Pictorial Review

Multiparametric MRI of solid renal masses: pearls and pitfalls

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Functional imaging [diffusion-weighted imaging (DWI) and dynamic contrast enhancement (DCE)] techniques combined with T2-weighted (T2W) and chemical-shift imaging (CSI), with or without urography, constitutes a comprehensive multiparametric (MP) MRI protocol of the kidneys. MP-MRI of the kidneys can be performed in a time-efficient manner. Breath-hold sequences and parallel imaging should be used to reduce examination time and improve image quality. Increased T2 signal intensity (SI) in a solid renal nodule is specific for renal cell carcinoma (RCC); whereas, low T2 SI can be seen in RCC, angiomyolipoma (AML), and haemorrhagic cysts. Low b-value DWI can replace conventional fat-suppressed T2W. DWI can be performed free-breathing (FB) with two b-values to reduce acquisition time without compromising imaging quality. RCC demonstrates restricted diffusion; however, restricted diffusion is commonly seen in AML and in chronic haemorrhage. CSI must be performed using the correct echo combination at 3 T or T2* effects can mimic intra-lesional fat. Two-dimensional (2D)-CSI has better image quality compared to three-dimensional (3D)-CSI, but volume averaging in small lesions can simulate intra-lesional fat using 2D techniques. SI decrease on CSI is present in both AML and clear cell RCC. Verification of internal enhancement with MRI can be challenging and is improved with image subtraction. Subtraction imaging is prone to errors related to spatial misregistration, which is ameliorated with expiratory phase imaging. SI ratios can be used to confirm subtle internal enhancement and enhancement curves are predictive of RCC subtype. MR urography using conventional extracellular gadolinium must account for T2* effects; however, gadoxetic acid enhanced urography is an alternative. The purpose of this review it to highlight important technical and interpretive pearls and pitfalls encountered with MP-MRI of solid renal masses.

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Introduction

CT remains the most widely used technique for the characterization of renal masses and is considered “the most important technique” for evaluating the indeterminate renal mass by the American College of Radiology (ACR). MRI
is considered comparable to CT by the ACR and offers several advantages over CT including: improved contrast resolution, functional imaging techniques, and the lack of ionizing radiation, which is of particular significance due to growing concerns over cumulative radiation exposure from multi-phase and repeat CT examinations. The non-ionizing property of MRI is critical for patients who undergo frequent repeat imaging examinations screening for renal cell carcinoma (RCC) including those patients with tuberous sclerosis (TS) and Von Hippel–Lindau disease. Furthermore, in a recent study, Willatt et al. demonstrated that MRI further characterized a large proportion of renal masses that were considered indeterminate at CT.

Conventional renal MRI protocols include T2-weighted (T2W), chemical shift imaging [CSI; in and opposed phase (IP + OP)], and fat-suppressed (FS) T1W sequences before and after gadolinium injection. Combining this protocol with dynamic contrast enhancement (DCE) and diffusion-weighted imaging (DWI) constitutes a multiparametric (MP) MRI protocol (Table 1). MP-MRI is rapidly becoming the reference standard for renal MRI. For depiction of the urothelium, MP-MRI is combined with MR urography (MRU). MP-MRI can be performed in a time-efficient manner and provides important information that is not available with standard renal MRI. The purpose of this review is to highlight important pearls and pitfalls of

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<td>90/1250–1500</td>
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FS, fat-suppressed; IP, in phase; OP, opposed phase; 3D, three-dimensional 2D, two-dimensional; TE/TR, echo time/repetition time.

Table 1

### Table 1

Multiparametric MRI protocol performed at both 1.5 and 3 T.

- MRI performed on four clinical MR systems including at 1.5 T (Symphony, Siemens Medical, Malvern PA, USA) and at 3 T (TRIO, Siemens Medical, and Discovery 750W, General Electric Health Care, Milwaukee, WI, USA). Combined surface (four channels for Symphony, six channels for TRIO, eight channels for Discovery) with activated spine array.
- Diffusion-weighted imaging performed with spectral fat suppression echo planar imaging with tri-directional motion probing gradients and b-values of 0, 600 mm²/sec with automatic apparent diffusion coefficient map generation using mono-exponential curve fitting.
- VIBE (Siemens Medical) and LAVA (General Electric Medical).
- Four phases acquired dynamically starting with the cortico-medullary phase timed empirically at 35 s, followed by the nephrographic phase at 120 s post-injection. Axial, coronal, and sagittal delayed sequences are also performed. Gadolinium injected at a concentration of 0.1 mmol/kg using gadobutrol (Gadovist, Bayer, Toronto, ON, Canada) at a rate of 3 ml/s.
- All breath-holds performed with end expiration.
- 3D sequences (VIBE or LAVA), 2D sequences are fast low-angled shot (FLASH, Siemens Medical) or spoiled GRE (spGRE, General Electric Medical).
- Section thickness: 6, 6, 5 for three-dimensional and 5 mm for two-dimensional acquisition.
- TE/TR times for TRIO; Discovery 750W and Symphony respectively.
- Number of signals averaged partitioned by b-value on 3 T Discovery 750 W (one for b = 0, six for b = 600 mm²/sec) and a standard of four signals used for b = 0 and 600 mm²/sec on 3 T TRIO and 1.5 T Symphony scanners.

**Figure 1** A 74-year-old male patient with Fuhrman grade 3 cc-RCC. Coronal T2W HASTE image demonstrates a well-circumscribed mass arising from the lower pole of the left kidney (white arrow). The mass is heterogeneously hyperintense to the adjacent renal cortical parenchyma, a specific imaging finding of RCC. Marked CM phase enhancement with washout on the NG phase was observed on DCE imaging (not shown) and combined with heterogeneously increased T2W SI is specific for cc-RCC subtype.
renal MP-MRI using a sequence-based approach. As illustrated in this review, MP-MRI provides new insights into the nature of renal masses; however, it may also result in technical and interpretive errors in less experienced users.

Figure 2 (a) A 37-year-old female patient with minimal-fat AML; (b) a 64-year-old man with p-RCC; and (c) a 53-year-old woman with a haemorrhagic cyst illustrating the differential diagnosis of low T2W signal intensity (SI) renal lesions. Axial T2W ssFSE (top) and axial fat only image (derived from T1W gradient recalled echo (GRE) two-point DIXON IP and OP imaging; bottom) in (a) demonstrate a small homogeneously low T2W SI nodule arising from the medial interpolar region of the left kidney (white arrow) with intralesional fat (white arrowhead). The nodule enhanced rapidly on CM phase imaging (not shown) and RCC was suggested. Diagnosis of minimal-fat AML was confirmed after partial nephrectomy. In retrospect, the diagnosis of minimal-fat AML may have been suggested given that the combination of homogeneously low T2W SI and microscopic fat has not been described in RCC. Axial T2W ssFSE (top) and axial pre-contrast CM and NG phase contrast-enhanced T1W FS GRE images (bottom) in (b) demonstrate typical imaging features of p-RCC arising from the medial interpolar region of the left kidney. The tumour is homogeneously hypointense on T2W imaging (long white arrow) and is haemorrhagic with minimal delayed enhancement (short white arrows). Also note large parapelvic cyst in (b). Axial T2W ssFSE (top), axial pre-contrast FS T1W GRE and CE subtraction image (left to right, bottom) demonstrates a typical haemorrhagic cyst in the right kidney. The cyst is of low T2W SI (long white arrow), increased T1W SI pre-contrast and is non-enhancing (short white arrows). Also note a complex Bosniak type IIF cyst in the anterior right kidney with thin enhancing septa for which the patient was being imaged.

Figure 3 A 34-year-old man with small p-RCC, 5 × 9 × 6 mm (anterior–posterior × transverse × craniocaudal) homogeneously low T2W SI nodule is barely perceptible on axial T2W ssFSE image (curved arrow in a) and much more apparent on sagittal T2W ssFSE image (white arrow in b). Multiplanar imaging is recommended for renal masses, because small renal nodules may be better depicted in a particular imaging plane due to the orientation of the kidneys.

T2W imaging

T2W imaging is essential to differentiate solid from cystic renal masses and can also help to characterize indeterminate solid renal masses. A solid renal mass that is
heterogeneously hyperintense to the renal cortex on T2W imaging is most likely a RCC, and usually of clear cell subtype (cc-RCC; Fig 1). T2W lesion-to-renal parenchyma signal intensity (SI) ratios can discriminate RCC from benign angiomyolipoma (AML) with high degrees of accuracy.

Although low T2W SI is considered typical for AML, low T2W SI is also commonly present in both papillary RCC (p-RCC) and haemorrhagic cysts (Fig 2). The overlap in T2W SI between p-RCCs and AMLs without visible fat often necessitates histological confirmation. Haemorrhagic cysts rarely pose a diagnostic dilemma, as their increased T1W SI and lack of enhancement will readily differentiate them from solid neoplasms (Fig 2).

T2W imaging is performed as breath-hold (BH) half-Fourier single-shot turbo spin-echo (ss-TSE) with parallel imaging (PI; Table 1). Compared to standard TSE, ss-TSE provides improved spatial and contrast resolution, less artefacts, and time efficiency. Three-plane acquisition is advised because the visibility of small renal lesions may depend on renal orientation (Fig 3). Image blur with ss-TSE is ameliorated with PI. ss-TSE can be performed with FB or respiratory-triggered (RT) techniques in non-cooperative patients.

CS (IP + OP) imaging

In 1997, Outwater et al. reported that cc-RCC demonstrates a SI decrease on CS-MRI due to the intracellular or intracytoplasmic lipid (Fig 4). Intracellular lipid is defined as fat molecules within the cytoplasm of cells, which differs from the presence of adipocytes (fat cells), which are only rarely present in RCC.

A significant SI drop (CSI SI index > 25%) in RCC is characteristic of cc-RCC subtype, whereas other RCC only rarely demonstrate...
minimal SI drop on CS-MRI. AML are composed of variable amounts of smooth muscle, blood vessels, and adipocytes. The depiction of gross fat at CT or with FS MRI is considered diagnostic of AML. Only rarely do RCC demonstrate gross internal fat content from various causes, including osseous metaplasia and engulfing of the renal sinus fat, which is a known pitfall for the diagnosis of AML. In these rare cases, the presence of synchronous calcification and fat within a renal mass favours the diagnosis of RCC. Less concentrated areas of fat cells within AML result in a SI drop on CS-MRI and are referred to as areas of microscopic fat. Microscopic fat is also variably detected in the 5% of AML that do not contain sufficient amounts of fat to be characterized with conventional MRI (minimal fat or fat poor AML). Although intracellular lipid and microscopic fat are readily differentiated at histopathology, they both result in SI drop at CS-MRI. Therefore, the presence of SI drop on CS-MRI is non-specific, as it can be seen in both RCC and AML.

Fortunately, CS-MRI in combination with other MRI findings is typically characteristic. In a mass that contains both SI-drop on CS-MRI and bulk fat, the diagnosis of classic AML is established. SI drop in a mass that is heterogeneous on T2W imaging and hyperenhancing is virtually pathognomonic for cc-RCC. Conversely, a significant SI drop on CS-MRI in a solid renal mass that is homogeneously hypointense on T2W imaging may represent a minimal-fat or fat-poor AML.
as this combination of findings has not been reported in RCC (Fig 2). In our practice, we recommend surveillance or histological sampling for the latter because the diagnosis of minimal-fat AML is likely.

CS-MRI should be performed by sampling the first echo pair during the same BH and in the correct order (OP before IP echo). At 3 T, because the first OP echo occurs at 1.1 ms, sampling the first echo pair is challenging and requires high receiver bandwidths. This technical limitation can be overcome; however, sampling the first IP and later OP echoes should not be performed because SI drop on the OP images could be due to either intralesional fat or susceptibility (T2*) effects (Fig 6).

CS-MRI can be performed using a two-dimensional (2D) or three-dimensional (3D) technique. 3D techniques improve spatial resolution and signal-to-noise ratio (SNR) and 2D acquisitions are more resistant to motion artefact. Slight improvements in image quality occur with 2D compared to 3D CS-MRI at both 1.5 and 3 T; however, volume averaging at 2D is problematic when India-ink artefact can be confused for intralesional fat. This occurs when lesion size is less than two-times the section thickness (Fig 7).

DWI

DWI has revolutionized abdominal MRI. A detailed explanation of DWI is beyond the scope of this manuscript but is described elsewhere. Briefly, DWI exploits the random motion of water molecules in differing environments to determine tissue cellularity. Although techniques vary, a FS single-shot spin-echo echo-planar imaging (EPI) sequence is typically performed. EPI can be performed as a BH; however, FB or RT techniques are preferred to improve image quality and sample multiple b-values. RT reduces motion artefact but results in prolonged acquisition times compared to FB, and FB DWI demonstrates comparable image quality to RT. Increasing the number of excitations (NEX) overcomes many of the artefacts observed with EPI. Choice of b-value and number of b-values is variable. A minimum of two b-values is required to generate an apparent diffusion coefficient (ADC) map. Typically strategies involve either two [short (<200) and long (>500) mm²/sec] or three or more b-values; the more b-values (particularly when >500 mm²/sec) selected, the longer the acquisition time. We perform DWI with two b-values to reduce scan time (Table 1); a

Figure 7 A 34-year-old man with small p-RCC depicted in Fig 3. Axial 2D IP–OP images (a) and 3D IP–OP images (b) were obtained at section thicknesses of 5 and 3 mm, respectively. On the 2D images there is internal SI drop on the OP image compared to the IP image (white arrow in a). The combination of homogeneously low T2W SI (see Fig 3) and intralesional fat resulted in a diagnosis of a minimal-fat AML and targeted biopsy, which was performed using ultrasound guidance. A diagnosis of p-RCC was confirmed at histopathology. In retrospect, the SI drop observed using 2D imaging in (a) is not present on the 3D imaging (white arrow in b) and is due to a volume-averaging artefact from India-ink artefact at the interface of the nodule and the retroperitoneal fat. Although 2D CSI provides slightly better imaging quality compared to 3D techniques, volume averaging (which occurs when lesion size is less that two-times the section thickness) can mimic intralesional fat. In this example, the tumour measured 6 mm in the cranio-caudal dimension.

Figure 8 A 34-year-old man with small p-RCC depicted in Figs. 3 and 7. (a) Axial b0 mm²/sec, (b) b = 600 mm²/sec, and (c) ADC map illustrates the utility of DWI in renal mass imaging. On the long b-value EPI image (b) the nodule is much more apparent compared to the short b value EPI image (a) improving lesion detection (white arrows). The nodule demonstrates restricted diffusion with low SI on ADC map (c), a finding that is suggestive of malignancy.
Figure 9 A 78-year-old female patient with chronic renal failure on haemodialysis and a p-RCC in the right kidney. (a) Coronal T2W ssFSE image demonstrates atrophic kidneys with multiple tiny cysts in both kidneys, typical findings in chronic renal failure with dialysis-induced cystic disease. There is a homogeneously low T2W SI mass in the lower pole of the right kidney (white arrow). Axial \( b = 0 \text{ mm}^2/\text{sec}, b = 800 \text{ mm}^2/\text{sec} \) and ADC map (left to right in b) demonstrates restricted diffusion within the mass (curved arrows). The mass was isointense on T1W imaging (not shown), which excluded a haemorrhagic cyst. No internal fat was present and the mass developed \textit{de novo} when compared to a baseline CT performed 5 years earlier (not shown), which effectively excluded AML as a potential cause. Therefore, the diagnosis of p-RCC was suggested and confirmed after total nephrectomy.

Figure 10 An 87-year-old woman with classic (triphasic) AML. (a) Axial IP, (b) OP, and (c) FS 3D T1W GRE images demonstrate a nodule arising from the posterior interpolar region of the right kidney. The nodule contains minute foci of bulk fat (arrowheads) that are of increased T1W SI in (a), demonstrate etching artefact with the adjacent kidney in (b) and lose SI on the FS image in (c). The diagnosis of AML was readily established. Corresponding axial \( b = 0 \text{ mm}^2/\text{sec} \) (d), \( b = 600 \text{ mm}^2/\text{sec} \) (e) and ADC map (f) demonstrates restricted diffusion in the AML (open white arrows).

Figure 11 A 53-year-old woman with a haemorrhagic cyst in the right kidney (Fig 2c). The cyst is of low T2W SI on coronal T2W ssFSE image (white arrow in a). Also note bilateral renal cysts in (a). There is restricted diffusion on \( b = 0 \text{ mm}^2/\text{sec} \) b = 600 mm²/sec EPI and ADC map (left to right in b) in the haemorrhagic cyst. Note that the haemorrhagic cyst demonstrates preserved SI on the \( b = 600 \text{ mm}^2/\text{sec} \) (white arrow) compared to the \( b = 0 \text{ mm}^2/\text{sec} \) (arrowhead) EPI and is of low SI on ADC map (curved arrow). Conversely, a simple cyst in the anterior interpolar region of the right kidney demonstrates a loss of SI on the \( b = 600 \text{ mm}^2/\text{sec} \) compared to the \( b = 0 \text{ mm}^2/\text{sec} \) EPI and T2 shine-through on the ADC map at the same level. Haemorrhagic cysts may demonstrate restricted diffusion due to internal viscosity but can be readily differentiated from solid renal masses by increased T1W SI on pre-contrast imaging and lack of enhancement (see Fig 2c).
single long b-value of 600 mm$^2$/sec has been previously shown to be the best discriminator between benign and malignant tissues.47

There are three principle applications of DWI for renal imaging. First, low b-value trace EPI can serve as a surrogate for FS T2W imaging, decreasing total examination time (Fig 5). This strategy has been previously validated for hepatic imaging at 1.5 T; however, image quality of EPI is limited at 3 T (due to artefact from cardiac motion and the lung bases).43,44 In our experience, because of decreased motion and retroperitoneal location, image quality of EPI is satisfactory for the evaluation of the kidneys even at high field strength. Second, the long b-value trace EPI increases the conspicuity of renal lesions improving lesion detection (Fig 8). Lastly, the presence or absence of restricted diffusion can potentially characterize renal lesions.7,49,50

Preliminary results using DWI to characterize solid renal lesions as malignant are encouraging, and DWI can be particularly useful when gadolinium is contraindicated or when enhancement is equivocal (Fig 9). Taouli et al.51 initially demonstrated lower ADC values in renal neoplasms compared with benign lesions. In a recent meta-analysis, Lassel et al.52 demonstrated significantly lower ADC values in RCCs compared to oncocytomas and benign renal tissue. DWI can also potentially distinguish between RCC subtypes. Both p-RCC and chromophobe RCC demonstrate significantly lower ADC values when compared to cc-RCC at both 3 T and 1.5 T. The utility of threshold ADC values for diagnosis is currently limited due to differences in acquisition parameters and intrinsic scanner variability.54 Lower ADC values have also been described in higher Fuhrman grade cc-RCC compared to lower Fuhrman grade cc-RCC; suggesting that DWI may be useful in guiding patient selection for targeted molecular therapy or the active surveillance of small renal neoplasms.

A potential pitfall of DWI in renal mass imaging is that benign lesions also exhibit restricted diffusion and may mimic neoplasia. Both classic triphasic AML and minimal-fat AMLs may show profound diffusion restriction,56 with similar ADC values compared to p-RCC. In classic AML, the presence of macroscopic fat is diagnostic (Fig 10). Chronic haemorrhagic cysts may also demonstrate restricted diffusion due to internal viscosity and “T2 black-out” effects.57 T1W hyperintensity, lack of enhancement, rim calcification and stability over multiple imaging studies is diagnostic.58 Infection, including pyelonephritis and abscess, also commonly results in restricted diffusion, although diagnosis is usually readily established by clinical history and laboratory analysis.

**Gadolinium-enhanced sequences**

FS T1W GRE sequences, before and after gadolinium, are necessary for renal MRI and should be performed unless there is a contraindication to gadolinium. In patients at risk for nephrogenic systemic fibrosis (NSF) due to renal impairment (estimated glomerular filtration rate <30 ml/min), the use of gadolinium can now be considered if iodinated contrast medium is contraindicated; however, extreme caution should be exercised, and gadopentetate dimeglumine (Magnevist), gadoversetamide (Optimark), and gadodiamide (Omniscan) should be avoided.59,60 Gadolinium is particularly beneficial in patients who have had a previous severe allergic reaction to iodinated contrast agents.59 The use of non-contrast-enhanced sequences to quantify tumour perfusion, such as arterial spin labelling (ASL), demonstrate promising preliminary results but require further validation on a larger scale.61,62
sequences are typically performed using a 3D interpolated technique to enhance spatial resolution. 3D GRE sequences are prone to motion artefact, which is overcome by BH. BH is more consistent with end-expiratory (compared to end-inspiratory) scanning, which improves subtraction imaging\(^\text{12}\); however, the duration of the BH (and therefore, anatomical coverage) is decreased. Typically, end-expiratory BH is sufficient for renal coverage and is suggested for renal mass imaging. 2D techniques, RT, or radial acquisitions can reduce motion artefact with necessary comprises in resolution or acquisition time.\(^\text{63}\)

To confirm subtle enhancement with MRI, subtraction imaging is generally performed; however, this technique is highly dependent on consistency of BH and does not work when data sets are not perfectly co-registered (Fig 12). Assessment of the degree of ghosting artefact around the renal contour and adjacent parenchyma has been suggested as a means to determine the degree of misregistration\(^\text{12}\);
however, in our experience cross-referencing the two images that are to be subtracted to a fixed reference (the spine) is a more reliable method to determine whether subtraction will be accurate (Fig 12). Quantitative assessment using SI ratios $\text{SIR} = (\text{SI}_{\text{post}} - \text{SI}_{\text{pre}}) / \text{SI}_{\text{pre}} \times 100\%$; where post is the post-gadolinium enhanced image and pre is the pre-gadolinium image can also be used to confirm enhancement in difficult cases. Using a threshold value of 15–20% (2–4 min post-contrast) to confirm enhancement provides excellent sensitivity and specificity for differentiating solid and cystic renal lesions. Previously, Hecht et al. demonstrated that qualitative assessment of subtracted images is superior to SIR to detect enhancement in renal masses; however, SIR remain of value when subtraction images are not adequately co-registered. It should be noted that quantification of enhancement in renal masses is better suited to the density measurements obtained at CT rather than SI measurements obtained at MRI due to technical variability in SI measures at MRI and the more linear relationship between iodine concentration and radiodensity at CT.

The acquisition of contrast-enhanced images in a dynamic fashion [corticomedullary (CM), nephrographic (NG) and excretory phases (EP)] yields important information for the characterization of renal masses. Studies evaluating quantitative assessment of DCE have consistently shown that cc-RCC enhance to a greater degree than the renal cortex during the corticomedullary phase of enhancement and washout during the nephrographic phase (Fig 13), whereas p-RCC enhance less than the renal cortex on both phases of enhancement and demonstrate gradual progressive enhancement (Fig 14). DCE shows promise for differentiation of AML without visible fat from p-RCC, which are otherwise difficult to differentiate due to similar low SI on T2WI. Although SI drop at CS-MRI in combination with low T2W SI is suggestive of minimal fat AML, a proportion of these AML will not demonstrate SI drop due to a paucity of microscopic fat. p-RCCs enhance more slowly than AMLs using a wash-in arterial index; therefore, the combination of homogeneous low T2W SI and rapid arterial enhancement is suggestive of minimal-fat AML rather than p-RCC. A single study demonstrated that oncocytoma could be differentiated from chromophobe and cc-RCCs based on delayed enhancement with high specificity and the imaging finding of segmental enhancement inversion has been described as a specific imaging finding of oncocytoma; however, other studies have been unable to...
reliably differentiate oncocytoma from RCC at MRI. DCE has also been shown to be useful for distinguishing tumour grade; a small series identified increased perfusion values in higher-grade tumours. Studies evaluating pharmacokinetic modelling using high-temporal resolution DCE in renal masses are emerging and are likely to become integrated into renal mass imaging protocols in the near future with further validation and as preliminary pulse sequence designs become more commercially available.

**MRU**

When imaging of the urothelium is desired, MRU can be performed in conjunction with MP-MRI. Dilution of gadolinium is a critical component of MRU because at high concentrations the T2* effects of gadolinium overwhelm T1 shortening effects rendering the examination non-diagnostic (Fig 15). A saline bolus, administration of a diuretic, and a reduced dose of contrast medium can be used to dilute gadolinium concentration in the collecting systems and improve image quality (Fig 16). The use of a hepatobiliary contrast agent (gadoxetic acid, Bayer Pharmaceuticals) may also be considered for MRU because it is only 50% excreted by the kidneys, generally resulting in adequate image quality (Fig 17); however, differences in cost should be considered when compared to conventional extracellular gadolinium agents.

**Conclusion**

In conclusion, combining function sequences with conventional renal MRI protocols constitutes a state-of-the-art MP-MRI protocol; which is becoming the reference standard for renal mass imaging in clinical practice. Slight modifications in the MRI protocol can make MP-MRI a time-efficient proposition. Critical information is provided through MP-MRI (Table 2); however, the technique is fraught with technical and interpretive pitfalls that can be only be avoided with a thorough understanding of principles of MP-MRI and an understanding of the basis for important imaging findings.

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