MRI of the Male Pelvis

MRI provides comprehensive information on many male pelvic diseases such as prostate cancer and bladder cancer as well as lymph nodes and bone metastases. The authors employ a set protocol incorporating T_1- and T_2-weighted sequences including transverse and sagittal data acquisitions, and the routine use of intravenous gadolinium.

IMAGING THE MALE PELVIS

BASIC PROTOCOL

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 A19.1.1 lists the hardware necessary to perform the procedure, along with appropriate parameters.

The following nine sequences comprise the imaging protocol for the male pelvis. This protocol employs multiple data acquisitions and serial post-gadolinium imaging. Most sequences require the patient to be able to suspend respiration for ~25 sec. It is imperative that there is 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 spectrum of male pelvic 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 by patient weight

Set up patient and equipment

1. Interview the patient to assess for contraindications such as cardiac pacemaker, implanted mechanical devices, and/or ferromagnetic materials. Also, determine if the patient will need sedation medication necessitating the use of appropriate monitoring equipment.

Table A19.1.1 Equipment Specifications Needed to Perform the Following Imaging Sequences

Coil type	Circularly polarized body phased array coil
Manufacturer and system type	Siemens, Vision
Field strength	1.5 T
Gradient coil strength	24 mT/m (or whatever the system permits)
Knee cushion	Yes
Use of contrast agents	Yes
Pulse oximeter	If patient requires sedation
Power injector	Yes
Normal saline	Yes
35" extension tubing	Yes

Contributed by Kathy Wilber, Richard Semelka, and Laurie Fisher
Current Protocols in Magnetic Resonance Imaging (2001) A19.1.1-A19.1.11
Copyright © 2002 by John Wiley & Sons, Inc.

A screening form is signed by each patient or legal guardian prior to bringing the patient into the exam area.

The presence of ferromagnetic materials may be a health hazard to the patient while in the magnetic field and/or adversely affect image quality. To determine the safety of scanning, such ferromagnetic materials, see Shellock (1996).

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.

2. Request the patient to change into a gown and 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. If the procedure is a research protocol, have the patient sign any necessary consent forms.
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.
4. Fill a 20-ml syringe with normal saline and attach to saline filled extension tubing (35 in.). Obtain 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. In cases in which a power injector is not available, this will allow you to prepare for bolus injection. 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.

   IMPORTANT NOTE: *If there is no access to a power injector, you will still be able to perform dynamic 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 contrast 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 agent, 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 agent packet insert and draw-up the amount indicated per killogram of patient weight. There is no need to double dose.
7. Escort the patient to the MR examination room and ask them to lie down accordingly with respect to the exam to be performed. Connect the extension tubing secured to the syringe to the power injector extension tubing. Review the following items with the patient:
   a. Provide earplugs or headphones to the patient to minimize the loud knocking noise that will be produced by the gradients but ensure them that they will still be able to hear you.
   b. Provide the patient with a safety squeeze-bulb and demonstrate how it works; explain to the patient when to use the squeeze-bulb (i.e., if they need assistance during the exam).

c. Explain to the patient that you will be talking to them between imaging sequences that will be when the loud knocking noise stops. Additionally, review breath-holding instructions with the patient.

d. Explain to the patient that it is imperative that they remain motionless during the loud knocking noise to ensure good results; also explain that they should not reposition their body between imaging sequences.

e. Position a support under the patient's knees to enhance patient comfort.

f. Provide the patient with an approximate time that the examination will take.

8. 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.

9. Using the laser light center the patient's pelvis to the coil. Position the CP-body array coil to include the entire pelvis and as much of the abdomen as possible. Do not sacrifice coil coverage at the bottom of the pelvis to include more of the abdomen.

10. Advance the patient table to isocenter.

11. 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 25 sec (contrast agent is injected, scan is initiated 25 sec after contrast agent and saline are delivered). Arm the power injector and keep the vein open.

Do not inject the contrast agent at this time!

Sequence 1: Three-plane positioning scout (breath-hold)

12. 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 A19.1.2 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).

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

Sequence 2: Transverse gradient echo (mid-abdomen)

14. Display both the coronal and transverse scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.3. Position slices on the coronal scout ensuring that the mid-abdomen is covered.

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

Sequence 3: Transverse gradient echo (pelvis)

16. Display both the coronal and transverse scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.4. Position slices on the coronal scout ensuring that the pelvis is covered.

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

Sequence 4: Transverse gradient echo with fat suppression

18. Display the coronal image and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.5. Position slices to cover the pelvis.

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

Table A19.1.2 Imaging Parameters for Sequence 1 (Scout Sequence)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Sagittal, transverse, and coronal
Central slice or volume center	Center to pelvis
Echo time (T_E)	6 msec
Repeat time (T_R)	15 msec
Flip angle (FA)	30°
Field 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 locations	Not applicable
Saturation pulses	Not applicable
Scan time	16 sec

Table A19.1.3 Imaging Parameters for Sequence 2 (Gradient Echo)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to mid-abdomen
Echo time (T_E)	4.5 msec
Repeat time (T_R)	140 msec
Flip angle (FA)	90°
Field 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)	7 mm
Number of slices	18
Slice gap	1.4 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice locations	Centered to cover abdomen
Saturation pulses	No
Slice series	Interleaved
Scan time	20 sec

Table A19.1.4 Imaging Parameters for Sequence 3 (Gradient Echo)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to pelvis
Echo time (T_E)	4.5 msec
Repeat time (T_R)	140 msec
Flip angle (FA)	90°
Field 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)	7 mm
Number of slices	18
Slice gap	1.4 mm
Number of acquisition (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover pelvis
Saturation pulses	No
Slice series	Interleaved
Scan time	20 sec

Table A19.1.5 Imaging Parameters for Sequence 4 (Gradient Echo with Fat Suppression)

Patient position	Supine
Scan type	Gradient Echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to pelvis
Echo time (T_E)	4.1 msec
Repeat time (T_R)	147.2 msec
Flip angle (FA)	80°
Field 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)	10 mm
Number of slices	20
Slice gap	2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover pelvis
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	19 sec

Figure A19.1.1 High resolution sagittal T_2-weighted turbo spin echo image.

20. Initiate the scan.

Sequence 5: High resolution sagittal T_2-weighted turbo spin echo (Fig. A19.1.1)

21. Display both the coronal and sagittal scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.6. Position slices to cover the pelvis.
22. Instruct the patient to remain motionless and to breathe normally as the scan will begin and last for ~3 min.

Sequence 6: High resolution transverse T_2-weighted turbo spin echo (Fig. A19.1.2)

23. Display both the coronal and transverse scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.7. Position slices to cover the pelvis.
24. Instruct the patient to remain motionless and to breathe normally as the scan will begin and last for ~3 min.

Sequence 7: Transverse gradient echo with fat suppression (immediate post-contrast scan; Fig. A19.1.3)

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

Table A19.1.6 Imaging Parameters for Sequence 5 (High Resolution T_2-Weighted Turbo Spin Echo)

Patient position	Supine
Scan type	Turbo spin echo
Imaging plane (orientation)	Sagittal
Central slice or volume center	Slices posted on coronal; center to prostate
Echo time (T_E)	132 msec
Echo train length (ETL)	15
Repeat time (T_R)	4902 msec
Flip angle (FA)	180°[a]
Field of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx,Δy)	0.68 mm, 0.97 mm
Number of data points collected (N_x, N_y)	512, 270
Display matrix (D_x, D_y)	512, 512
Slice thickness (Δz)	5 mm
Number of slices	19
Slice gap	1.0 mm
Number of acquisitions (N_{acq})	2
Swap read and phase encoding	No
Slice location	Centered to cover prostate
Saturation pulses	No
Fat suppression	No
Slice series	Interleaved
Scan time	3 min, 1 sec

[a]The system displays the flip angle of the refocusing pulse. The flip angle of the first pulse of this sequence is 90°.

25. Display the midline slice of the scout coronal image and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.8. Position slices to cover the pelvis.

26. Explain to the patient that you will now be injecting the contrast agent and that he or she may feel a cool sensation in his or her arm. Initiate the injection. Do not begin scanning until the 25-sec scan delay has expired. However, breathing instructions should be delivered when 10 sec of delay are remaining (see step 27).

    If you do not have access to a power injector and are "hand" injecting follow step 26. However, after you have completed the bolus contrast agent injection reattach the saline filled syringe and flush with 10 ml of saline. Begin breathing instructions. After all 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, the suggestion of incorporating the use of a 3-way stopcock.

27. When 15 sec after the contrast agent injection has passed, instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it.

28. Initiate the scan.

Sequence 8: Sagittal gradient echo with fat suppression (post contrast)

29. Display the transverse image and the sagittal scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.9. Position slices to cover the pelvis.

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

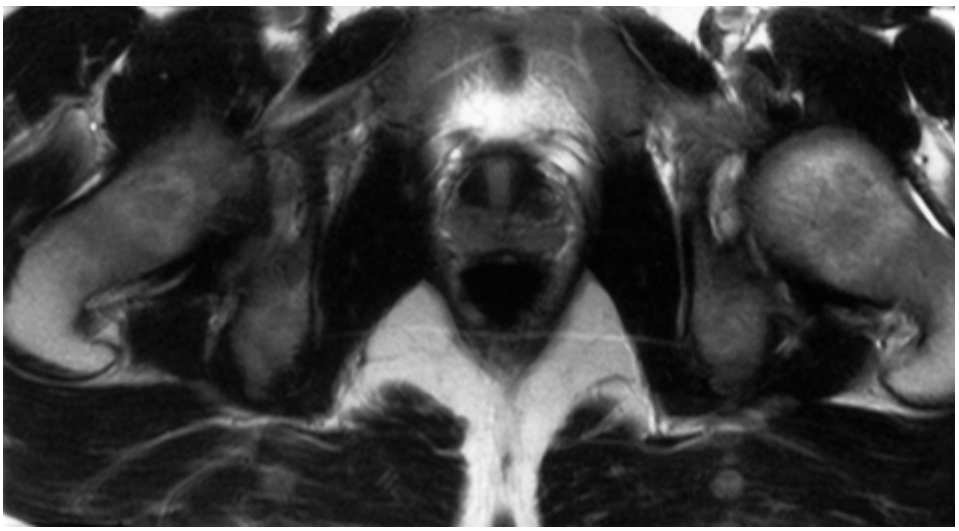

Figure A19.1.2 High resolution transverse T_2-weighted turbo spin echo image.

Table A19.1.7 Imaging Parameters for Sequence 6 (High Resolution T_2-Weighted Turbo Spin Echo)

Patient position	Supine
Scan type	Turbo spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to prostate
Echo time (T_E)	132 msec
Echo time length (ETL)	15
Repeat time (T_R)	4902 msec
Flip angle (FA)	180°[a]
Field of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	0.68 mm, 0.97 mm
Number of data points collected (N_x, N_y)	512, 270
Display matrix (D_x, D_y)	512, 512
Slice thickness (Δz)	5 mm
Number of slices	19
Slice gap	1.0 mm
Number of acquisitions (N_{acq})	2
Swap read and phase encoding	No
Slice location	Centered to cover prostate
Saturation pulses	No
Fat suppression	No
Slice series	Interleaved
Scan time	3 min, 1 sec

[a]The system displays the flip angle of the refocusing pulse. The flip angle of the first pulse of this sequence is 90°.

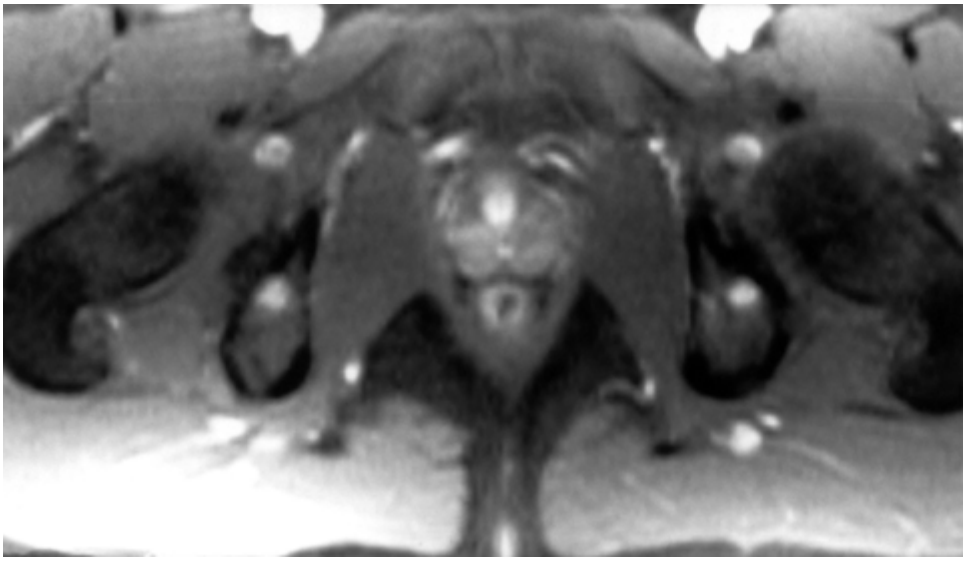

Figure A19.1.3 Transverse gradient echo with fat suppression immediate post contrast image.

Table A19.1.8 Imaging Parameters for Sequence 7 (Gradient Echo with Fat Suppression; Immediate Post-Contrast Scan)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to pelvis
Echo time (T_E)	4.1 msec
Repeat time (T_R)	147.2 msec
Flip angle (FA)	80°
Field of view (FOV_x, FOV_y)	350 mm, 300 mm
Resolution (Δx, Δy)	1.37 mm, 1.74 mm
Number of data points collected (N_x, N_y)	256, 172
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8 mm
Number of slices	20
Slice gap	1.6 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover pelvis
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	25 sec

Table A19.1.9 Imaging Parameters for Sequence 8 (Gradient Echo with Fat Suppression)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Sagittal
Central slice or volume center	Slices posted on transverse; center to pelvis
Echo time (T_E)	4.1 msec
Repeat time (T_R)	147.2 msec
Flip angle (FA)	80°
Field of view (FOV_x, FOV_y)	350 mm, 300 mm
Resolution (Δx, Δy)	1.37 mm, 1.74 mm
Number of data points collected (N_x, N_y)	256, 172
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 pelvis
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	25 sec

Table A19.1.10 Imaging Parameters for Sequence 9 (Gradient Echo with Fat Suppression)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to mid-abdomen
Echo time (T_E)	4.1 msec
Repeat time (T_R)	147.2 msec
Flip angle (FA)	80°
Field of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.74 mm
Number of data points collected (N_x, N_y)	256, 96
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 abdomen
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	14 sec

31. Initiate the scan.

Sequence 9: Transverse gradient echo with fat suppression (post contrast; mid-abdomen)

32. Display the coronal image and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A19.1.10. Position slices to cover the mid-abdomen.
33. Instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it.
34. Initiate the scan

COMMENTARY

Background Information

The major indication for MRI of the male pelvis is for the investigation of prostate cancer (Mirowitz et al., 1994; Nunes et al., 1995; Hricak et al., 1994; Schnall et al., 1991; Huch Boni et al., 1996). The male pelvis MR protocol is designed to evaluate the prostate gland and the most common forms of metastases, lymph nodes, and bone metastases.

Critical Parameters and Troubleshooting

High-resolution T_2-weighted images are critical for the detection of prostate cancer (Mirowitz et al., 1994; Nunes et al., 1995; Hricak et al., 1994; Schnall et al., 1991; Huch Boni et al., 1996). Using local receiver coils helps achieve high spatial resolution imaging. The above described protocol employs a phased array multicoil. Other investigators have used endorectal coils.

Anticipated Results

The non-contrast T_1-weighted spoiled gradient echo images of the upper abdomen and pelvis are used to evaluate for lymph nodes. Five millimeter thick transverse and sagittal T_2-weighted images are the principal technique to evaluate the prostate and seminal vesicles. The post-gadolinium T_1-weighted fat suppressed spoiled gradient echo sequence is the most consistent sequence to detect bony metastases. Using the above described sequences, the detection and staging of prostate cancer is well performed. This protocol is also effective at evaluating other pelvis tumors such as bladder cancer.

Literature Cited

Hricak, H., White, S., Vigneron, D., Kurhanewicz, J., Kosco, A., Levin, D., Weiss, J., Narayan, P., and Carroll, P.R. 1994. Carcinoma of the prostate gland: MR imaging with pelvic phased-array coils versus integrated endorectal-pelvic phased-array coils. *Radiology.* 193:703-709.

Huch Boni, R., Meyenberger, C., Pok Lundquist, J., Trinkler, F., Lutolf, U., and Krestin, G. 1996. Value of endorectal coil versus body coil MRI for diagnosis of recurrent pelvic malignancies. *Abdom. Imaging.* 21:345-352.

Mirowitz, S.A., Heiken, J.P., and Brown, J.J. 1994. Evaluation of fat saturation technique for T2-weighted endorectal coil MRI of the prostate. *Magn. Reson. Imaging.* 12:743-747.

Nunes, L.W., Scheibler, M.S., Rauschning, W., Schnall, M.D., Tomaszewski, J.E., Pollack, H., and Kressel, H. 1995. The normal prostate and periprostatic structures: Correlation between MR images made with an endorectal coil and cadaveric microtome sections. *AJR Am. J. Roentgenol.* 164:923-927.

Schnall, M., Imai, Y., Tomaszewski, J., Pollack, H., Lenkinski, R., and Kressel, H. 1991. Prostate cancer: Local staging with endorectal surface coil MR imaging. *Radiology.* 178:797-802.

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

Key References

Shellock, 1996. See above.

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

Laurie Fisher
Siemens Uptime Service Center
Cary, North Carolina