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CHAPTER SIX

MRI of the Female Pelvis

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

- **Describe the major anatomical areas of the female pelvis**
- **Explain the main MRI findings of the female pelvis**
- **Respond appropriately to the patient, given the sensitive nature of the female pelvic MRI exam**

While ultrasonography is the first-line imaging modality for evaluation of most benign disorders of the female pelvis, MR imaging is playing an increasingly important role. The advantages of MRI include a more global assessment of the pelvis, multiplanar imaging that can be reproduced more reliably than ultrasound, and capacity for tissue specificity.

OVERVIEW

Recently, several technological developments have had a significant impact on MR imaging of the female pelvis. High-channel phased-array coils have substantially improved SNR and allowed for smaller fields of view, increasing resolution. Higher gradient performance results in shorter scanning times and sharper images due to shorter echo spacing times. Lastly, advances in pulse sequence design permit higher and more varied tissue contrasts (Figure 80).

IMAGING PARAMETERS

The standard pelvic imaging protocol consists of an axial T1-weighted image of the pelvis and three planes of T2-weighted images centered on the uterus. T1-weighted images provide information for tissue characterization as well as evaluation of lymphadenopathy, while T2-weighted images provide the best depiction of the zonal anatomy of the uterus and adnexa (Figure 81).

FSE/TSE techniques significantly decrease scan time as compared to older spin-echo techniques. For certain applications, like evaluation of fibroids, even faster imaging with ultrafast T2 sequences (fast imaging employing steady-state acquisition [**FIESTA**] or fast imaging with steady-state precession [**FISP**]) techniques

POINTS FOR PRACTICE

1. Given that ultrasound is usually sufficient for imaging most benign disorders of the female pelvis, what role can MRI play?
2. What are the benefits of using obstetrical and fetal MRI?

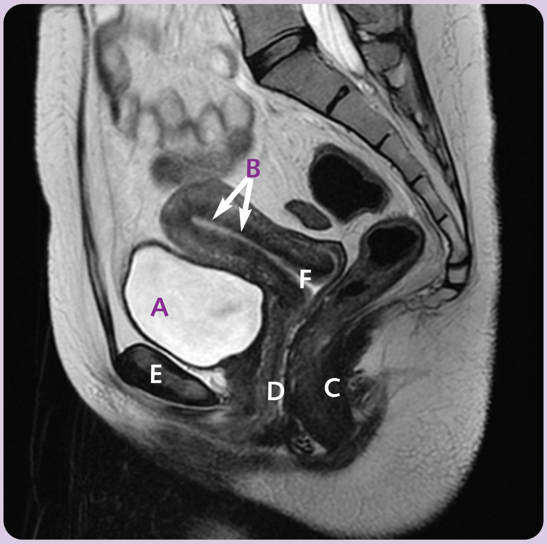

Figure 80. MR sagittal image of the female anatomy.
A = bladder
B = uterus
C = rectum
D = vagina
E = symphysis pubis
F = cervix

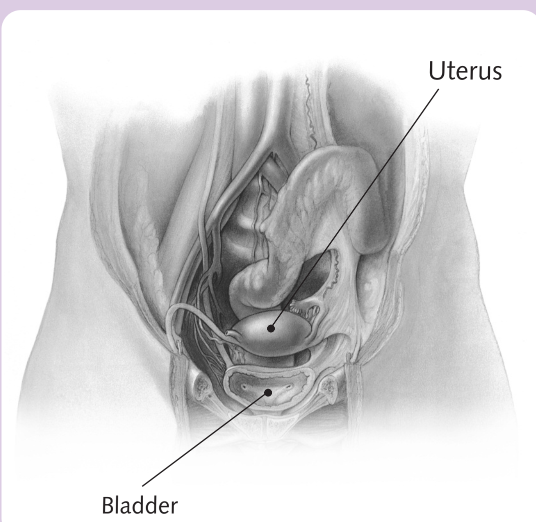

Figure 81. Female pelvic anatomy, anterior view. MR imaging protocols generally cover the pelvic contents from sidewall to sidewall, using multiplanar T2 and T1 imaging.

results in a time-efficient protocol with excellent resolution. Rapidly acquired FIESTA/FISP images also provide prenatal evaluation of complex fetal abnormalities. See Tables 12 and 13 on pages 85 and 86 for scan protocols.

CONTRAST AGENTS

Intravenous gadolinium is administered as necessary for characterization of **adnexal** masses, and subtraction techniques are used to evaluate for areas of contrast enhancement. Out-of-phase and fat saturation techniques provide greater tissue specificity in the diagnosis of fat-containing tumors, such as **dermoids** or **lipoleiomyomata**. The more recently developed 3D T1 gradient-echo sequences provide contiguous 2 mm slices of the pelvis in approximately 20 seconds, allowing dynamic imaging and generation of high quality MR angiographic images. In addition, the 3D data set provides high quality multiplanar reconstruction in an infinite number of projections. This can be helpful for preoperative planning for **myomectomy** or **embolotherapy** of fibroids.

MRI FINDINGS

Congenital Uterine Anomalies

Congenital uterine anomalies occur in 5% of the general population. MRI is performed when US is technically inadequate, indeterminate, or if cervical or vaginal malformations are suspected. MRI depicts the fundal contour of the uterus, which is important in the distinction of **septate** from **bicornuate** uterus. MRI may identify a rudimentary horn in a patient with a **unicornuate** uterus, which often requires surgical removal if it does not communicate with the endometrial cavity (Figure 82).

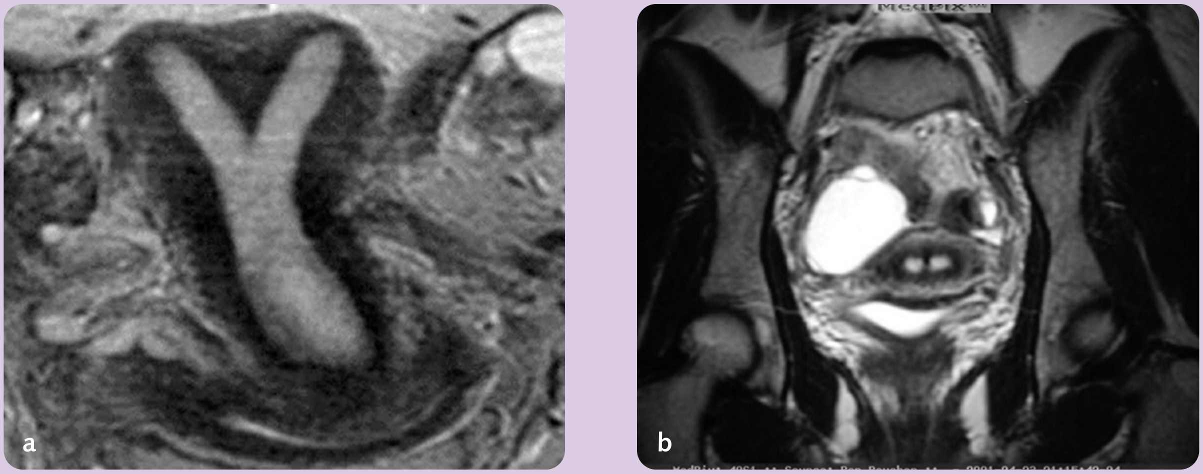

Figure 82. (a) Septate uterus. (b) Bicornuate uterus. *Courtesy of MedPix.*

MRI is used to identify the presence and degree of **agenesis** of the vagina, cervix, and uterus when endovaginal ultrasound may be impossible to perform. It is important that the slice orientation be carefully suited to the patient's particular anatomy. Slice orientations should follow the plane of the **uterine stripe** in both the short axis and perpendicular long axis views (Figure 83).

Fibroids

Fibroids are very common and usually diagnosed on US with little difficulty. MRI is beneficial in preoperative characterization of the size and location of fibroids for women who elect uterus-sparing myomectomy. This is particularly true for women with a markedly enlarged uterus with multiple fibroids. MR imaging also serves as a useful adjunct for

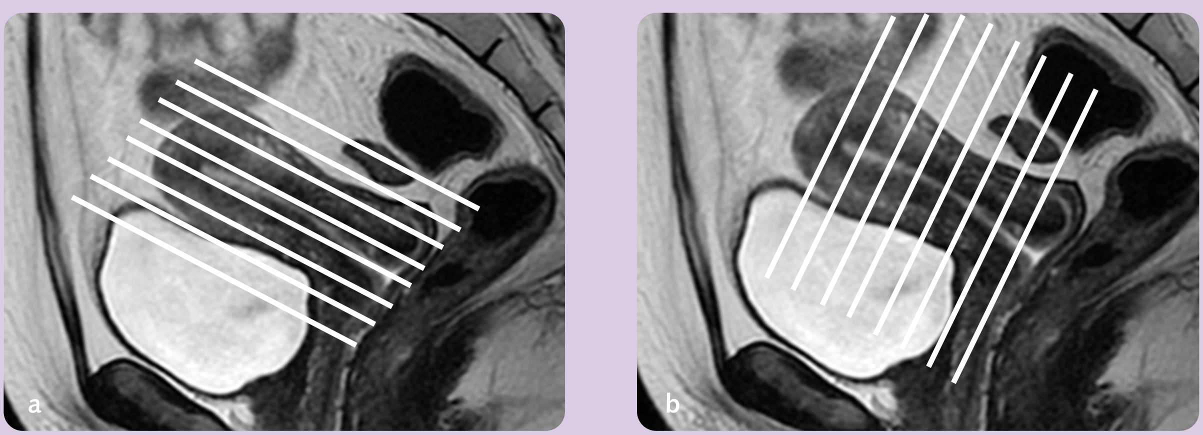

Figure 83. Proper slice orientation when imaging the uterus for uterine anomalies. Slices should be angled. (a) Parallel and (b) perpendicular to the uterine stripe.

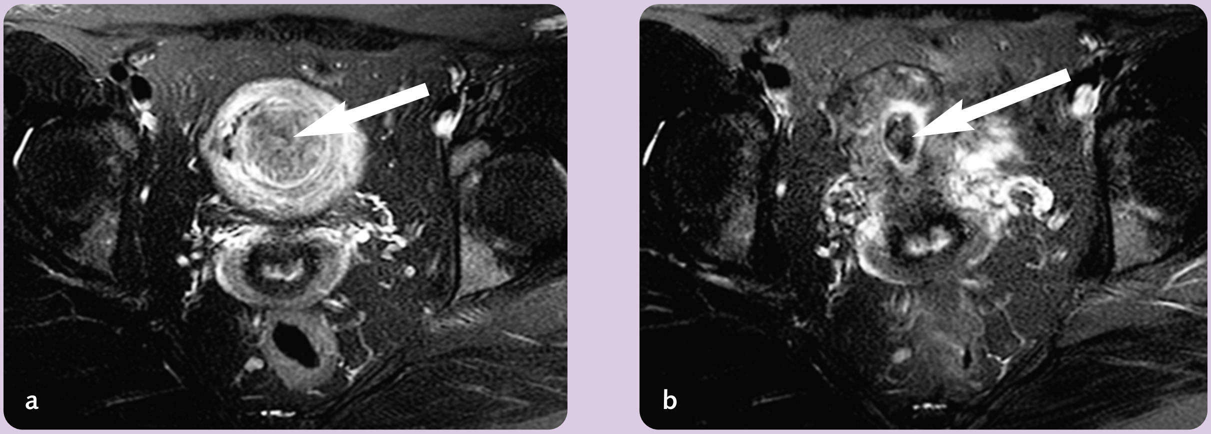

Figure 84. (a) **Axial T2-weighted fat suppressed image of a 42-year-old female with a 35.2mm fibroid *pre*-embolization.** (b) **Axial T2-weighted fat suppressed image of the same patient *after* embolization. The fibroid measures 13.4 mm.**

differentiating fibroids from other pelvic pathology, such as solid adnexal masses. Recently, transcatheter uterine artery embolization (**UAE**) has become an option for treatment of women with symptomatic fibroids. MR images performed with IV gadolinium may help to identify those women who will respond to such therapy. Several recent studies have described the post-embolization appearance of fibroids with gadolinium-enhanced MRI (Figure 84).

Adenomyosis

Adenomyosis refers to the presence of misplaced endometrial glands and stroma in the uterine wall, with adjacent myometrial hyperplasia. If symptoms are severe, hysterectomy is considered the definitive therapy; therefore, it is important to distinguish this disorder from fibroids. Diagnosis of adenomyosis is best made on T2-weighted images. Criteria for diagnosis include: focal or diffuse thickening of the junctional zone greater than 12 mm, low-signal intensity lesion adjacent to the junctional zone, and low-signal intensity myometrial mass. In distinguishing the focal form of adenomyosis from a fibroid, the most helpful features include an ill-defined border, contiguity with the endometrium, and minimal mass effect (Figure 85).

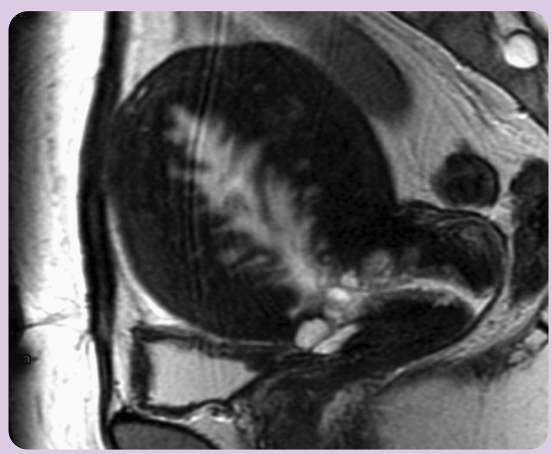

Figure 85. **This sagittal T2-weighted FSE image depicts an enlarged uterus with diffuse adenomyosis. There is diffuse thickening of the junctional zone, and high-signal intensity fluid-filled glands are seen to extend from the endometrium.**

Dermoids

Dermoids are common benign ovarian **neoplasms**. They frequently contain fat in one form or another, and this histologic marker can be used to advantage on MRI. MR imaging findings include fat content within a cyst, fat-water chemical shift artifact, low-signal intensity calcification or "teeth," and soft tissue nodules.

Several techniques can be used to confirm the presence of fat within a dermoid. These include out-of-phase imaging, as well as frequency selective fat suppression.

Frequency selective fat suppression is also commonly referred to as "chemical fat saturation." The fat suppression here is accomplished by exciting the proton spins of fat that precess 220Hz (at 1.5 T) from water with a very finely tuned (or "selective") RF pulse. This "pre-saturation" RF pulse places only the fat spins into the transverse plane. Any signal coming from these spins is ignored. Immediately thereafter, a water-selective RF pulse excites the water spins. As the water spins are placed into the transverse plane, any fat spins still in the transverse plane are forced into the negative longitutinal plane and therefore produce no signal.

The technologist should remember that with out-of-phase imaging there must be relatively equal numbers of fat and water molecules for there to be suppressed signal; therefore, a mass that is relatively pure fat may not suppress, and frequency selective fat suppression may be necessary. Conversely, out-of-phase imaging can detect mixtures of fat and water that may not contain enough fat to show signal intensity loss by frequency selective fat suppression (Figure 86).

Endometriosis

Endometriosis is the presence of actively growing and functioning endometrial tissue outside the uterus. The usual appearance of an **endometrioma** is of high-signal intensity on T1 and low signal on T2. This phenomenon is believed to be secondary to repeated bleeding into the endometrioma, resulting in a high

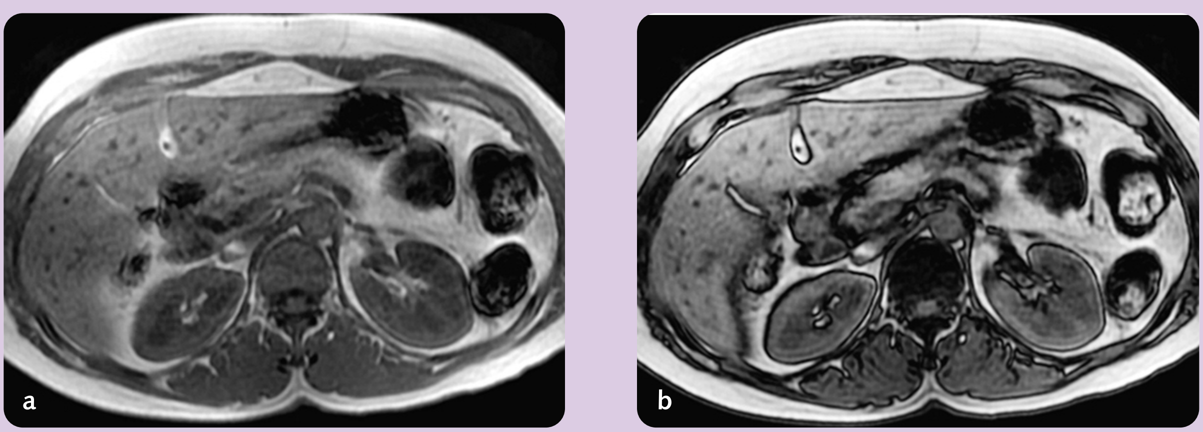

Figure 86. (a) In-phase image of an axial RF spoiled gradient-echo image of the kidneys using a TE of 4.2 msec. (b) Out-of-phase image of an axial RF spoiled gradient-echo image of the kidneys using a TE of 2.1 msec. Note the differences in contrast near the fat/water interfaces around the kidneys, liver, and other abdominal structures.

concentration of blood components that shorten T2. Endometriomas may also exhibit high-signal intensity T2, but this appearance is nonspecific and may be seen in hemorrhagic functional cysts. Small hemorrhagic endometriotic deposits in the pelvis are often most apparent on T1-weighted fat-suppressed images.

Endometrial Carcinoma

Endometrial carcinoma often presents as isointense on T1-weighted imaging versus normal myometrium. However, on T2-weighted imaging, endometrial carcinoma usually appears hyperintense versus normal myometrium. Fat suppression techniques are useful in increasing the contrast between the two. Post-gadolinium injection findings typically demonstrate hetergeneous signal enhancement.[1]

Cervical Carcinoma

Although MR imaging is not typically the modality of choice, MRI demonstrates distinct findings in the setting of cervical carcinoma. Usually T1, T2 (usually fat-suppressed), and T1 post-contrast imaging are performed. Cervical carcinoma often demonstrates as hypointense-to-isointense signal on T1-weighted imaging. On T2-weighted imaging, the carcinoma displays a heterogeneous as well as homogeneous signal characteristic. Following gadolinium injection, cervical carcinoma usually demonstrates mildly heterogeneous enhancement[2] (Figure 87).

OBSTETRICAL AND FETAL IMAGING

Obstetrical and fetal MRI have recently become more common. Many studies have shown the utility of MR for characterizing adnexal and uterine masses in the pregnant

Figure 87. Sagittal (a) and coronal (b) Non-fat-suppressed T2-weighted images of a 64-year-old female with a large uterine fibroid (arrow) and cervical mass (circles).

patient in whom ultrasound is indeterminate and where ionizing radiation must be avoided. Another useful application for MRI of the pregnant patient is in the evaluation of the appendix. Appendicitis can lead to sepsis if left untreated to the point that the appendix bursts. Symptoms typical of appendicitis include severe right lower quandrant pain, and a blood test to check for an elevated white cell count usually helps diagnose the presence of appendicitis. In the pregnant patient, however, white blood counts may be elevated naturally. Ultrasound can be used to evaluate the appendix, but the assessment may be inadequate due to interference from the enlarged abdominal cavity. Thus, MRI has proven to be an effective alternative to visualizing the appendix. Ultrafast imaging techniques are now fast enough to "freeze" abdominal motion and at the same time limit the amount of radiofrequency pulses to the fetus. While no adverse effects to the fetus have been shown with MRI, it is recommended that the amount of radiofrequency used while scanning the pregnant patient be limited in order to reduce SAR. The most effective method in reducing SAR is to adopt gradient-echo pulse sequences instead of long RF-echo-based sequences like FSE and TSE.

Recently, MR also has been shown to be a useful adjunct to ultrasound in the prenatal detection and characterization of complex fetal anomalies. This is due to the rapid imaging time afforded by ultrafast T2 pulse sequences (FIESTA and FISP), with decreased artifacts secondary to fetal motion (Figure 88).

PELVIC FLOOR WEAKNESS

Pelvic floor weakness is common in middle-aged and elderly **parous** women. Pelvic floor prolapse occurs in roughly 50% of females who have had children. Most commonly, these patients present with stress incontinence, uterine prolapse, incomplete defecation, and

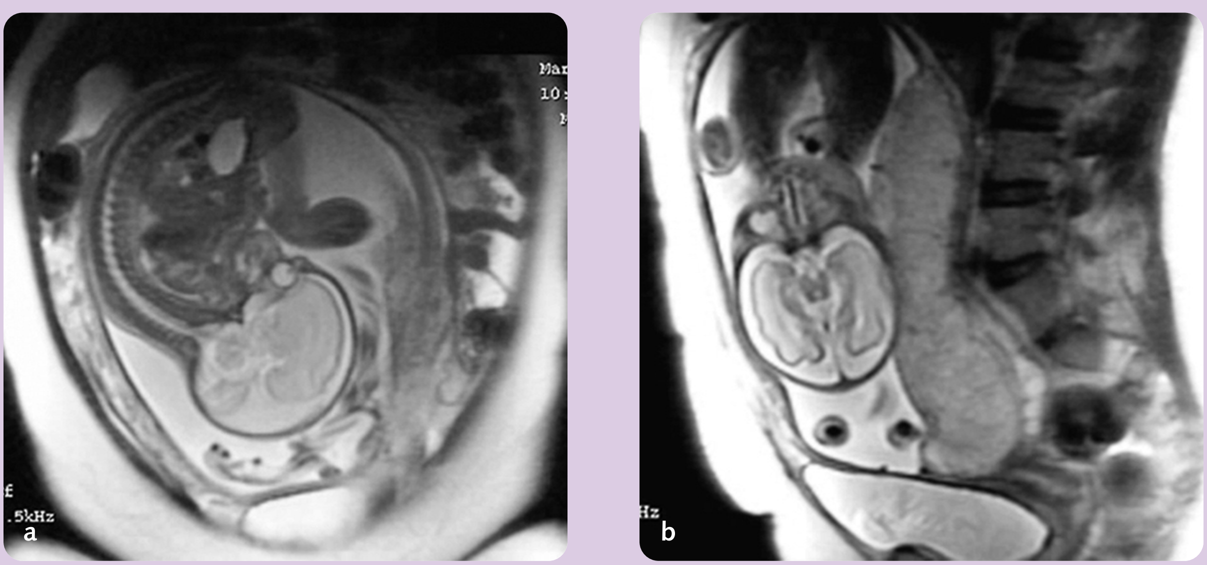

Figure 88. Fetal imaging in utero using single-shot FSE in (a) sagittal and (b) coronal anatomic planes. Note lack of motion due to very rapid scanning, yet spatial detail remains relatively robust.

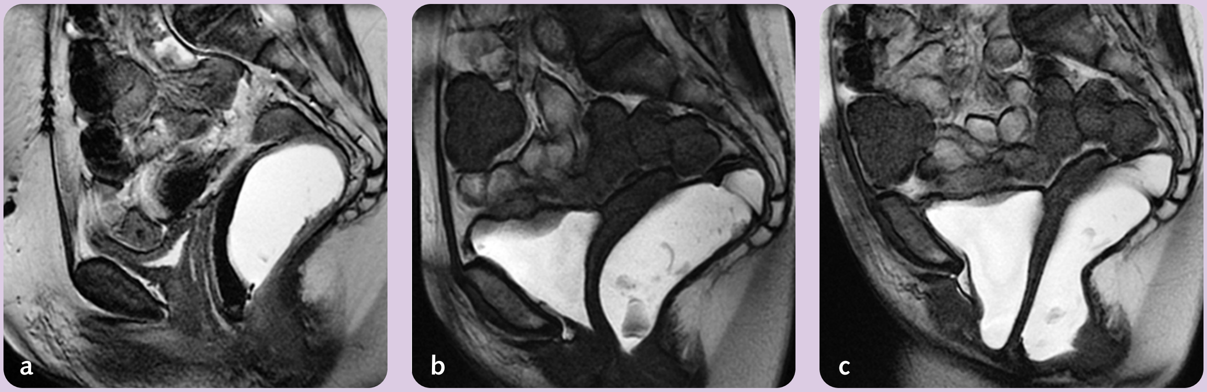

Figure 89. (a) Sagittal FIESTA image of 53-year-old female with normal positioning of internal pelvic organs above the pelvic floor. Line from inferior symphysis to the bottom of the coccyx indicates the boundary of the pelvic floor. (b, c) Sagittal FIESTA images of 55-year-old female at rest (b) and after "push." (c) [Note the moderate prolapse of the rectum, inferior vagina, and mild prolapse of the bladder at rest. Note the severe prolapse (c) at full "push." The rectum, vagina, and bladder are all nearly completely below the pelvic floor boundary.]

chronic constipation. Women with prolapse often require surgery, and for patients where complex surgical repair may be required for multi-compartmental involvement, MR is an essential pre-surgical tool. MRI offers superior resolution for evaluation of soft tissues compared with ultrasound. Using ultrafast and high-resolution T2 sequences, assessment of the pelvic floor and organs has become possible in a dynamic fashion. Several breath-hold sets of images can be obtained, one at each of several different degrees of pelvic straining. Dynamic MRI reliably detects descent of the pelvis, demonstrating all pelvic organs and pelvic floor musculature, often critical information for both diagnosis and surgical planning.

Pelvic Floor MR Examination

This exam is very quick, usually 15 minutes or less. While a contrast agent is not needed, the exam requires the patient's rectum to be filled with a gel that displays bright signal. Water-soluble ultrasound gel provides this contrast. Sensitive handling of the patient is paramount. Approximately 120 mL of room-temperature gel is injected into the rectum via a standard enema tip. Once the gel is in place, the enema tip is removed. The exam typically requires high-resolution imaging in two planes, acquired at the beginning of the exam, and axial and coronal are most common. The diagnostic portion of the evaluation occurs at the end of the exam when the patient is instructed to strain and push the gel out during high-resolution dynamic imaging. Pulse sequences typically used are FIESTA/true-FISP or single-shot FSE/TTSE. A single mid-line sagittal image is acquired in multi-phases. When displayed in a cine-loop, the displacement of the pelvic organs can be observed in detail and precise measurements made. Figure 89 shows normal and abnormal pelvic floor images demonstrating normal and abnormal placement of pelvic organs.

See Tables 12 and 13 on pages 85 and 86 for sample scan protocols.

This exam requires the utmost sensitivity to the patient to guarantee their privacy and maintain dignity. The exam needs to be explained in detail prior to the beginning of the exam. A private, reserved bathroom must be available to the patient immediately following the exam. While this is a fast, virtually pain-free, and highly diagnostic exam, few MR facilities offer this application because of the nature of the exam.

SUMMARY

MRI plays a pivotal role in the diagnosis and staging of many female pelvic pathologies. The inherent ability of MRI to produce different contrasts of the same tissue as opposed to adjacent tissue makes MRI a valuable adjunct to ultrasonography evaluation and other imaging modalities.

Table 12.

SAMPLE DYNAMIC PELVIS MRI PROTOCOL

Parameter	3D Gradient In/Out Axial T2	Coronal T1	Sagittal Fiesta (FISP)	Sagittal Fiesta (FISP)
Imaging Parameters				
Pulse Sequence	Fast Spin Echo	Fast Spin Echo	FIESTA	FIESTA
Plane	Axial	Coronal	Sagittal	Sagittal
Repetition Time (TR)	4000	4000	Min	Min
Echo Time (TE) (msec)	100	100	Min	Min
Slice Thickness (mm)	4.5	7	10	10
Field of View (FOV) (cm)	25	26	30	30
ETL	15	15		
Flip Angle			75	75
NEX (NSA)	4	3	1	1
Phase	512	256	320	320
Frequency	384	192	320	320
Images/Loc			10 REST	10 PUSH

Table 13.

SAMPLE FEMALE PELVIS MRI PROTOCOL					
Parameter	**3 Plane Localizer**	**Sagittal T2**	**Axial T1**	**Axial T2**	**Coronal T2**
Patient Position					
Orientation	Feet first, Supine	Feet first, Supine	Feet first, Supine	Feet first, Supine	Feet first, Supine
Coil	Torso phased array	Torso phased array	Torso phased array	Torso phased array	Torso phased array
Plane	3 Planes	Axial	Oblique	Oblique	Oblique
Imaging Parameters					
Pulse Sequence	GRE	FSE	SPGR	FSE	FSE
Scan Timing					
Number of Shots					
TE (msec)		120	In-Phase	120	120
TR (msec)		6,000	250	6,000	6,000
TI (msec)					
FA			70°		
ETL		12-16		12-16	12-16
Options		NPW, VBw FC, EDR	NPW, EDR	NPW, VBw FC, EDR	NPW, VBw FC, EDR
Scanning Range					
FOV (cm)	48	22	28	20	20
Slice Thickness (mm)	8	4	5	5	5
Slice Spacing (mm)	2	1	0	1	1
SAT Bands		Anterior Inferior Superior	Anterior Inferior Superior	Anterior Inferior Superior	Anterior Inferior Superior
Acquisition Time					
Acquisition Matrix Frequency	256	256	256	256	256
Acquisition Matrix Phase	128	256	160	256	256
NEX	1	3	2	3	3
Phase FOV	1	1	1	1	1
Frequency Direction		S/I	R/L	R/L	S/I
Auto Center Frequency	Water	Water	Water	Water	Water
Autoshim	Yes	Yes	Yes	Yes	Yes

Notes

- The axial T1 images should start at the distal pole of the kidneys and end at the pubis symphysis.
- The axial T2 images should be prescribed perpendicular to the uterus.
- The coronal T2 images should be prescribed parallel to the uterus.

POINTS FOR PRACTICE

1. **Given that ultrasound is usually sufficient for imaging most benign disorders of the female pelvis, what role can MRI play?**

   The advantages of MRI include:

   - A more global assessment of the pelvis
   - Multi-planar imaging can be reproduced more reliably than ultrasound
   - Capacity for tissue specificity

2. **What are the benefits of using obstetrical and fetal MRI?**

   MRI often is able to characterize adnexal and uterine masses in the pregnant patient in whom US has been indeterminate and where ionizing radiation must be avoided. MRI is also useful in helping diagnosis appendicitis in the pregnant patient, while posing little risk to the fetus. A useful adjunct to US, MRI has also shown to be valuable in the detection and characterization of complex fetal anomalies.

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2. Li XC, Shang JB, Wu XM, et al. MRI findings of uterine cervical cancer and value of MRI in preoperative staging. *US National Library of Medicine, National Institutes of Health.* 2007;27:352-354.

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

Notes