MRI of the Female Pelvis

MRI provides an effective means for evaluating the female pelvis. The benign female pelvis protocol is designed to evaluate for the presence of fibroids or adenomyosis, uterine anomalies, and endometriosis. This protocol also provides limited evaluation of adnexal disease processes including: identification of ovaries, hemorrhagic ovarian cysts, and dermoid tumors.

IMAGING THE FEMALE PELVIS

BASIC PROTOCOL

The benign disease protocol includes high-resolution turbo T_2 and gradient echo sequences through the pelvis, and does not include gadolinium-enhanced images. 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 A20.1.1 lists the hardware necessary to perform the procedure, along with appropriate parameters.

The following seven sequences comprise the imaging protocol for the female pelvis. Gradient echo sequences require the patient to be able to suspend respiration for ~20 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 benign 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.

Set up patient and equipment

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 will need sedation medication necessitating the use of appropriate monitoring equipment.

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

Table A20.1.1 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, but minimum of 24 mT/m for sequence 2)
Knee cushion	Yes
Use of contrast agents	No
Pulse oximeter	If patient requires sedation

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Current Protocols in Magnetic Resonance Imaging (2001) A20.1.1-A20.1.11

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.
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. Set up the exam room by securing the circularly polarized (CP)-body array coil onto the table and providing a clean exam table.
5. Escort the patient to the MR examination room and ask them to lie down accordingly with respect to the exam to be performed. 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, which 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.
6. 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 that are directly attached to the coil.
7. Using the laser light center the patient's pelvis to the coil.
8. Advance the patient table to isocenter.

Sequence 1: Three-plane positioning scout

9. 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 A20.1.2 for specific parameters. Run the scan.

   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).

Sequence 2: Coronal half-acquisition (partial Fourier) turbo spin echo (Fig. A20.1.1)

10. Display both the transverse and coronal scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A20.1.3.

Table A20.1.2 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 location	Not applicable
Saturation pulses	Not applicable
Scan time	16 sec

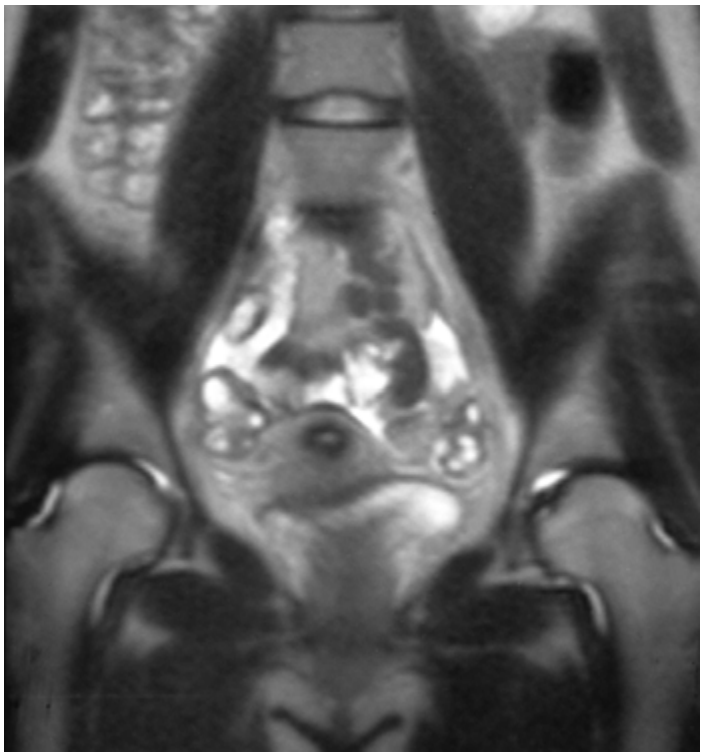

Figure A20.1.1 Coronal half-acquisition turbo spin echo image.

Position slices to center of the transverse scout ensuring that the pelvis and as much of the abdomen as possible is covered.

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

Sequence 3: High resolution transverse T_2-weighted turbo spin echo (Fig. A20.1.2)

12. Display both the coronal and transverse scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A20.1.4. Position slices to cover the pelvis.

Table A20.1.3 Imaging Parameters for Sequence 2 (Half-Acquisition Turbo Spin Echo)

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 abdomen and pelvis
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 abdomen and pelvis
Saturation pulses	No
Slice series	Interleaved
Scan time	40 sec

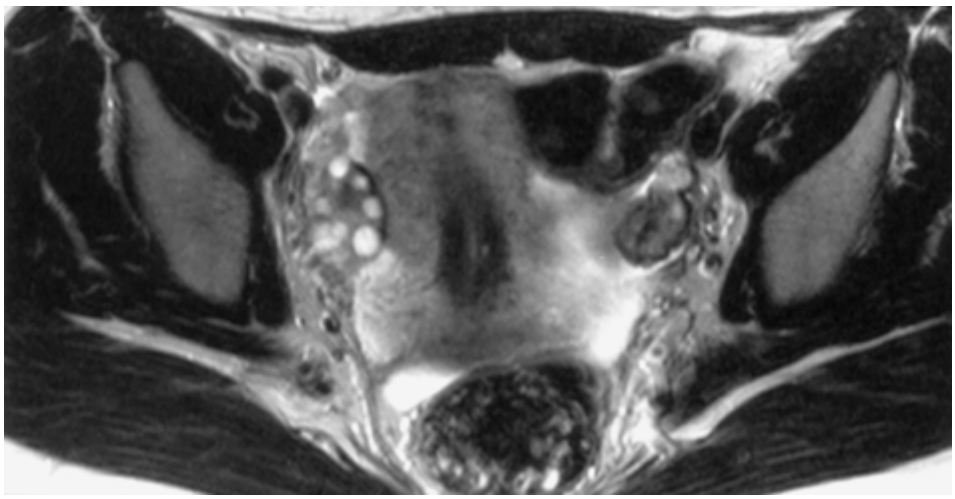

Figure A20.1.2 High resolution transverse T_2-weighted turbo spin echo image.

Table A20.1.4 Imaging Parameters for Sequence 3 (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 pelvis
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
Numbers of acquisitions (N_{acq})	2
Swap read and phase encoding	No
Slice location	Centered to cover pelvis
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°.

13. Instruct the patient to remain motionless and to breathe normally as the scan will begin and last for ~3 min. Run the scan.

Sequence 4: High resolution sagittal T_2-weighted turbo spin echo (Fig. A20.1.3)

14. Display both the transverse and sagittal scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A20.1.5. Position slices to cover the pelvis.

15. Instruct the patient to remain motionless and to breathe normally as the scan will begin and last for ~3 min. Run the scan.

Sequence 5: Transverse gradient echo

16. Display the midline slice of the coronal and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A20.1.6. Position slices to cover the pelvis.

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

Sequence 6: Sagittal gradient echo with fat suppression

18. Display both the transverse and sagittal scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A20.1.7. Position slices to center of the transverse scout ensuring that the pelvis covered.

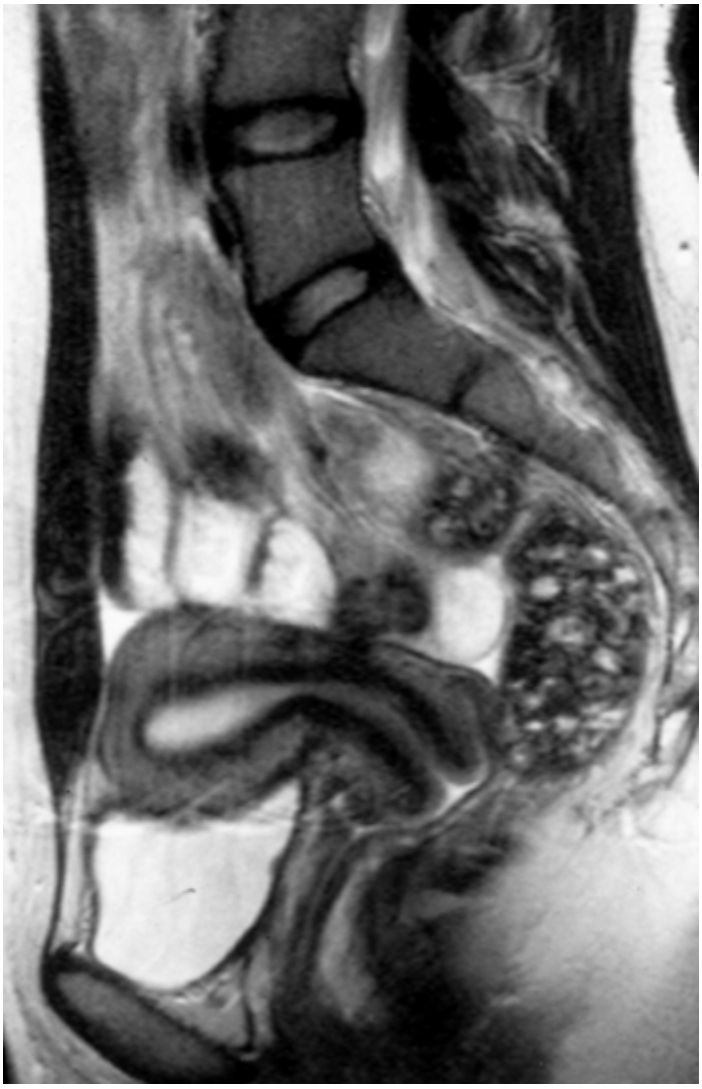

Figure A20.1.3 High resolution sagittal turbo spin echo-image.

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

Sequence 7: Transverse gradient echo with fat suppression

21. Display both the coronal and transverse scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A20.1.8. Position slices to center of the coronal scout ensuring that the pelvis covered.
22. Instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it.
23. Initiate the scan.

Table A20.1.5 Imaging Parameters for Sequence 4 (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 pelvis
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 locations	Centered to cover pelvis
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°.

Table A20.1.6 Imaging Parameters for Sequence 5 (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)	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)	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 pelvis
Saturation pulses	No
Slice series	Interleaved
Scan time	18 sec

Table A20.1.7 Imaging Parameters for Sequence 6 (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, 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)	7 mm
Number of slices	20
Slice gap	1.4 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice locations	Centered to cover pelvis
Saturation pulses	No
Fat suppression	Yes
Slice series	Interleaved
Scan time	19 sec

Table A20.1.8 Imaging Parameters for Sequence 7 (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)	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	19 sec

COMMENTARY

Background Information

Noncontrast enhanced MR protocols emphasizing T_2-weighted sequences (Hricak, 1986; Smith et al., 1992; Scoutt et al., 1991; Pellerito et al., 1992; Carrington et al., 1990; Reinhold et al., 1997; Zawin et al., 1990; Weinreb et al., 1990; Hricak et al., 1986; Mark et al., 1987; Ascher et al., 1994; Togashi et al., 1989), and T_1-weighted (short echo) sequences especially with fat suppression (Kier et al., 1992; Stevens et al., 1993; Sugimura et al., 1993; Outwater et al., 1996; Togashi et al., 1991; Ascher et al., 1995; Ha et al., 1994; Siegelman et al., 1994) are effective at evaluating benign diseases in the female pelvis. The benign female pelvis protocol is designed to evaluate for the presence of fibroids or adenomyosis (T_2-weighted sequences; Hricak, 1986; Smith et al., 1992; Scoutt et al., 1991; Zawin et al., 1990; Weinreb et al., 1990; Hricak et al., 1986; Mark et al., 1987; Ascher et al., 1995; Togashi et al., 1989), uterine anomalies (T_2-weighted sequences; Pellerito et al., 1992; Carrington et al., 1990; Reinhold et al., 1997) and endometriosis (T_1-weighted fat suppressed spoiled gradient echo sequences). Limited evaluation of adnexal disease processes is also achieved including: identification of ovaries (T_2-weighted sequences), hemorrhagic ovarian cysts (T_1-weighted fat suppressed spoiled gradient echo sequences), and dermoid tumors (combined T_1-weighted conventional and fat suppressed spoiled gradient echo sequences; Kier et al., 1992; Stevens et al., 1993; Sugimura et al., 1993; Outwater et al., 1996; Togashi et al., 1991; Ascher et al., 1995; Ha et al., 1994; Siegelman et al., 1994).

The high soft tissue contrast resolution of MRI of benign disease of the female pelvis has been extensively documented (Hricak, 1986; Smith et al., 1992; Scoutt et al., 1991; Pellerito et al., 1992; Carrington et al., 1990; Reinhold et al., 1997; Zawin et al., 1990; Weinreb et al., 1990; Hricak et al., 1986; Mark et al., 1987; Ascher et al., 1995; Togashi et al., 1989; Kier et al., 1992; Stevens et al., 1993; Sugimura et al., 1993; Outwater et al., 1993; Togashi et al., 1991; Ascher et al., 1995; Ha et al., 1994;

Table A20.1.9 Imaging Parameters for Transverse Half-Acquisition Turbo Spin Echo[a]

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 pelvis
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)	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 the pelvis
Saturation pulses	Yes, superior and inferior to slices
Fat suppression	No
Slice series	Interleaved
Scan time	40 sec

[a]Use instead of high resolution T_2-weighted turbo spin echo for patients who are unable to hold still.

Table A20.1.10 Imaging Parameters for Sagittal Half-Acquisition Turbo Spin Echo[a]

Patient position	Supine
Scan type	Half acquisition turbo spin echo
Imaging plane (orientation)	Sagittal
Central slice or volume center	Slices posted on coronal; center to pelvis
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)	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 locations	Centered to cover the pelvis
Saturation pulses	Yes, superior and inferior to slices
Fat suppression	No
Slice series	Interleaved
Scan time	40 sec

[a]Use instead of high resolution T_2-weighted turbo spin echo for patients who are unable to hold still.

Siegelman et al., 1994). No other imaging modality can demonstrate the same clarity of findings in the evaluation of benign diseases of the female pelvis.

Critical Parameters and Troubleshooting

The critical sequences for the evaluation of benign diseases of the female pelvis are T_2-weighted sequences and T_1-weighted fat suppressed sequences. It is also important to acquire images in both the transverse and sagittal planes. The sagittal plane is crucial as the female gynecological organs all line up in this projection and can be readily identified by following the course of the vagina to the cervix to the uterus. Coronal plane images are used to supplement the transverse and sagittal plane images. The cervix is a useful landmark as it can be readily identified as a dark tubular structure on T_2-weighted sequences.

In general, the authors attempt to acquire high-resolution (512 points in the read direction) T_2-weighted turbo spin echo sequences. In the event that patients are unable to hold relatively still, it has been found that obtaining transverse and sagittal projection images using the half-acquisition turbo spin echo sequence (see Tables A20.1.9 and A20.1.10) is adequate to define normal organs and the majority of disease processes.

The potential problem with fat suppression is heterogeneous fat suppression that results in difficulty interpreting the variations of tissue signal intensity. Because of the relatively homogeneous magnetic susceptibility and large volume of tissues in the pelvis, and relatively stationary tissue position through the respiratory cycle, fat suppression is generally homogeneous.

Anticipated Results

Using an MR protocol that employs image acquisition in the transverse and sagittal planes, T_2-weighted images, and fat suppressed T_1-weighted images, a comprehensive range of female pelvic diseases can be evaluated.

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Key References

Shellock and Kanal, 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.

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