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REVIEW ARTICLE

Magnetic Resonance Imaging and the Use in Small Renal Masses

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Abstract The incidence of small renal masses (SRM) has been increasing, and this is mainly attributed to the incidental finding of such masses on imaging performed in asymptomatic patients. Consequently, this calls for careful evaluation and management of these masses to determine their nature and need for treatment. This article reviews current literature regarding the evaluation and management of SRM. It focuses on the specific use of MRI in the diagnosis and management of SRM. A Medline review of the literature was performed from 1996 to the present time. Computed tomography (CT) imaging has been the investigation of choice for evaluating SRM. However, some remain difficult to determine their malignant or benign nature and remain indeterminate. In such cases, further imaging with magnetic resonance imaging (MRI) can be performed to evaluate the mass in more detail. It can also be used where CT is contraindicated and where active surveillance is the treatment of choice and radiation exposure is a concern. MRI is a useful tool in evaluating an indeterminate small renal mass. Accurate diagnosis and management of SRM require close collaboration between a urologist and radiologist to identify potentially malignant tumours to subsequently reduce mortality from renal cell cancer.

Keywords Small renal masses · Magnetic resonance imaging (MRI)

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Introduction

It is well known that the incidence of small renal masses (SRM) has increased. Analysis of nine registries from the Surveillance, Epidemiology and End Results (SEER) programme demonstrated the rising incidence of renal cell cancer (RCC). This was mainly due to increased detection of SRM, where SRM are tumours ≤4 cm [1]. The majority of cases are incidental as the patients are asymptomatic and the scans are performed as part of investigations for other problems [2]. This rising trend can be attributed not only to the increase in cross-sectional imaging performed but also to the improved resolution of these modalities [2].

With this increase in detection of incidental renal masses, the need for accurate imaging and diagnosis is important. This requires close collaboration between a urologist and radiologist to identify potentially malignant tumours that require treatment and subsequently to reduce mortality from RCC. This must be carefully balanced with differentiating benign SRM to reduce overtreatment and potentially avoidable morbidity to a patient.

Characterising SRM can pose a diagnostic challenge. Several studies have shown that an increase in tumour size is associated with an increased risk of malignancy. A large study by Frank et al. showed that in tumours <4 cm, 20% were of benign histology compared to 6.3% in those ≥7 cm [3]. This is further reflected in a recent systematic review, which demonstrated benign histology in 20% of masses 1–4 cm. This increased to 40% in masses <1 cm [4]. Therefore, in the group of SRM, potential co-morbidity and cost can be avoided if imaging can be used to identify the group of SRM with benign versus malignant features.

When faced with a SRM, the management options include active surveillance with serial imaging, which may be particularly favoured in the elderly or frail patient [5]. Percutaneous

biopsy can be performed if histological confirmation is required [6]. When the decision has been made to treat, SRM can be treated with surgical excision by either a radical nephrectomy (RN) or partial nephrectomy (PN). Huang et al. showed that the trend of the surgical approach to SRM had changed over the years. The use of RN has decreased over time and nephron-sparing surgery with PN is favoured for SRM [7]. This can be performed laparoscopically or robotically. Robotic surgery has been applied to PN and shown favourable surgical outcomes. A comparative study of assisted laparoscopic PN (RALPN) and laparoscopic PN showed that RALPN achieved shorter operative and ischaemic time and less blood loss [8]. Ablative therapies such as radiofrequency ablation and cryoablation have evolved significantly in the last decade, are also options available for treatment and can be favoured in those with significant co-morbidities who cannot undergo major surgery [5].

SRM can be broadly differentiated into cystic and solid lesions. Cystic masses are mainly composed of fluid and can vary in appearance from simple to more complex. When evaluating SRM, several factors need to be assessed. These include the size, presence of calcification, wall thickness, presence of septa and enhancement with contrast. One must also be aware of the differential diagnosis of a solid SRM including minimal fat angiomyolipomas (AML) and oncocytoma [9, 10].

The Bosniak Classification of renal cysts for diagnosis and management of cystic renal masses is widely used and recognised (Table 1) [10–12]. When evaluating cystic renal masses, the Bosniak Classification is used to predict the risk of malignancy based on computed tomography (CT) appearances of cystic masses. Renal cysts are classified into five categories, Bosniak categories I, II, IIF, III and IV. Cysts graded I and II are regarded as benign and do not warrant follow-up [10]. The European Association of Urology recommends surveillance of IIF cysts, as there is a potential risk of malignancy. In cysts graded III and IV, surgery is generally recommended due to the increased risk of malignancy; however, this depends on the patients co-morbidities [10].

Computerised Tomography in the Diagnosis of SRM

CT imaging is the investigation of choice for evaluating renal masses. Pre- and post-contrast images are taken, and the post-contrast images are obtained usually 8–10 min after injection of iodine contrast material [2]. The images obtained prior to contrast injection are required to obtain the attenuation value of the mass. Images obtained during the urographic phase are used to detect enhancement of the mass. An enhancing mass or enhancing component within a cystic mass indicates increased vascularity and subsequently raises suspicion of renal malignancy [13]. If the attenuation value increases only by 0–10 Hounsfield units (HU), the mass is considered not enhancing and therefore can be termed benign. For example, a benign cyst is one that does not enhance and is surrounded by a smooth wall [11, 12]. An increase of ≥20 HU is indicative of enhancement diagnostic of malignancy. An increase of 10–20 HU is considered indeterminate or equivocal prompting further imaging or investigation [12, 14].

The importance of clinical history cannot be overemphasised and should be provided to radiologists to help differentiate benign and malignant masses, as solid renal masses could also be a result of infection, infarction or trauma [12].

Magnetic Resonance Imaging in the Diagnosis of SRM

The role of magnetic resonance imaging (MRI) in SRM has evolved and has its specific role. MRI is performed usually during end-expiratory breath-hold and subsequently requires patient cooperation and ability to do so [15, 16]. During an MRI, provided there are no contraindications, intravenous

Table 1 The Bosniak Classification of renal cysts for diagnosis and management of cystic renal masses

Bosniak category	Imaging features	Recommended workup
I	Hairline-thin wall; no septa or calcification or solid components; the same density; no contrast enhancement	Benign, no follow-up
II	Few hairline-thin septa; fine calcification in wall or septa; homogenous high-attenuating lesions ≤3 cm; no contrast enhancement	Benign, no follow-up
IIF	Multiple hairline-thin septa; minimal enhancement of septa or cyst wall; nodular or thick calcification without enhancement; no enhancing soft tissue; intra-renal high attenuating lesions ≥3 cm without contrast enhancement	Small percentage malignant, follow-up
III	Indeterminate cystic masses with thickened or irregular wall; some enhancement of septa or wall	50% malignant, surgery or follow-up
IV	Thickened or irregular wall; some enhancement of septa or wall; enhancing soft tissue components	Mostly malignant, surgery

gadolinium is administered. T1- and T2-weighted images are obtained before contrast administration and after [2].

T2-weighted images are useful in evaluating renal cysts [2]. Enhancement after intravenous gadolinium is used to assess malignant features of a SRM. However, this is not as easily and quantitatively assessed as in CT and is a more subjective assessment [9].

Image subtraction (gadolinium-enhanced fat-suppressed T1-weighted image minus unenhanced fat-suppressed T1-weighted image) has been recommended as a way of assessing enhancement and is a reproducible method [15]. This represents signal void within unenhanced tissue so that any residual signal is a representative of enhancing tissue [17]. Measurement of signal intensity units is also another way of assessing enhancement. This technique is also helpful in the small group of hypovascular tumours that may not enhance as significantly as hypervascular tumours [15].

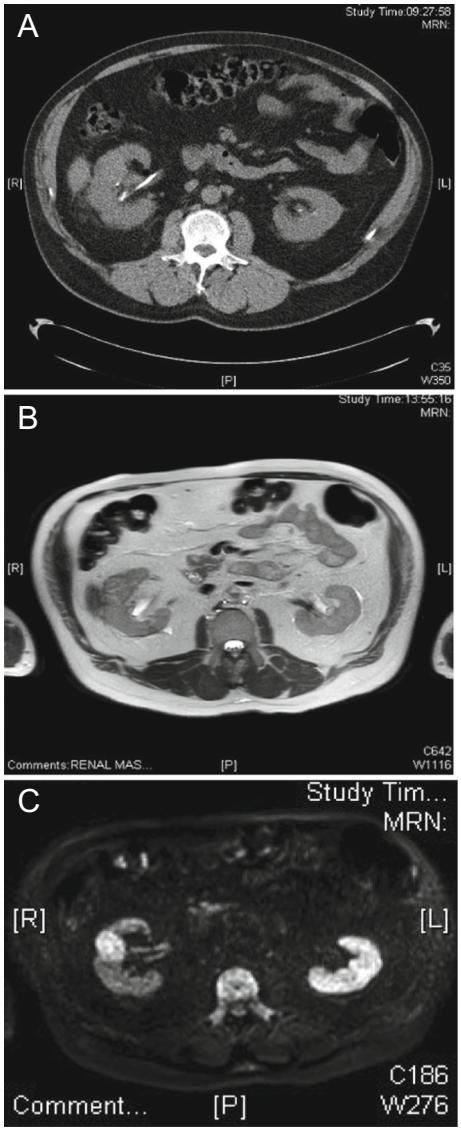
Although CT is often the investigation of choice, there are situations when CT is contraindicated. This is so in cases of impaired renal function, iodine contrasts allergy, or concerns of radiation exposure such as in the young or pregnant patient. In such cases, MRI may prove a useful diagnostic tool [2, 9, 12]. This is also important in this group of patients if they are on active surveillance or post-ablative therapy and require serial imaging for follow-up.

Assessment of enhancement depends on the attenuation values of the mass seen on CT. An increase in the attenuation value of ≥20 HU is indicative of enhancement diagnostic of malignancy. An increase of 10–20 HU is considered indeterminate or equivocal prompting further imaging or investigation [12, 14]. In such cases, MRI can be useful to clarify the nature of these lesions (see Fig. 1)

Certain variables may alter the attenuation value, and one issue that may arise with imaging cystic SRM using CT is pseudoenhancement [13, 18]. This is an increase in attenuation, and therefore, enhancement seen after contrast administration is due to beam-hardening artefact and technical factors [15, 18]. Potentially, this can result in a benign cystic SRM being classified as malignant [18].

MRI avoids the problem of pseudoenhancement seen with CT and is thought to offer better contrast between soft tissues allowing a radiologist to differentiate between fat, fluid, and soft tissue [14, 19]. It has been recommended as a problem-solving modality in cases [15]. Enhancement on MRI is not as easily assessed, but using a manually drawn region of interest signal intensity can be assessed. This has been seen as an increase of >15% on the contrast-enhanced images to represent malignancy [17].

When assessing cystic SRM, MRI is unable to assess calcification, which is one of the features required for the Bosniak grading system [17]. However, Israel et al. compared CT and MR imaging in the evaluation of cystic masses and demonstrated that MR can give additional details compared to



A – Post contrast CT

B – T1 weighted MRI

C – T2 weighted MRI

Fig. 1 *A* displays poor enhancement of the renal mass during a contrast CT. An MRI was done to further assess a right renal mass, and comparison of images *B* and *C* shows there is evidence of enhancement of the right renal mass

CT, such as additional septa, wall thickening or enhancement. This may lead to an upgrading of a cystic lesion. In this study, 10% of lesions resulted in a higher classification on the Bosniak Classification System using MR; however, it must be mentioned that in this group, there was no pathologic correlation available [19].

AML are benign lesions that contain fat and, when small, require no intervention. A majority of these lesions can be diagnosed with unenhanced CT. However, approximately 5% of AMLs contain little or no fat making it difficult to differentiate from small RCC as they appear as hyperattenuating lesions on unenhanced CT and small homogenously enhancing masses when IV contrast is administered [12, 20]. In such cases, gradient-echo chemical shift

MR imaging may be used to identify minimal fat AMLs [20]. Further evaluation with MR imaging may prove beneficial due to the smooth muscle content of AMLs with minimal fat, which appear hypodense on T1- and T2-weighted MR images [21]. However, papillary RCC share these features. A recent retrospective study showed that 89% of pathologically proven papillary RCC were hypointense on T2-weighted MR imaging. Of those <3 cm, 100% were hypointense [22]. In such cases, percutaneously targeted biopsy will aid in the diagnosis [6, 22].

Some renal cell carcinomas are hypovascular and therefore do not demonstrate enhancement in comparison to the surrounding renal parenchyma. This makes it difficult to differentiate from these benign lesions such as AML [23]. Using the subtraction technique, MRI can be useful in imaging and differentiating such lesions [23].

Ablative therapies for SRM are an option for nephron-sparing intervention and can be performed using an open or laparoscopic approach or percutaneously with or without general anaesthesia [5, 24]. A systematic review comparing laparoscopic cryoablation (LCA) to laparoscopic PN (LPN) suggested that LCA had less perioperative complications but was associated with a higher risk of tumour progression [25]. This is therefore generally an option for those with multiple co-morbidities or elderly patient and is the chosen option after a careful discussion of risks and benefits discussed with the patient [5].

Interventional MRI allows the surgeon to perform percutaneous cryoablation under MRI guidance. A small series assessing the outcome of this procedure in the treatment of SRM ≤4 cm showed that it was technically feasible with minimal morbidity to the patients [24]. The advantage of using MRI for this is that surgeon is provided with images in the sagittal and coronal plane simultaneously allowing more accurate positioning of the probe. It allows continuous monitoring of the ice ball formation and does not expose the surgeon or patient to continuous radiation as seen with CT [24].

SRM rarely metastasise, and therefore, active surveillance (AS) is adopted in those who are elderly or considered unfit to proceed to surgical intervention [26]. A multicentre prospective clinical trial demonstrated that in those with biopsy-proven malignancy, the growth rate was low at approximately 0.14 cm/year. This suggests that in the elderly or those with multiple co-morbidities, AS is a suitable option as mortality will likely be a result of an alternative cause [17]. In this group of patients, serial imaging is required to monitor growth and there is no recommended routine. In the study by Jewett et al., serial imaging was performed at 3, 6 months, then 6-monthly for 3 years and subsequently annually [26]. To reduce radiation exposure, MRI follow-up scan could be considered an alternative to follow-up CT. A follow-up scan should be of the same imaging modality to allow accurate comparison and growth rate assessment of the SRM [26].

MRI is also useful in planning surgical intervention. The imaging planes of the sequence can be altered to clearly demonstrate a mass and its position in the kidney and relation to the vasculature and collecting system. This is useful when planning a partial nephrectomy (PN) to perform nephron-sparing surgery, particularly in the cases of a solitary kidney [15].

When planning a PN, there are factors that pose a good prognostic outcome for the patient. The presence of a pseudocapsule is one and represents a low risk of perinephric fat invasion [9]. Studies have shown an increased sensitivity in detecting a pseudocapsule using MRI compared to CT and can therefore be a useful tool in the preoperative planning [9, 27]. RCC can also extend into the renal vein and assessment of this is imperative during the preoperative planning process [28]. MRI is a sensitive mode of imaging to identify a tumour thrombus in comparison to US or CT [28].

When discussing SRM, masses <1 cm are the most challenging diagnostically. They are often also too small to biopsy. Such tumours can be observed with serial imaging [12]. However, potential renal donor patients are a group in which clarification of the diagnosis of these very small renal masses is important to transplant surgeons. A study looking to assess the use of MRI in characterising such lesions showed that 89.5% of renal lesions <15 mm were incompletely characterised by CT alone. Using MRI, 99% of these were determined to be simple cysts, haemorrhagic cysts or AMLs. However, these findings were not supported with pathologic examination [14].

Nephrogenic systemic fibrosis (NSF) has been associated with the use of gadolinium-based contrast agents (GBCA) used in patients with renal insufficiency for MR imaging [29]. In patients with end-stage renal failure or acute kidney disease, NSF is a potential complication of IV gadolinium administration [29]. If no alternative mode of imaging is suitable, patients at risk must be carefully counselled about this potential complication associated with morbidity and death [2]. As this article focuses on the use of MRI in SRM, it is also important to make readers aware of potential complications with its use in a particular group of patients.

Conclusion

The incidence of SRM is increasing and studies have shown that approximately 20% of SRM are benign. This highlights the need for accurate diagnosis through imaging to limit the risks associated with biopsy or surgical intervention. MR is especially useful when CT findings are equivocal or when further imaging is required in the young patient where radiation exposure is a concern, or patients with renal impairment.

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