MRI of the Kidney

MRI provides comprehensive information on the full range of kidney diseases including benign and malignant processes and diffuse renal parenchymal disease. We employ a set protocol incorporating various types of sequences including transverse, coronal and sagittal data acquisition, and the routine use of intravenous gadolinium.

IMAGING THE KIDNEY

BASIC PROTOCOL

The high signal-to-noise ratio (SNR) obtained at high field strength makes it possible to image the kidneys during a single breath-hold sequence. The sequences described herein are based on the authors' experience with a Siemens 1.5 T Vision scanner, but are expected to be equally applicable to machines from other manufacturers.

Scanning a patient or volunteer is a joint effort among technologists, nurses, and physicians, with the technologist normally responsible for following proper scanning protocols and techniques. Unless otherwise specified, in what follows the person to whom directions are given is assumed to be the technologist. Table A16.1.1 lists the hardware necessary to perform the procedure, along with appropriate parameters.

The following nine sequences comprise the kidney imaging protocol. This protocol employs pre- and post-gadolinium T_1 weighted imaging acquired utilizing nonsuppressed and fat suppressed sequences. Most sequences require the patient to be able to suspend respiration for ~25 sec. It is imperative that there be clear communication between the technologist and the patient throughout the exam. This protocol results in consistent, reproducible image quality that is effective for evaluating the full range of renal diseases.

NOTE: Be sure that technologists and nurses have immediate access to any emergency equipment that may be relevant to a given study, or that may be needed for a particular patient, such as crash carts or oxygen.

Materials

Normal saline (0.9% NaCl), sterile, 40 ml minimum
Extravascular contrast agent (e.g., Magnevist, Omniscan, or Prohance), volume prescribed by patient weight

Table A16.1.1 Equipment Specifications Imaging of the Kidney

Coil type	Circular polarized body-phased array coil
Field strength	1.5 T
Gradient strength	24 mT/ m (or whatever the system permits, but minimum of 24 mT/m for sequences 3 and 4)
Knee cushion	Yes
Use of contrast agents	Yes
Pulse oximeter	If patient requires sedation
Power injector	Yes
Normal saline	Yes
35-in. extension tubing	Yes

Contributed by Richard Semelka, Laurie Fisher, and Kathy Wilber
Current Protocols in Magnetic Resonance Imaging (2001) A16.1.1-A16.1.13

Set up equipment and patient

1. Interview (screen) the patient to assess for contraindications such as cardiac pacemaker, implanted mechanical devices, and/or ferromagnetic materials. Also, determine if the patient has any health conditions that may require the presence of special emergency equipment during the scanning procedure, of if he or she will need sedation medication necessitating the use of appropriate monitoring equipment.

   Generally standard screening forms are used for all patients scanned in a magnetic resonance system.

   The presence of any ferromagnetic metals may be a health hazard to the patient when he or she is inside the magnet, and will also affect the imaging. If in doubt as to the exact composition of the items, it is best to exclude patients with any metal implants; see Shellock (1996) for discussion of what implants may be safely scanned using magnetic resonance.

   The presence of ferromagnetic materials in the globe of the eye is contraindicated for MRI. Patients with prior metal exposure to the eye should have plain X rays of the orbital area to ensure that all metal has been removed prior to placing them in the magnetic field.

   Patients may be accompanied into the magnet room by a friend or family member, who can sit in the room during the scan and comfort the patient as needed. This companion must be screened as well to ensure the absence of loose metal objects on the body or clothing.

2. Request that the patient change into a gown to eliminate any metal that might be found in clothing. Ask the patient to remove all personal effects such as, jewelry, hearing aids, glasses, etc., prior to entering the MRI scan room.

   All personal belongings should be secured during the examination.

3. Explain the procedure to the patient and record relevant clinical history. Ensure that the patient understands what is expected and ask them if they have any questions; answer appropriately. If the procedure is a research protocol, have the patient sign any necessary consent form.

4. Fill a 20 ml syringe with normal saline and attach to saline filled extension tubing (35-in.). Obtain intravenous (i.v.) access utilizing a 22-G angiocatheter and attach saline-prepared extension tubing and syringe. This will allow you to flush the extension tubing while the patient waits to be imaged, and, in cases in which a power injector is not available, this will allow preparation for bolus injection (see Note below). Secure the position of the angiocatheter with tegraderm or tape.

   Obtaining i.v. access prior to entering the scan room will promote patient throughput and eliminate "dead" time of starting the i.v. while the patient is on the exam table. Follow power injector manufacturer guidelines with regard to appropriate gauge needle/angiocatheter to be used; this will depend on chosen injection/flow rates.

   NOTE: *If you do not have access to a power injector you will still be able to perform dynamic renal imaging as the extension tubing will allow the saline syringe to be placed at the foot of the patient table during pre-contrast imaging. In this case, you will need to draw up the contrast agent in another syringe. When you are ready to bolus inject the contrast agent, simply disconnect the saline syringe and connect the syringe filled with contrast agent; once you have injected the bolus of contrast reconnect the saline syringe and bolus an appropriate volume of flush, usually ~10 ml. Alternatively, to eliminate the need of switching syringes, incorporate the use of a 3-way stopcock.*

5. Set up the exam room by securing the circularly polarized (CP) body array coil onto the table and providing a clean exam table.

6. Set up the power injector as specified by the manufacturer.

A minimum of 40 ml normal saline should be drawn up to ensure sufficient saline is available to keep the vein open (KVO) throughout the exam. To determine the amount of contrast agent to be used, reference the contrast packet insert and draw up the amount indicated per kg of patient weight. There is no need to double dose.

7. Escort the patient to the MR examination room and ask the patient to lie down accordingly with respect to the exam to be performed. Help the patient mount onto the table. Either before or right after the patient lies down, set up any triggering devices or other monitoring equipment that is to be used.
8. Connect the extension tubing secured to the syringe to the power injector extension tubing.
9. Inform the patient about what will occur during the procedure, what he or she will experience while in the magnet, and how to behave, including the following:
   a. If earphones or headphones are used to protect the ears from the loud sounds produced by the gradients, the patient will be asked to wear these, but will be able to communicate with you at any time during the imaging.
   b. The patient will be given a safety squeeze-bulb or similar equipment to request assistance at any time (demonstrate how this works).
   c. For good results the patient should not talk, and should avoid or minimize swallowing or other movement, during each scan—i.e., as long as the banging sounds continue. Between scans, talking and swallowing are allowed in most cases, but should be avoided when comparative positional studies are being performed; the patient will be informed when this is the case. Explain to the patient that one should not reposition one's body between imaging sequences.

      Additionally, review breath-holding instructions with the patient, and provide the patient with an approximate time that the examination will take.

   d. Nevertheless, the patient may call out at any time if he or she feels it necessary.
   e. Position a support under the patient's knees to enhance patient comfort.
10. Secure the top portion of the CP-body array coil to prevent it from moving side-to-side during breath-holding imaging sequences.

    Usually straps are provided by the manufacturer that are directly attached to the coil.

11. Use the laser light to position the patient, and to center the coil (see Table A16.1.2). Then, advance the patient table to isocenter.
12. If the patient is unable to hold still, provide an appropriate sedative.
13. Program the power injector for a contrast agent and saline injection rate of 2 ml/sec. Total volume of saline following contrast agent injection should be programmed for 10 ml. Program a scan delay of 18 sec (contrast agent is injected, scan is initiated 18 sec after contrast agent and saline are delivered). Arm the power injector and begin the keep the vein open.

    Do not inject the contrast agent at this time!

Sequence 1: Three-plane positioning scout

14. To validate the patient's position and to have a reference to prescribe successive imaging sequences, acquire a three-plane orthogonal scout sequence. See Table A16.1.2 for specific parameters.

    Most MR scanners can be programmed to acquire the scout automatically after coil tuning or after the patient has been placed in isocenter (for systems that do not require tuning).

Table A16.1.2 Imaging Parameters for Scout Sequences (Sequences 1 and 2)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Sagittal, transverse, and coronal
Central slice or volume center	Laser light centered approximately one hand width above the inferior rib margin
Echo time (T_E)	6 msec
Repeat Time (T_R)	15 msec
Flip angle (FA)	30°
Fields of view (FOV_x, FOV_y)	450 mm, 450 mm
Resolution (Δx, Δy)	1.76 mm, 3.52 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix ($D_{x,}$ D_y)	256, 256
Slice thickness (Δz)	10 mm
Number of slices	3
Slice gap	Not applicable
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Not applicable
Saturation pulses	Not applicable
Scan time	16 sec

Sequence 2: Breath-hold three-plane positioning scout

15. To have a reference to prescribe successive breath-hold imaging sequences, acquire a second three plane orthogonal scout sequence. See Table A16.1.2 for specific parameters.
16. Instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it.
17. Initiate the scan.

Sequence 3: Half-acquisition (partial Fourier) turbo spin echo coronal

18. Display both the coronal and transverse scout images (use *non*-breath-hold images) in two separate quadrants on the scan monitor.

    Change imaging parameters to those listed in Table A16.1.3. Position slices to center of the transverse scout, ensuring that both kidneys are entirely covered.

19. Instruct the patient to remain motionless and to breathe normally as the scan will begin and last for ~40 sec.

Sequence 4: Half-acquisition turbo spin echo transverse (Fig. A16.1.1)

20. Display both the coronal and transverse scout images (use *non*-breath-hold images) in two separate quadrants on the scan monitor.

    Change imaging parameters to those listed in Table A16.1.4. Position slices to center of the coronal scout, ensuring that both kidneys are entirely covered.

21. Instruct the patient to remain motionless and to breathe normally as the scan will begin and last for ~40 sec.

Sequence 5: Transverse gradient echo with fat saturation (Fig. A16.1.2)

22. Display both the coronal and transverse scout images (use breath-hold images) in two separate quadrants on the scan monitor.

Change imaging parameters to those listed in Table A16.1.5. Position slices to center of the coronal scout ensuring that both kidneys are entirely covered.

It is imperative that the slices are prescribed off of the breath-hold scout images as this is a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held scout image is used.

Table A16.1.3 Imaging Parameters for Half-Acquisition Turbo Spin Echo (Sequence 3)

Patient position	Supine
Scan type	Half acquisition turbo spin echo
Imaging plane (orientation)	Coronal
Central slice or volume center	Slices posted on transverse scout; center to kidneys
Echo time (T_E)	90 msec
Repeat time (T_R)	4.4 msec (note: The true T_R is infinite; 4.4 msec represents the echo spacing)
Delay time (T_D)	1500 msec
Flip angle (FA)	150°
Field of view (FOV_x, FOV_y)	400 mm, 400 mm
Resolution (Δx, Δy)	1.56 mm, 2.08 mm
Number of data points collected (N_x, N_y)	256, 192 (using half Fourier)
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover both kidneys
Saturation pulses	No
Slice series	Interleaved
Scan time	40 sec

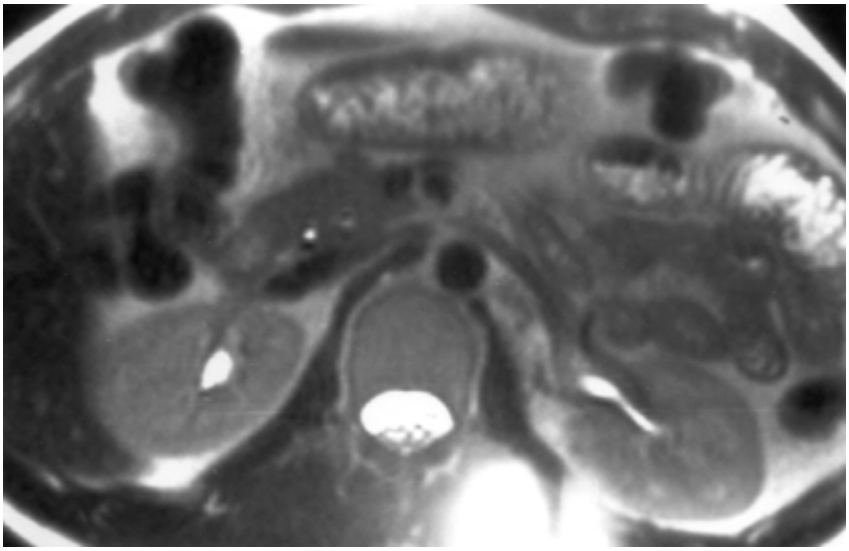

Figure A16.1.1 Unenhanced transverse half-acquisition turbo spin echo image.

23. Instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it.
24. Initiate the scan.

Sequence 6: Transverse gradient echo (Fig. A16.1.3)

25. Display the midline slice of the transverse gradient echo image (sequence 5) and the breath-hold coronal scout image in two separate quadrants on the scan monitor.

Table A16.1.4 Imaging Parameters for Half-Acquisition Turbo Spin Echo (Sequence 4)

Patient position	Supine
Scan type	Half-acquisition turbo spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to kidneys
Echo time (T_E)	90 msec
Repeat time (T_R)	4.4 msec (note: The true T_R is infinite; 4.4 msec represents the echo spacing)
Delay time (T_D)	1500 msec
Flip angle (FA)	150°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 1.37 mm
Number of data points collected (N_x, N_y)	256, 192 (using half Fourier)
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover both kidneys
Saturation pulses	Yes, superior and inferior to slices
Fat suppression	No
Slice series	Interleaved
Scan time	40 sec

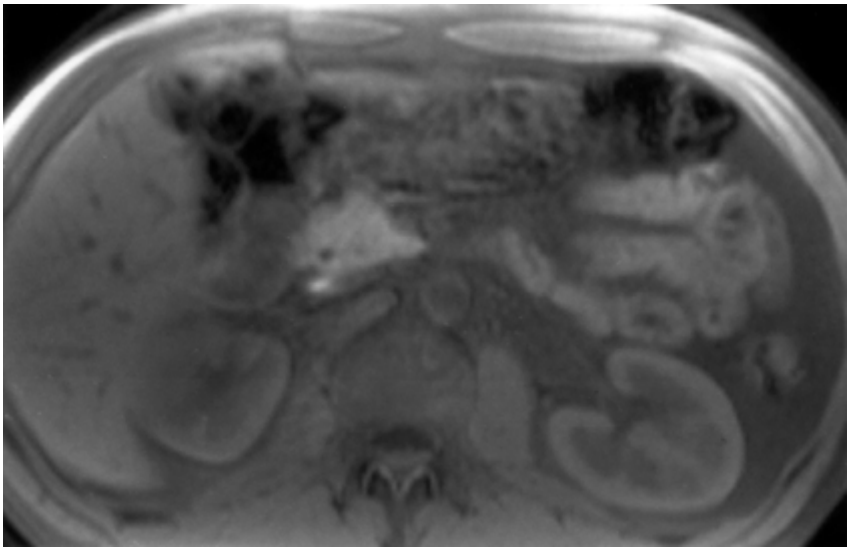

Figure A16.1.2 Unenhanced fat-suppressed transverse spoiled gradient echo image.

Change imaging parameters to those listed in Table A16.1.6. Position slices to cover the kidneys.

It is imperative that the slices be prescribed off of breath-hold coronal image as this is a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held image is used.

26. Instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it.
27. Initiate the scan.

Table A16.1.5 Imaging Parameters for Gradient Echo with Fat Saturation (Sequence 5)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to kidneys
Echo time (T_E)	4.1 msec
Repeat time (T_R)	147.2 msec
Flip angle (FA)	80°
Fields of view (FOV_x FOV_y)	350 mm, 263 mm
Resolution (Δ_x, Δ_y)	1.37 mm, 1.83 mm
Number of data points collected (N_x, N_y)	256, 144
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover both kidneys
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	21 sec

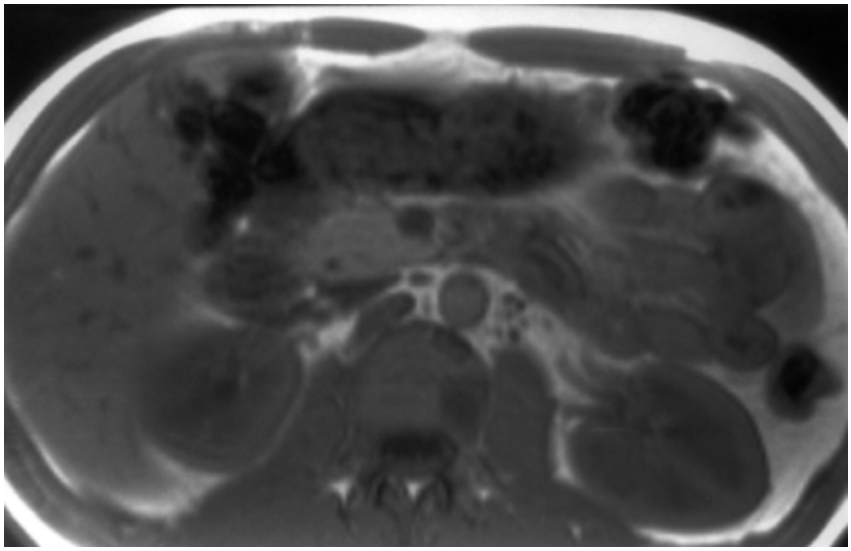

Figure A16.1.3 Unenhanced transverse spoiled gradient echo image.

Sequence 7: Transverse gradient echo—immediate post-contrast (Fig. A16.1.4)

NOTE: See patient setup section for specific instructions on preparation for contrast agent injection. This preparation must be done prior to placing the patient in the scanner.

28. Repeat step 25.

NOTE: *If possible, cover the liver in addition to the kidneys on the immediate post-contrast imaging.*

It is imperative that the slices be prescribed off of the breath-hold coronal image as this is a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held image is used.

Table A16.1.6 Imaging Parameters for Gradient Echo (Sequence 6)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to kidneys
Echo time (T_E)	4.1 msec
Repeat time (T_R)	140 msec
Flip angle (FA)	80°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	19
Slice gap	1.6–2 mm
Number of acquisition (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover both kidneys
Saturation pulses	No
Slice series	Interleaved
Scan time	18 sec

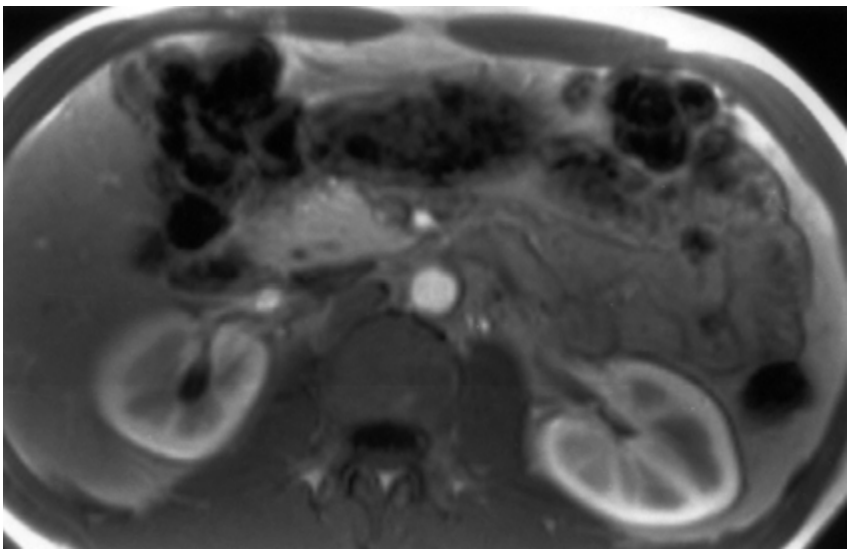

Figure A16.1.4 Immediate post-gadolinium transverse spoiled gradient echo image.

29. Explain to the patient that you will now be injecting the contrast agent and he/she may feel a cool sensation in his/her arm. Initiate the injection. Do not begin scanning until the 18 sec scan delay has expired. However, deliver breathing when 10 sec of delay are remaining (see step 30).

    If you do not have access to a power injector and are "hand" injecting, you can still use step 29. However, after you have completed the bolus contrast injection, reattach the saline-filled syringe and flush with 10 ml of saline. Begin breathing instructions after *5 ml of the saline has been injected, then proceed to initiate the scan. The process of switching syringes must be completed as quickly as possible and thus it is suggested that a 3-way stopcock be incorporated.*

30. When there are 10 sec of delay remaining, instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it.

31. Initiate the scan.

Sequence 8: Transverse gradient echo with fat saturation (45 sec delay after injection; Fig. A16.1.5)

32. Display the midline slice of the transverse gradient echo image (sequence 5) and the breath-hold coronal scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A16.1.7. Position slices to cover kidneys.

    It is imperative that the slices are prescribed off of the breath-hold coronal image as this is a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held image is used.

33. Once 45 sec has expired, instruct the patient to take in a deep breath and exhale, then take in another deep breath and hold it.

34. Initiate the scan.

Sequence 9: Gradient echo sagittal

35. Display the midline slice of the transverse gradient echo image (sequence 5) and the breath-hold sagittal scout image in two separate quadrants on the scan monitor.

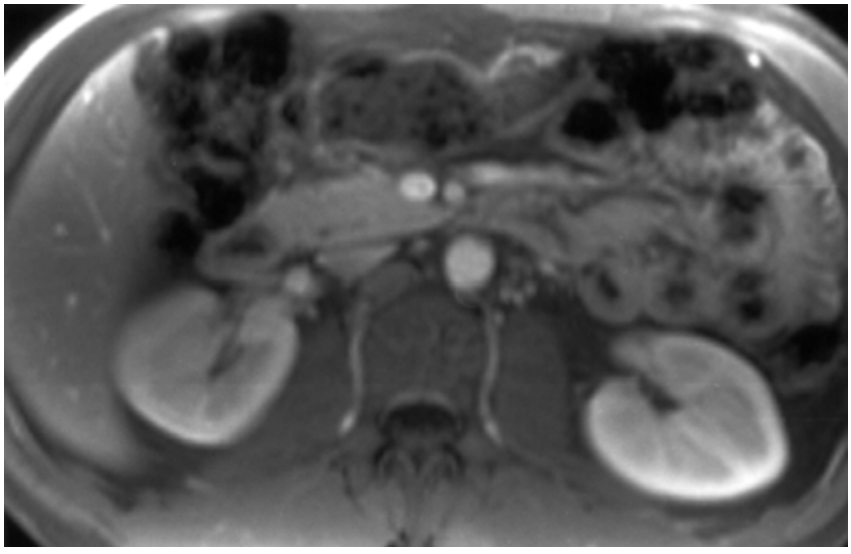

Figure A16.1.5 Contrast-enhanced fat-suppressed spoiled gradient echo transverse image.

Table A16.1.7 Imaging Parameters for Gradient Echo with Fat Saturation—45 Sec Delay (Sequence 8)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to kidneys
Echo time (T_E)	4.1 msec
Repeat time (T_R)	147.2 msec
Flip angle (FA)	80°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 1.83 mm
Number of data points collected (N_x, N_y)	256, 144
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover both kidneys
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	21 sec

Table A16.1.8 Imaging Parameters for Sagittal Gradient Echo (Sequence 9)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Sagittal
Central slice or volume center	Slices posted on transverse; center to kidneys
Echo time (T_E)	4.1 msec
Repeat time (T_R)	140 msec
Flip angle (FA)	80°
Fields of view (FOV_x FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	19
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover both kidneys
Saturation pulses	No
Slice series	Interleaved
Scan time	18 sec

Change imaging parameters to those listed in Table A16.1.8. Position slices to cover the kidneys.

It is imperative that the slices are prescribed off of breath-hold transverse and sagittal images, as this is a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if non-breath-held images are used.

36. Instruct the patient to take in a deep breath and exhale, then take in another deep breath and hold it.

37. Initiate the scan.

COMMENTARY

Background Information

Appropriate MR imaging of the kidneys requires the standard use of intravenous gadolinium (Balci et al., 1999; John et al., 1997; Hricak et al., 1988; Huch Boni et al., 1996; Rofsky et al., 1991; Semelka et al., 1991; Semelka et al., 1992; Semelka et al., 1993). Our standard renal protocol acquires the majority of sequences in the transverse plane. We believe this minimizes the potential problem with partial volume effects, that coronal or sagittal images may have, because the volume of kidney tissue at its edges is smaller in the transverse plane than in other orthogonal planes. Coronal images do have the attractive feature of displaying the kidneys in an intravenous urographic format, and the upper and lower poles are displayed in the same image. Breath-hold imaging, as performed in this protocol, is useful in the evaluation of cyst versus solid mass in the kidney. It allows for less motion artifact blurring and less contribution of noise to the calculation of lesion signal, if region-of-interest measurements are made. Sagittal plane images are a useful component to the protocol, as they allow good determination of extra- or intrarenal masses in the region of the superior pole of the kidneys. The immediate post-contrast images may also be acquired as an MR angiographic sequence, which thereby also provides information on the renal arteries.

In patients who are able to breath-hold for the 20 sec required for spoiled gradient echo, MR appears to be marginally superior to CT

Table A16.1.9 Imaging Parameters for Non-Slice Selective Turbo Flash (Use Pre-Contrast for Patients Unable to Breath-Hold)

Patient position	Supine
Scan type	Inversion recovery prepared snap shot gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to kidneys
Echo time (T_E)	4.2 msec
Repeat time (T_R)	11 msec
Flip angle (FA)	15°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	21
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover kidneys
Saturation pulses	No
Slice series	Interleaved
Scan time	2 min, 20 sec

Table A16.1.10 Imaging Parameters for Slice Selective Turbo Flash (Use Post-Contrast for Patients Unable to Breath-Hold)

Patient position	Supine
Scan type	Inversion recovery prepared snap shot gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to kidneys
Echo time (T_E)	4.2 msec
Repeat time (T_R)	11 msec
Flip angle (FA)	15°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	21
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover kidneys
Saturation pulses	No
Slice series	Interleaved
Scan time	36 sec

Table A16.1.11 Imaging Parameters for Breathing Averaged Fat Suppressed Spin Echo (Use for Patients Unable to Breath-Hold)

Patient position	Supine
Scan type	Spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to kidneys
Echo time (T_E)	15 msec
Repeat time (T_R)	500 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	10
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	4
Swap read and phase encoding	No
Slice location	Centered to cover kidneys; may need two sets
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	4 min, 19 sec

(computed tomography) for the detection of small renal masses and the distinction between cystic and solid lesions (Semelka et al., 1992; Semelka et al., 1993). In general, the advantages of MR over CT for renal imaging include: decreased incidence of allergic reaction to the contrast agent; better enhancement of renal parenchyma and tumors in the setting of chronic renal failure (John et al., 1997; Rofsky et al., 1991); better evaluation of the presence and extent of tumor thrombus; better determination of cyst versus solid renal lesions; and better evaluation of the liver in the setting of suspected metastases. In addition, gadolinium does not appear to worsen renal runction, unlike iodine (John et al., 1997; Rofsky et al., 1991).

Critical Parameters and Troubleshooting

The most critical component for determining cyst versus solid renal tumor is that the patient must breath-hold well for 20 sec. If they are not able to do so, they may be better served with a CT or ultrasound study. In order to evaluate the superior and inferior margins of renal lesions, imaging in two planes is useful. Our standard approach is to image in the transverse plane supplemented with images acquired in the sagittal plane. Other investigators image primarily in the coronal plane.

The most problematic artifact in renal imaging, particularly when the question is cyst versus solid renal lesion, is breathing artifact. As a rule, our recommendation is to perform CT or ultrasound in patients who cannot breath-hold satisfactorily. Nevertheless, it is possible to substitute in breathing independent inversion recovery prepared gradient echo (see Table A16.1.9 and Table A16.1.10), or breathing-averaged fat suppressed spin echo (see Table A16.1.11) for the breath-hold spoiled gradient echo.

Anticipated Results

Employing the protocol described above, the full range of renal diseases may be evaluated well by MRI. MRI does not, however, show calcium well, and since the majority of renal calculi contain calcium, MRI is not recommended generally for renal stone disease. These patients are best evaluated by non-contrast spiral CT.

Literature Cited

Balci, N.C., Semelka, R.C., Patt, R.H., Dubois, D., Freeman, J.A., Gomez-Caminero, A., and Woosley, J.T. 1999. Complex renal cysts: Findings on MR images. *Am. J. Roentgenol.* 172:1495-1500.

Hricak, H., Thoeni, R.F., Carroll, P.R., Demas, B.E., Marotti, M., and Tanagho, E.A. 1988. Detection and staging of renal neoplasms: A reassessment of MR imaging. *Radiology* 166:643-649.

Huch Boni, R.A., Debatin, J.F., and Krestin, G.P. 1996. Contrast-enhanced MR imaging of the kidneys and adrenal glands. *Magn. Reson. Imaging Clinics of North America* 4(1):101-131.

John, G., Semelka, R.C., Burdeny, D.A., Kelekis, N.L., Woosley, J.T., Kettritz, U., and Freeman, J.A. 1997. Renal cell cancer: Incidence of hemorrhage on MR images in patients with chronic renal insufficiency. *J. Magn. Reson. Imaging.* 7:157-60.

Rofsky, N.M., Weinreb, J.C., Bosniak, M.A., Libes, R.B., and Birnbaum, B.A. 1991. Renal lesion characterization with Gadolinium-enhanced MR imaging: Efficacy and safety in patients with renal insufficiency. *Radiology* 180:85-89.

Semelka, R.C., Hricak, H., Stevens, S.K., Fingold, R., Tomei, E., and Carroll, P.R. 1991. Combined gadolinium-enhanced and fat saturation MR imaging of renal masses. *Radiology* 178:803-809.

Semelka, R.C., Shoenut, J.P., Kroeker, M.A., MacMahon, R.G., and Greenberg, H.M. 1992. Renal lesions: controlled comparison between CT and 1.5T MR imaging with nonenhanced and gadolinium-enhanced fat-suppressed spin-echo and breath-hold FLASH techniques. *Radiology* 182:425-430.

Semelka, R.C., Shoenut, J.P., Magro, C.M., Kroeker, M.A., MacMahon, R., and Greenberg, H.M. 1993. Renal cancer staging: Comparison of contrast-enhanced CT and gadolinium-enhanced fat-suppressed spin-echo and gradient-echo MR imaging. *J. Magn. Reson. Imaging* 3:597-602.

Shellock, F.G. 1996. Pocket Guide to MR Procedures and Metallic Objects. Lippincott-Raven , Philadelphia.

Key References

Shellock, F.G. 1996.

Covers a number of important patient management issues related to MR imaging, including recommended safety procedures, a list of metallic implants that have been tested for MR compatibility, and a list of other sources on MR safety.

Contributed by Richard Semelka and Kathy Wilber
University of North Carolina–Chapel Hill
Chapel Hill, North Carolina

Laurie Fisher
Siemens Uptime Service Center
Cary, North Carolina