade are pathological features, which would be desirable to be extracted from imaging data.

This review article presents the established and emerging literature regarding the capabilities of both CT and MRI to differentiate between benign and malignant small renal masses, subtypes among the various RCC categories and also predict histological grade of disease [12—27].

Computed tomography

CT is the mainstay for the primary assessment of indeterminate renal masses [28]. CT is highly accurate to differentiate solid masses from simple and complex cysts by noting enhancement within a mass and absence of enhancement within a cyst. On conventional CT, enhancement is considered present when there is a >20 Hounsfield unit (HU) difference in attenuation of a mass comparing non-contrast enhanced CT (NECT) and contrast-enhanced CT (CECT) images [29,30]. Pitfalls in the CT evaluation of renal masses have been previously described [29]; however, there are two notable exceptions which merit discussion. Pseudoenhancement, which is the artificial increase in attenuation of a cyst on CECT compared to NECT images, can result in the misclassification of a cyst as a solid mass on CT [29,31]. Pseudoenhancement tends to occur more commonly in small endophytic masses [29] and is thought to be related to inadequate algorithmic correction of beam hardening artifacts from iodine [29,31]. Typically, when pseudoenhancement is suspected, an MRI can be performed to confirm the presence or absence of enhancement within a lesion [29]. More recently, it has been shown that dual-energy (DE) CT can effectively eliminate pseudoenhancement in renal masses through the use of higher keV monoenergetic images or iodine overlay images due to better correction of beam hardening effects [29,32] (Fig. 1). Not all solid tumors show a >20 HU difference in attenuation comparing NECT to CECT images and a substantial proportion of papillary RCC will not meet this threshold for enhancement at multiphase CT [29]. Most of these tumors will show intermediate range enhancement (between 10 or 15 and 20 HU difference) and can be further characterized with MRI (Fig. 2) [29]. DE-CT has also been recently preliminarily shown to be more sensitive for detection of enhancement using 70 keV images or through the use of iodine overlay data and iodine concentration measurements compared to attenuation measurement (Fig. 2) [29,33]; however, further study into this topic is required.

Non-enhanced computed tomography

On NECT, characterization of small renal masses relies predominantly on the detection of bulk or macroscopic fat, calcification and the baseline density of a mass. A small renal mass containing bulk or macroscopic fat can be confidently diagnosed as a renal angiomyolipoma [34]. The presence of bulk fat in RCC is rare [34]. Calcifications occur sporadically in RCC, generally does not occur in angiomyolipoma (AML) [34] and may occur in renal oncocytoma [35], therefore presence of calcification is useful to exclude the diagnosis of fat-poor AML only. Baseline attenuation of a renal mass at NECT has been investigated in fat-poor AML as a potential discriminating feature from RCC because the smooth muscle predominance of fat-poor AML should result in higher baseline attenuation (Fig. 3) [12,36]. It has been shown repeatedly that higher attenuation in a small renal mass at NECT is a feature of fat-poor AML; however, as a stand-alone feature, density is insufficient for diagnosis due to unacceptable overlap in attenuation values with RCC [13]. When the density of a homogeneous renal mass at NECT exceeds 70 HU, a diagnosis of a hemorrhagic cyst can be confidently established [28,29,37].

Contrast-enhanced computed tomography

At multi-phase CECT, enhancement pattern can be used to discriminate clear cell from papillary RCC with the former showing avid enhancement with washout of iodine and the latter showing gradual progressive enhancement

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