MRI of the Adrenals, Kidneys, and Bladder

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MR TECHNIQUES

A phased-array torso coil is optimally used to perform GU MRI because it significantly increases signal and reduces noise in the abdomen. A combination of routine T1 and T2 weighted sequences are used for most GU purposes. In selected cases newer sequences, including ultra-fast T2 (HASTE, SSFSE) are employed. Opposed-phase imaging techniques are also commonly used for adrenal lesion characterization. 3D gadolinium-enhanced MR angiography is useful for angiographic evaluation of the GU system, including renal donor and recipients, renal cell carcinoma evaluation, and other selected cases.

Ultra-fast T2 sequences are heavily T2 weighted and fluid is bright (Fig 1). These provide for very rapid "MR urograms" that can be performed during suspended respiration. These can be used for rapid screening of the bladder, ureters, and other fluid filled structures.

Opposed-phase imaging is a useful tool for characterization of certain fat-water admixtures, such as that which occurs in adrenal adenomas. Fat and water protons spin at slightly different frequencies. At predictable time points, they will be completely "in-phase" or "out of phase" with each other. When in-phase, their signal adds, when out of phase (180 degrees opposite each other) their signal destructively interferes. For this reason fat-water mixtures lose signal when out of phase. This signal loss occurs with adrenal adenomas, myelolipomas, renal angiomyolipomas, and adnexal lesions.

Another technique that is useful as indicated above is 3D Gad MR Angiography. This provides for a very rapid and accurate angiographic analysis of the arteries and veins of the abdomen and pelvis. Most scanners can perform this sequence in approximately 20-30 second. Please refer to the Gadolinium-enhanced MR angiography chapter for further information.

MR CONTRAST AGENTS

Several contrast agents are currently available for MRI. As a whole these agents are significantly safer than iodinated agents used for CT and other radiographic exams. Gadolinium is used most frequently for both evaluations of tumor, infection, and angiography. The other two new agents, ferumoxides and Mn-DpDp, are usually used for hepatic imaging.

AGENT	MECHANISM	USE
Gadolinium	Extracellular fluid	General, 3D MRA
Ferumoxides	RES specific	Liver lesion detection, FNH
Mn-DpDp	Hepatocyte specific	HCC, liver lesions, pancreas

Gadolinium can be used safely in patients with renal insufficiency. It has no reported renal toxicity. Both ionic and nonionic iodinated contrast media have a real risk of producing nephrotoxicity.

In one study (Schwab et al, NEJM 1989; 302:149-153), nephrotoxicity, defined as a 44 mumol/l serum creatinine increase, was evaluated in 443 patients s/p cardiac catheritization. They were randomized to ionic or nonionic contrast. Nephrotoxicity was seen in a substantial number of patients who received both nonionic and ionic iodinated contrast agents (see table).

Incidence of Iodinated Contrast Induced Nephrotoxicity

	All Patients	High Risk
Nonionic	8.2%	15%
Ionic	10.2%	17%

(Schwab et al, NEJM 1989; 302:149-153)

Gadolinium is safe to use in these patients. In one study of 342 patients with renal insufficiency who received both nonionic contrast exam and gadolinium (on separate days), a significant rise in serum creatinine was noted after iodinated contrast, but not after gadolinium. (Prince et al, JMRI 1996; 6:162-166). In this study nephrotoxicity = 5mg/dl serum creatinine increase.

Gad vs. Nonionic contrast; Nephrotoxicity

	Creatinine change	Nephrotoxicity
Nonionic	+ 0.35 mg/dl	17%
Gadolinium	– 0.07 mg/dl	0%

(Prince et al, JMRI 1996; 6:162-166)

Fig 1. *An obstructed right ureter is depicted on this coronal ultrafast T2 weighted image (SSFSE single shot fast spin echo) acquired in less than 1 second.*

ADRENALS

MR evaluation of the adrenal glands is rapid and accurate. MR is more specific than spiral CT for characterization of adrenal adenomas. Adrenal MR studies are performed rapidly and are very specific.

Use of opposed-phase technique with a single in-phase followed by an out of phase series takes less than 5 minutes of "table time" and can characterize adenomas with a greater than 95% specificity and sensitivity. Using opposed-phase techniques, adenomas lose signal intensity by 10% or more between in and out of phase images. All imaging parameters, except for the TE, must be identical (i.e. the same TR, fov, slice thickness, gap, bandwidth, flip angle etc).

Opposed-phase Imaging Technique

- Use standard T1-weighted GRE images.
- Incremental TE change makes the sequence in-phase or out-of-phase.
- Fat and water have different resonance frequencies.
- When imaged "out of phase" fat and water signals interfere destructively.
- Used to depict areas of hepatic steatosis and adrenal adenomas.

Because the adrenal glands are thin structures, and adrenal lesions may be quite small, thin sections are optimal when performing adrenal MRI. We normally use 4-mm slices for imaging. Fat saturation is both useful and can be a hindrance. The retroperitoneal fat provides for good internal contrast and makes 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 one wants to prove that a lesion in the adrenals contains fat, then it is best to perform a T1 GRE series with and without fat saturation, any bulk fat containing lesions, such as a myolipoma, will lose signal on the fat-saturated series.

T2-weighted images are useful when evaluating other adrenal lesions, such as cysts, hemorrhage, and pheocromcytomas. Therefore as a standard adrenal protocol, we include T2-weighted images, even though they are not helpful for the most common indication for adrenal MRI; characterization of adrenal adenomas

Sample Adrenal MR Protocol

Sequence	Plane
GRE T1 In-phase & Out of phase	axial
Optional- T2 FSE fat sat	axial
GRE T1 fat sat	axial

KIDNEYS

Renal MR can be thought of in a similar manner to renal CT, i.e., pre and post contrast images are essential for evaluation of the enhancement of masses to differentiate cysts from solid masses. In addition, T2 pulse sequences and fat saturation techniques can be used to evaluate the histologic composition of masses and other pathology.

Fig 2. *An adrenal adenoma is depicted as a low signal intensity mass on this out of phase T1 weighted GRE image (FLASH TR 150, TE 2.5, and FA 80).*

The one disadvantage of MR as compared to CT is the relative insensitivity of MR to small calcified stones in the collecting system or ureters. Therefore in the evaluation of a potential renal donor, we obtain a plain radiograph to evaluate for nephrolithiasis.

Most commonly, renal MR is doe to evaluate an indeterminate renal mass seen on another examination. Patients may be renal insufficient or have iodinated dye allergies, and therefore cannot have a CT. Occasionally, a mass seen on renal-protocol CT is sent for MR evaluation because of an indeterminate CT reading. Protocol for these studies is pretty simple; we do a T2 FSE in one or occasionally 2 planes (axial, or axial and coronal). This is followed by a pre and dynamic post-contrast t1 GRE series performed as a breathhold. It is best to use thin slice; 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-contrasted images to produce a "subtraction" series. This is excellent for determination of mass enhancement.

MR is an excellent tool for evaluating the renal vascular system, especially the main renal arteries in case of suspected renovascular hypertension and for evaluating the renal veins in cases of suspected thrombosis or tumor extension. Please see the chapter on renal and aortic MRI in this syllabus.

Sample Renal MR Protocol

Sequence	Plane
T2 FSE	axial
T1 GRE - Pre and Post Gadolinium	axial
Optional	
1. GRE T1-Opposed phase 2. 3D MRA	axial coronal

BLADDER

Bladder imaging is performed less frequently than adrenal or renal MR, but it can still provide useful diagnostic information in a number of diagnoses. In our practice, we use dynamic contrast enhanced bladder MRI for staging of invasive bladder cancer. Cancers typically enhance earlier than normal bladder muscle, so an arterial phase study is helpful to fully delineate the tumor.

Other bladder applications include the evaluation of uretheral diverticulum in women. We perform T2 weighted sequences in multiple planes using thin slices with a high matrix to achieve high spatial resolution.

Occasionally we image the bladder with MR to evaluate for other tumors such as extra-adrenal pheochromocytomas.

References

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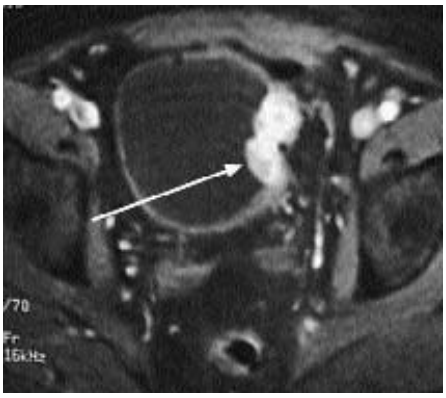

Fig 3. *Gadolinium is safe to use in patients with renal insufficiency. Here it enhances a bladder transitional cell CA in a patient with a serum Cr of 3.0 and chronic renal insufficiency.*