Tom Schrack, BS, ARMRIT
Fairfax Radiological Consultants
Fairfax, VA

CHAPTER FIVE

MRI of the Adrenal Glands and Kidneys

After completing this chapter, the reader will be able to:

- **Explain the location and anatomy of the adrenal glands and kidneys**
- **Describe the basic imaging requirements for each organ**
- **List the major MR findings of each**

ADRENAL GLANDS

MR evaluation of the adrenal glands is quick and accurate. Most adrenal MR studies are referred for evaluation of an indeterminate mass detected by either CT or ultrasound. Most often, these masses are adrenal **adenomas**, a common benign adrenal mass. MRI can also differentiate benign masses from a **neoplasm** that has spread to the adrenal gland, such as from the lung. Adrenal gland MRI typically does not require the use of IV gadolinium contrast, which substantially reduces exam time. Therefore, adrenal MRI is not only a quick exam for the patient but a more comfortable one.

Introduction

The adrenals are a type of endocrine gland. There are two adrenal glands, and they sit atop each kidney in a hood-like, thin, triangular layer. Made up of two layers, the outer cortex and the inner medulla, the adrenal glands produce epinephrine and norepinephrine (adrenaline), as well as salts to maintain electrolyte balance.

In- and Out-of-Phase Imaging

For characterization of adrenal masses, MR is more specific than CT because of the use of **in-phase** and **out-of-phase imaging** techniques. In- and out-of-phase imaging is a type of gradient-echo imaging, typically a T1 **spoiled GRE (SPGR)**. "Spoiled" in this instance means that the residual transverse magnetization characteristic of GRE pulse sequences is dephased by an RF pulse just prior to the next slice-excitation pulse. Dephasing the residual magnetization yields a T1-weighted image instead of a mixture of T2* and T1. Once the image weighting is set, useful contrast is obtained by collecting image data at TE times when fat and water signals

POINTS FOR PRACTICE

1. What are the primary indications for MRI of the adrenal glands?
2. When is renal MRI most often indicated?

are in the same phase (in-phase) as well as opposed (out-of-phase or opposed-phase).

That fat precesses at a different frequency than water is a well-known phenomenon in MR. When one voxel contains protons of both fat and water, the rotation of fat protons is faster than the rotation of water protons by approximately 220Hz at 1.5 T. This means that every 2.3 msec, the fat and water protons will alternate between being in-phase and being out-of-phase. When in phase, the fat and water signals combine to yield stronger, therefore higher, overall signal displayed in the image. Approximately 2.3 msec later (at 1.5 T), the fat and water protons are exactly opposed to the other, yielding a weaker, slightly fat-suppressed image.

Obtaining a single SPGR in-phase set of images followed by an out-of-phase series requires less than five minutes of "table time." These images can characterize lesions as adenomas with a greater than 95% specificity and sensitivity. Using out-of-phase techniques, adenomas lose signal intensity by 10% or more between in- and out-of-phase images (Figure 74). All imaging parameters, except for the TE, must be identical for in- and out-of-phase acquisitions, that is, the same TR, field of view, slice thickness, intersection gap, bandwidth, flip angle, etc. Advances in pulse sequence design and gradient performance have made 3D in- and out-of-phase SPGR imaging possible in a breath hold. Using thin slices to acquire both in- and out-of-phase images in a single breath hold increases both the resolution and the SNR of the images.

Slice Thickness and Fat Suppression

Because the adrenal glands are thin structures and adrenal lesions may be quite small, thin sections are optimal when performing adrenal MRI. Typically, a slice thickness of 4 or 5 mm is

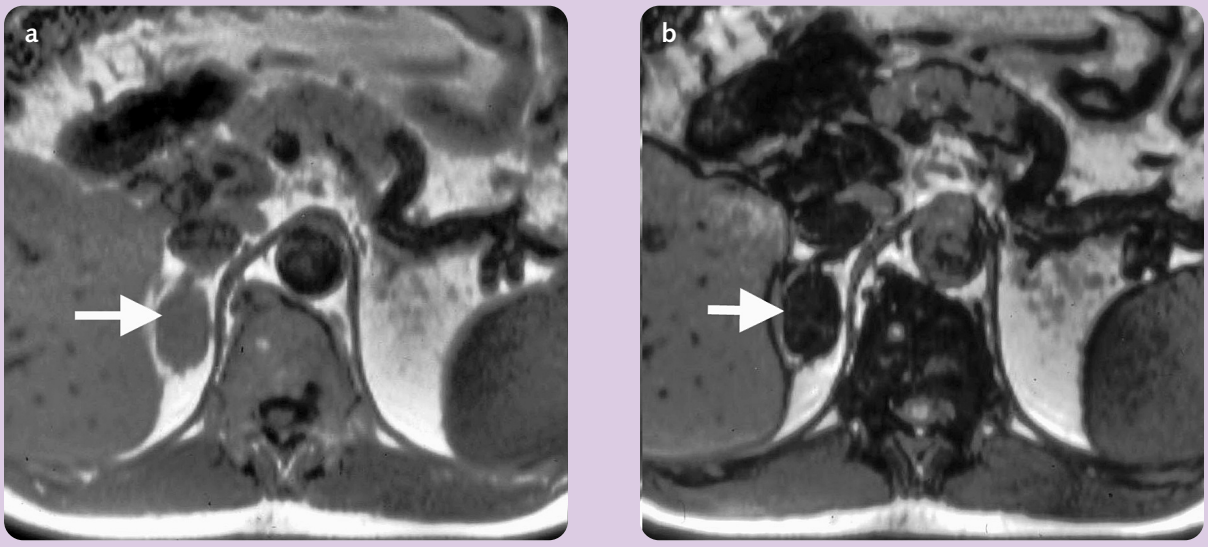

Figure 74. The adrenal adenoma located in this patient's right adrenal gland (arrows) loses a substantial amount of signal between the (a) in-phase and (b) out-of-phase images.

best for imaging. Fat saturation is useful but can also be a hindrance. The retroperitoneal fat provides good internal contrast, making the adrenals easy to see, so suppression of the fat with fat saturation may actually make it more difficult to visualize subtle abnormalities. However, if the technologist wants to prove that a lesion in the adrenals contains macroscopic amounts of fat, it is best to perform a T1 GRE series both with and without fat saturation; any bulk fat-containing lesions, such as a myolipoma, will lose signal on the fat-saturated series.

MRI Findings

The major findings of adrenal MRI reveal cysts, hemorrhage, and adrenal carcinomas, such as **myolipoma** and **pheochromocytoma**. T2-weighted images are useful when evaluating these pathologies and therefore are included as a standard adrenal protocol. It should be noted that when pheochromocytoma is suspected, imaging should not be limited to only the adrenal area but used throughout the entire abdomen and pelvis, as cancerous cells typically migrate from the adrenals to other areas in the peritoneum. Given these clinical circumstances, T2-weighted imaging and in- and out-of-phase imaging are useful, although they are not helpful for the most common indication for adrenal MRI, the characterization of adrenal adenomas. As mentioned earlier, the preferred sequence for imaging adenoma is a T1-weighted in- and out-of-phase gradient-echo sequence in conjunction with a "spoiler" pulse.

Imaging of the adrenals should be fast and painless for the patient, while yielding high diagnostic information. See sample adrenal scan protocol at the end of this chapter (Table 10).

KIDNEYS

The kidneys are bean-shaped organs located posteriorly at the bottom of the rib cage, one on each side of the spine (Figures 75 and 76). Their primary function is to filter waste products and extra water from blood. Each day the kidneys filter approximately 200 quarts of blood, removing approximately two quarts of waste (in the form of urea) and extra water. This extra water combined with urea forms urine, which then moves from the kidneys down the ureters into the bladder.

The kidneys also play an important role in maintaining proper blood pressure. Their role

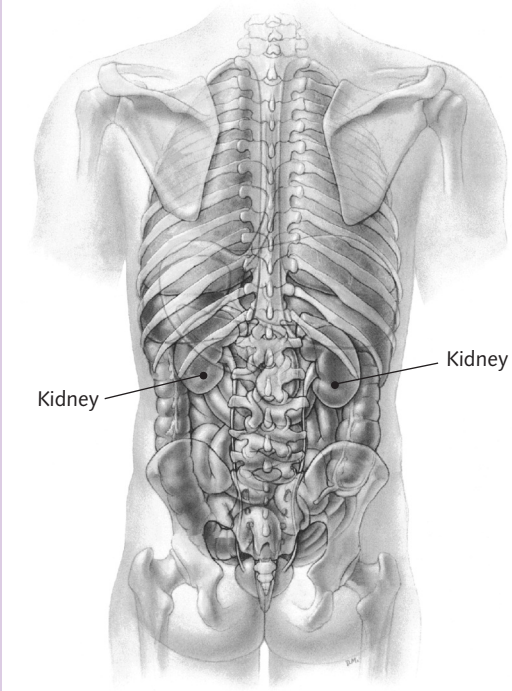

Figure 75. Renal anatomy. The kidneys are often positioned relatively high within the abdomen. Most MRI protocols include a combination of axial and coronal imaging. *Courtesy of LifeArt.*

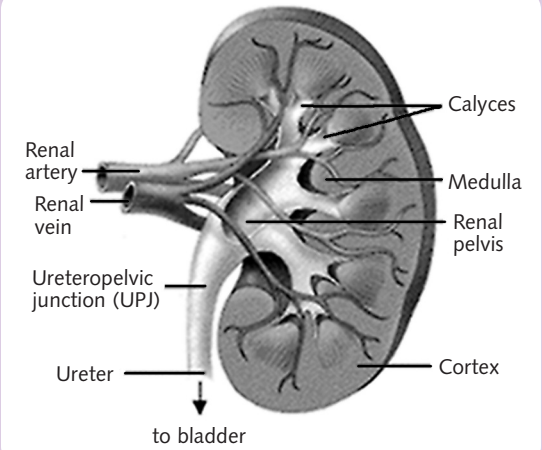

Figure 76. Anatomy of the kidney.

in blood pressure maintenance is two-fold: the kidneys cause the arteries and veins to constrict, and they increase the circulating blood volume.

The **nephron** is the basic cell unit of the kidney. Pathologies that prevent the proper amount of blood from flowing into the nephrons, for example, renal artery stenosis, signal the nephrons to release hormones that increase blood pressure. This "**nephrogenic hypertension**," left uncontrolled, can lead to other serious cardiovascular conditions such as stroke.

Renal MR imaging is most commonly performed to evaluate an indeterminate renal mass seen on another examination. Spiral CT remains the workhorse for evaluating suspected renal masses. However, some patients may have renal insufficiency or have iodinated dye allergies and cannot undergo CT imaging. Occasionally a mass seen on a renal-protocol CT cannot be fully diagnosed, and the patient is referred for MR evaluation.

Renal MR can be thought of and performed in a similar manner to renal CT. Pre- and post-contrast images are essential for evaluation of the enhancement of masses, and the contrast information is used to differentiate cysts from solid masses (Figures 77 and 78). T2-weighted pulse sequences and fat saturation techniques are used to evaluate the histological composition of masses and other pathology. The one disadvantage of renal MR as compared to CT is the relative insensitivity of MR to calcified stones in the collecting system and ureters. Since calcium is absent water, there are virtually no useful protons for MR imaging. Where calcium exists, a black void appears in the image.

Imaging Parameters

Renal MRI protocols are simple and normally can be performed in 25 minutes or less. A T2 FSE/TSE sequence is acquired in two planes, axial and coronal. This is followed by a pre- and dynamic post-contrast T1 SPGR series performed as a breath hold in a similar manner to the liver protocol already discussed. It is best to use thin slices; 4-5 mm is optimal, depending on the length of time the patient is able to hold their breath. The pre-contrast images can be subtracted from the post-contrast images to produce a subtraction series. This is excellent for determining the degree of enhancement of a mass or indeterminate lesion.

In addition to imaging the renal **parenchyma**, MR is an excellent tool for evaluating the renal vascular system. MR is especially useful for visualization of the main renal arteries in cases of suspected renovascular hypertension and for evaluating the renal veins in cases of suspected thrombosis or tumor extension. Using 3D T1-weighted techniques, both 2D axial data and 3D MR angiography and venography can be performed.

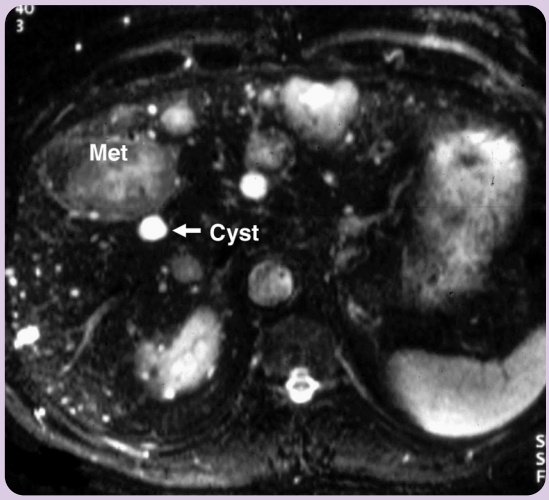

Figure 77. Differentiating cysts from solid masses. A properly selected TE helps differentiate cystic from solid masses, as depicted on this T2-weighted liver MR in a patient with both benign liver cysts and solid liver metastases. Most liver protocols use a TE of approximately 100 msec for this purpose.

MRI Findings

Renal Cell Carcinoma

Renal cell carcinoma is the most commonly encountered renal malignancy. Renal cells are solid masses that typically are hyperintense on T2 and hypointense on T1-weighted sequences. Enhancement occurs following gadolinium contrast administration and is best demonstrated by reviewing the subtracted data series. Even subtle areas of enhancement that are not apparent on post-contrast images become obvious on subtraction imaging.

MRI is also very useful in staging renal cell carcinomas because the size and location of the primary tumor can be easily depicted. MR is an excellent method for evaluating for local extension, either by direct extension into the

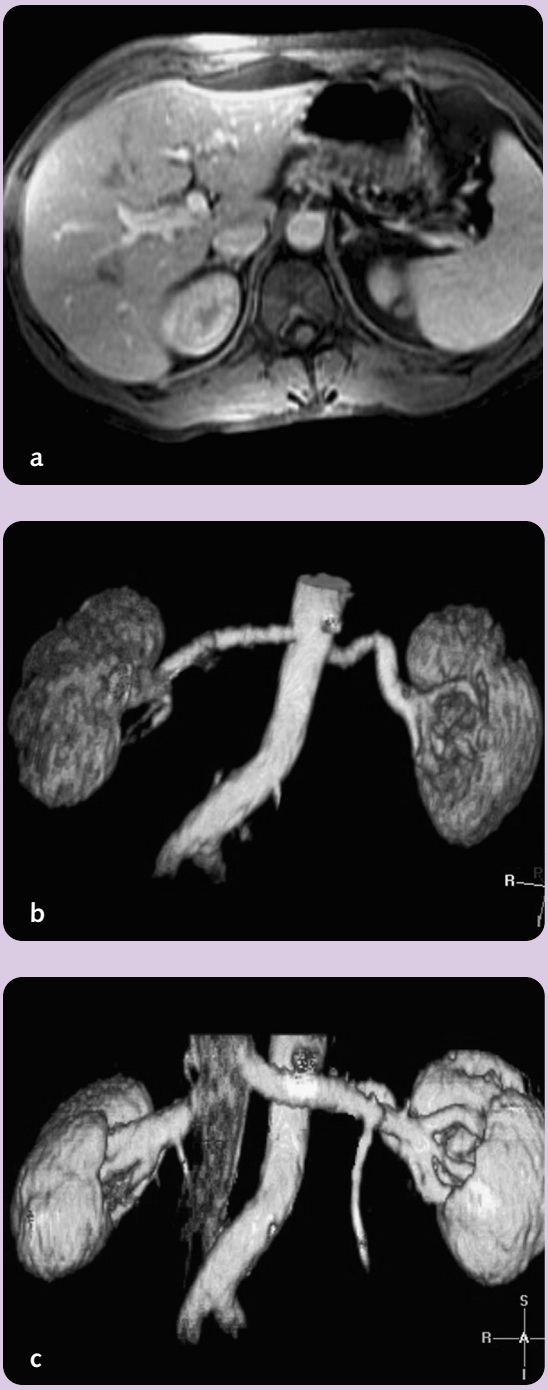

Figure 78. A 3D GRE Fast Acquisition with Multiphase Efgre 3D (FAME) study generates (a) diagnostic 2D images for evaluation of organs and other anatomy, as well as 3D angiographic data depicting both (b) the arterial anatomy and (c) venous structures.

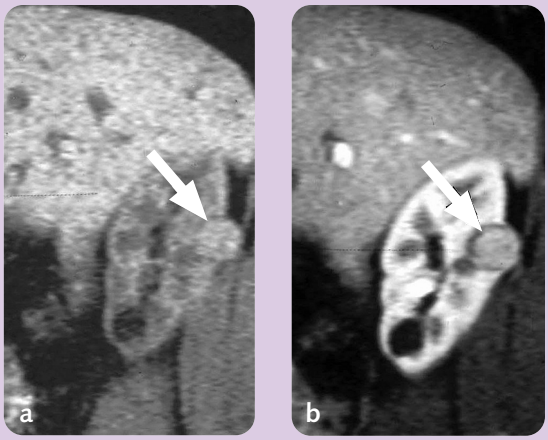

Figure 79. (a) Pre- and (b) postgadolinium-enhanced T1-weighted GRE images depict a small solid renal cell carcinoma (arrow) that clearly enhances.

renal vein or into the inferior vena cava (**IVC**) or for depicting **renal hilar lymphadenopathy**. Metastases to the liver, bone, and other structures can be easily depicted, as well (Figure 79) (Table 11).

Angiomyelolipomas (AML) are benign neoplasms of fat and **myloid** tissue. Because they are not cysts and they clearly demonstrate contrast enhancement, they are often mistaken for renal cell carcinomas. The use of out-of-phase techniques or frequency selective fat suppression may be helpful in depicting the fat or fat/water mixtures associated with these lesions, helpful in characterizing AML accurately and differentiating them from renal cell carcinomas

Hemorrhage

MRI can typically differentiate among simple renal cysts, hemorrhagic cysts, and renal cell carcinoma. Simple renal cysts appear rounded, are homogeneous, and hypointense on T1 imaging. Hemorrhagic cysts appear medium-to-hypointense. Renal cell carcinoma also exhibits areas of higher intensity due to the presence of hemorrhage.

SUMMARY

Although CT remains the primary modality for imaging the kidneys, MRI plays an increasingly significant role in evaluating kidney-specific pathologies.

Table 10.

SAMPLE ADRENAL MRI PROTOCOL		
Parameters	**1. Scout**	**2. T1 (in-phase and out-of-phase)**
Sequence	Ultrafast T2 (HASTE, SSFSE)	Fast GRE (FSPGR, FLASH)
Plane	Coronal	Axial
NEX	1	1
TR	∞	150-250
TE (msec)	99	4.6 and 2.3 (at 1.5 T)
Flip angle	NA	70-90
Thickness	8	4
Gap	2	1
Matrix	256 x 160	256 x 192
Options	Breath-hold	Breath-hold

Table 11.

SAMPLE RENAL MRI PROTOCOL				
Parameters	**1. Scout**	**2. T2**	**3. T2**	**4. T1**
Sequence	Ultrafast T2 (HASTE)*	T2 (FSE, TSE, etc)*	T2 (FSE, TSE)*	Fast GRE (FMPSPGR, FLASH)*
Plane	Coronal	Axial	Coronal	Axial
NEX	1	2-3	2-3	1
TR	∞	>2,000	>2,000	150-250
TE (msec)	99	102	102	4.6
Flip angle	NA	NA	NA	70-90
Thickness	8	5	5	5
Gap	2	0-2	0-2	0-2
Matrix	256 x 160	256 x 256	256 x 256	256 x 160
Options	Breath-hold	Fat saturation	Fat saturation	Breath-hold Fat saturation

POINTS FOR PRACTICE

1. **What are the primary indications for MRI of the adrenal glands?**
   Adrenal MR is typically used for evaluation of an indeterminate mass detected by CT or US. These masses are most often a benign adenoma, but MRI can also differentiate between benign masses and neoplasms that have spread to the adrenal gland, most often from the lung.

2. **When is renal MRI most often indicated?**
   While spiral CT is usually adequate for visualizing the kidneys, MRI is used to assess an indeterminate mass seen on CT. Some patients may have renal insufficiency or allergy to iodinated dye and therefore cannot undergo CT. Like renal CT, pre- and post-contrast images best evaluate the enhancement of masses and differentiate cysts from solid masses.

All images, tables, and protocols courtesy of Fairfax Radiological Consultants, Fairfax, VA, unless otherwise noted.

Notes