MR Imaging–based Assessment of the Female Pelvic Floor[1]

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Abbreviations: FIESTA = fast imaging employing steady-state acquisition, MPL = midpubic line, PCL = pubococcygeal line

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Describe the normal anatomy of the female pelvic floor and recognize the main MR imaging features of pelvic floor weakness.
- Discuss the role of MR imaging, especially dynamic sequences, in the evaluation and management of pelvic floor weakness.
- Describe the MR imaging protocols used in evaluating pelvic floor weakness and in MR defecography.

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Pelvic floor weakness is a functional condition that affects the anatomic structures supporting the pelvic organs: fasciae, ligaments, and muscles. It is a prevalent disorder among people older than 50 years, especially women, and may substantially diminish their quality of life. Many complex causes of pelvic floor weakness have been described, but the greatest risk factors are aging and female sex. Pelvic floor weakness can provoke a wide range of symptoms, including pain, urinary and fecal incontinence, constipation, difficulty in voiding, a sense of pressure, and sexual dysfunction. When the condition is diagnosed solely on the basis of physical and clinical examination, the compartments involved and the site of prolapse are frequently misidentified. Such errors contribute to a high number of failed interventions. Magnetic resonance (MR) imaging, which allows visualization of all three compartments, has proved a reliable technique for accurate diagnosis, especially when involvement of multiple compartments is suspected. MR imaging allows precise evaluation of ligaments, muscles, and pelvic organs and provides accurate information for appropriate surgical treatment. Moreover, dynamic MR imaging with steady-state sequences enables the evaluation of functional disorders of the pelvic floor. The authors review the pelvic floor anatomy, describe the MR imaging protocol used in their institutions, survey common MR imaging findings in the presence of pelvic floor weakness, and highlight key details that radiologists should provide surgeons to ensure effective treatment and improved outcomes. *Online supplemental material is available for this article.*

Introduction

Pelvic floor weakness refers to a spectrum of functional disorders caused by impairment of the ligaments, fasciae, and muscles that support the pelvic organs. Such disorders include urinary and fecal incontinence, obstructed defecation, and pelvic organ prolapse.

Pelvic floor weakness is prevalent and debilitating, substantially diminishing the quality of life of those whom it affects. Approximately 50% of women older than 50 years are affected by this condition worldwide, with a direct annual cost of $12 billion (1–3). In the United States, disorders of the pelvic floor affect 23.7% of women (4), and prolapse is one of the most common indications for gynecologic surgery (5). In developing countries, the prevalence of pelvic organ prolapse is 19.7%, that of urinary incontinence is 28.7%, and that of fecal incontinence is 7% (6).

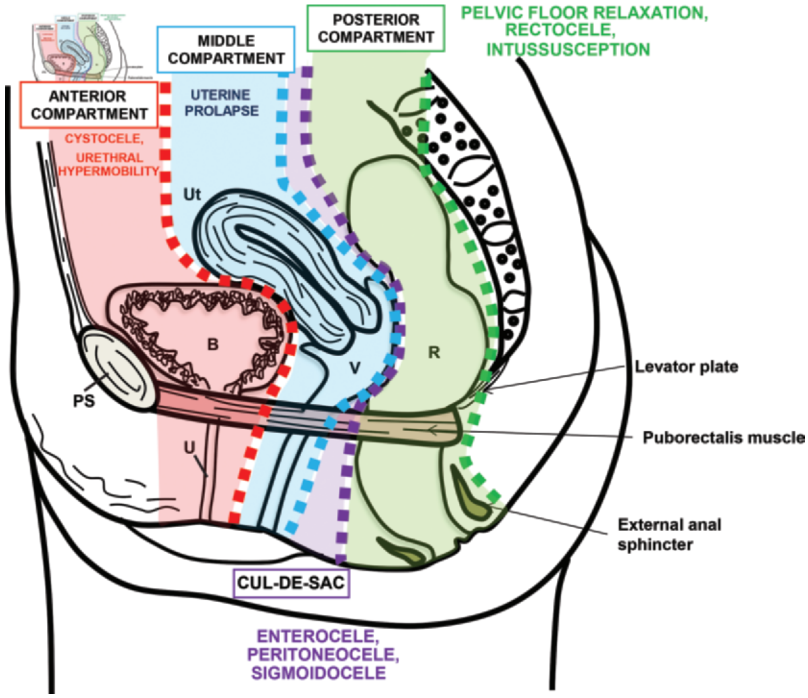


Figure 1. Schematic in the midsagittal plane shows the three functional anatomic compartments of the female pelvis and the most important pathologic conditions that may occur in each: the anterior compartment (red), containing the bladder *(B)* and urethra *(U)*; the middle compartment (blue), containing the uterus *(Ut)*, cervix, and vagina *(V)*; and the posterior compartment (green), containing the anus, anal canal, rectum *(R)*, and sigmoid colon. A fourth "virtual" compartment called the cul-de-sac (violet) is also shown. Note that the puborectalis muscle surrounds the bladder neck, vagina, and rectum. *PS* = pubic symphysis.

Pelvic organ prolapse and pelvic floor relaxation are related and often coexistent components of pelvic floor weakness but must be differentiated. Pelvic organ prolapse is the abnormal descent of a pelvic organ through the hiatus beneath it. This condition may affect the bladder (cystocele), vagina (vaginal prolapse), uterus (uterine prolapse), mesenteric fat (peritoneocele), small intestine, or sigmoid colon (sigmoidocele). In pelvic floor relaxation, active and passive supporting structures within the pelvic floor become weakened and ineffective, with resultant excessive descent and widening of the entire pelvic floor during rest and/or evacuation, regardless of whether prolapse is present (7).

Many causes of pelvic floor weakness have been described, including multiparity, advanced age, pregnancy, obesity, menopause, connective tissue disorders, smoking, chronic obstructive pulmonary disease, and conditions resulting in a chronic increase in intraabdominal pressure (8). The greatest risk factors are aging and female sex.

Pelvic floor weakness can provoke a wide range of symptoms, including pain, urinary and fecal incontinence, constipation, difficulty in voiding, a sense of pressure, and sexual dysfunction. Symptoms are observed in 10%–20% of women with pelvic prolapse and depend on the compartment involved. Because pelvic weakness often involves multiple compartments, symptoms may occur in various combinations (9). According to study results reported by Rush et al (10), 50% of patients with urinary stress incontinence and 80% of patients with uterovaginal prolapse had symptoms of obstructed defecation. In another study of patients with defecatory disorders, dynamic cystocolpoproctography showed a cystocele in 71% of the patients, hypermobility of the bladder neck in 65% of the patients, and a vaginal vault prolapse of more than 50% in 35% of the patients (11).

A standardized system for assessing and documenting pelvic organ prolapse with a physical examination, the pelvic organ prolapse quantification (POP-Q) system, was proposed by the International Continence Society in 1996 (12). In this system, the descent of each compartment is measured by using the vaginal hymen as a reference line while the patient is in the lithotomy position and is performing the Valsalva maneuver (13). Although this clinical grading system is widely accepted, it often leads to underestimation of the number of compartments affected. Moreover, failure to recognize prolapse in a substantial number of patients by using this approach contributes to high rates of therapeutic failure (11). Several imaging techniques may be used as adjuncts to physical examination. Traditional imaging procedures (eg, urodynamic study, voiding cystourethrography, and fluoroscopic cystocolpodefecography) remain practical and cost-effective methods for evaluating uncomplicated anorectal and pelvic dysfunction. Over the past decade, magnetic resonance (MR) imaging with dynamic sequences has been proven accurate and reliable for identifying pelvic floor weakness, especially when multiple

Teaching Point

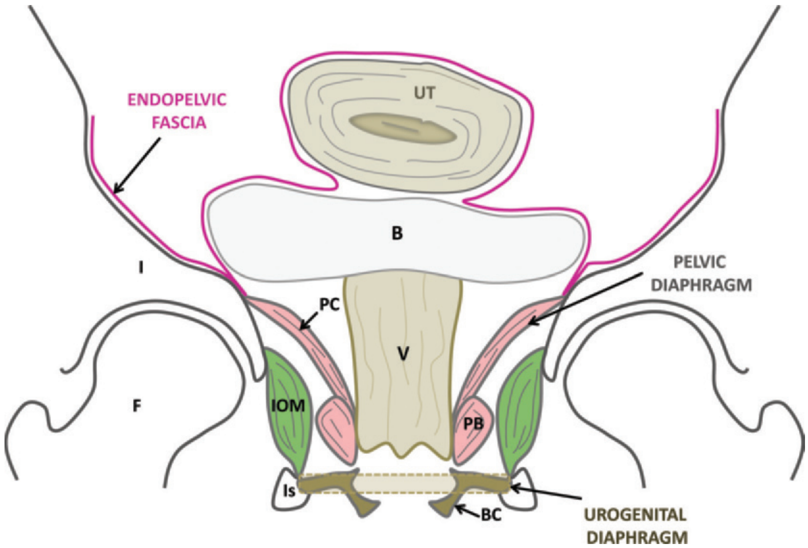


Figure 2. Schematic in the coronal plane at the level of the vagina *(V)* depicts the three levels of pelvic floor support: the endopelvic fascia, the pelvic diaphragm (levator ani level), and the urogenital diaphragm. *B* = bladder, *BC* = bulbocavernosus muscle, *F* = femur, *I* = iliacus muscle, *IOM* = internal obturator muscle, *Is* = ischial ramus, *PB* = puborectalis muscle, *PC* = pubococcygeus muscle, *UT* = uterus.

compartments are involved, because it allows all three compartments to be visualized simultaneously. In addition, ultrasonography (US) has emerged in the past several years as an important diagnostic method.

The next section of this article provides an overview of the normal female pelvic floor anatomy, fundamental knowledge for the accurate and comprehensive interpretation of MR imaging findings. Next, the technical advantages and limitations of MR imaging for surgical planning are surveyed, and the MR imaging protocol used at the authors' institutions, which includes the use of dynamic steady-state sequences, is outlined. Key MR imaging appearances for diagnosing pelvic floor weakness and determining its extent and severity are described in detail. Last, the most important points that should be covered in the radiologist's report are reviewed.

Anatomy of the Female Pelvic Floor

Basic knowledge of the anatomy of the female pelvic floor is crucial to correctly interpret pelvic MR images and to fully understand dysfunction associated with pelvic floor weakness.

The pelvic floor is classically described as comprising three compartments: an anterior compartment containing the bladder and urethra, a middle compartment containing the vagina and uterus, and a posterior compartment containing the rectum (14) (Fig 1). The supporting structures of the female pelvis consist of a complex network of fascia, ligaments (fascial condensations), and muscles attached to pelvic bone. These structures form three contiguous layers from a superior to an inferior location: the endopelvic fascia, the pelvic diaphragm, and the urogenital diaphragm (Figs 2, 3).

Endopelvic Fascia

The urethral ligaments and perineal body are the only components of the endopelvic fascia and ligaments that are directly depicted on MR images obtained with standard sequences. Damage to other supporting structures within the pelvic floor can only be inferred from the presence of secondary signs and abnormal descent of the pelvic organs during a dynamic MR imaging study (15). By contrast, the supporting fascia and ligaments are visible on high-resolution MR images obtained with an endovaginal coil (16–18).

The endopelvic fascia, the most superior layer of the pelvic floor, covers the levator ani muscles and pelvic organs in a continuous sheet. In the anterior compartment, the portion of endopelvic fascia that extends from the anterior vaginal wall to the pubis is known as the pubocervical fascia. Macura et al (19) described three groups of ligaments supporting the female urethra: periurethral ligaments arising from the puborectalis muscle, ventral to the urethra; paraurethral ligaments arising from the lateral wall of the urethra and extending to the periurethral ligaments; and pubourethral ligaments, which extend from the pelvic bone to the ventral wall of the urethra (Fig 4). The ligaments and anterior vaginal wall provide a hammock-like support and play an important role in maintaining urinary continence in women (16,20). Therefore, a tear in the pubocervical fascia or periurethral ligament can lead to a cystocele, urethral hypermobility, or urinary incontinence.

In the middle compartment, elastic condensations of endopelvic fascia known as the paracolpium and parametrium provide support to the vagina, cervix, and uterus, preventing genital organ prolapse (21).

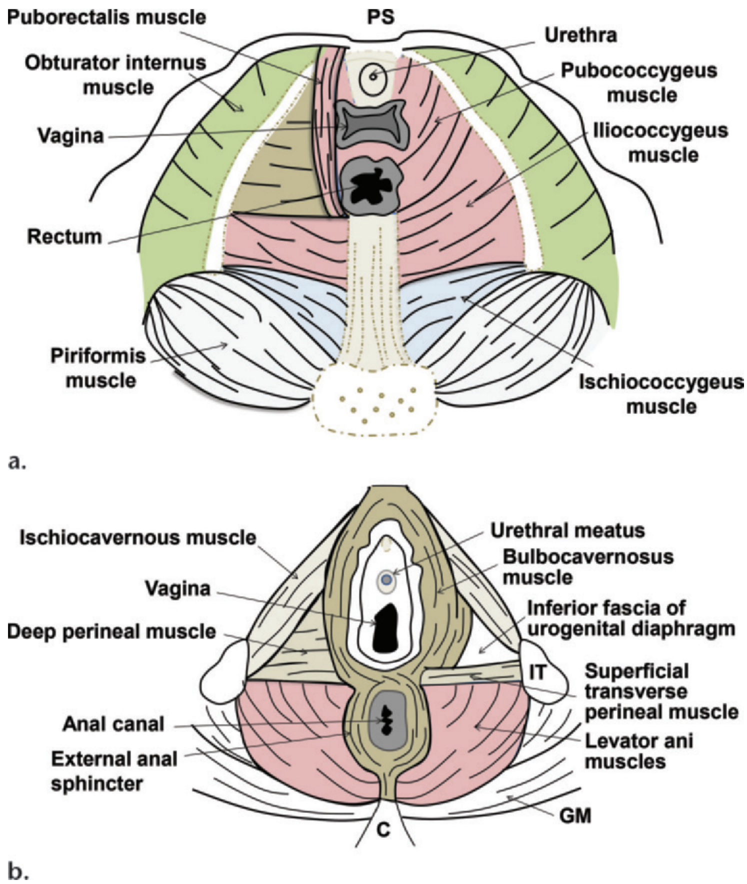


Figure 3. Schematics show the anatomy of the female pelvic floor at the level of the pelvic diaphragm **(a)** and the urogenital diaphragm **(b)**. The pelvic diaphragm is composed of the ischiococcygeus muscle and levator ani muscle, the latter of which consists of the iliococcygeus, puborectalis, and pubococcygeus muscles. The location of the urogenital diaphragm is caudal to the pelvic diaphragm and anterior to the anorectum. It is composed of connective tissue and the deep transverse muscle of the perineum. It originates at the inner surface of the ischial ramus and has multiple attachments to surrounding structures including the vagina, perineal body, external anal sphincter, and bulbocavernosus muscle. *C* = coccyx, *GM* = gluteus muscle, *IT* = ischial tuberosity, *PS* = pubic symphysis.

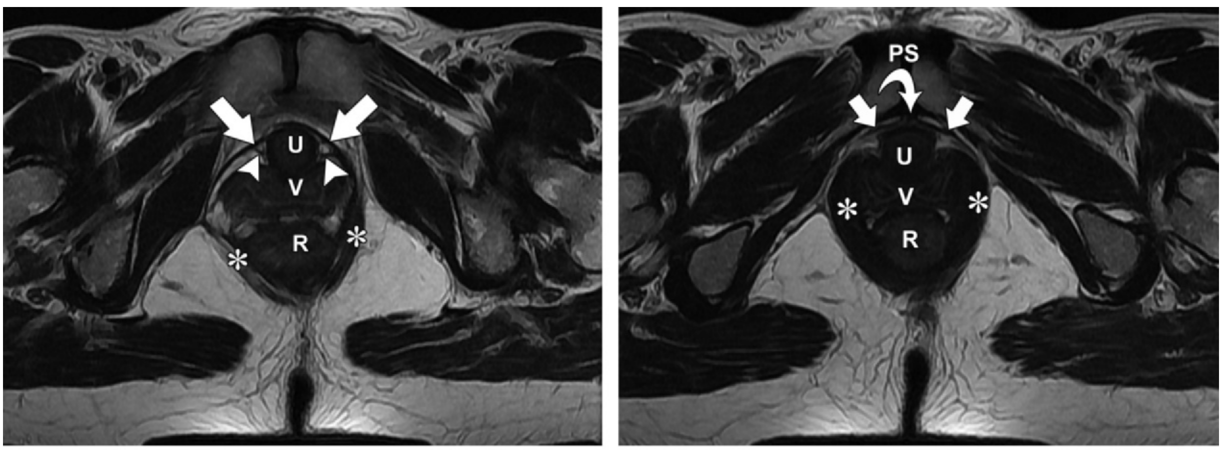


Figure 4. Normal female pelvic floor anatomy. Axial T2-weighted MR images show the ligaments that support the female urethra at superior **(a)** and inferior **(b)** levels: the periurethral ligaments (arrows), which arise from the puborectalis muscle (*); paraurethral ligaments (arrowheads in **a**), which arise from the lateral wall of the urethra *(U)*; and periurethral and pubourethral ligaments (curved arrow in **b**), which arise from the pubic bone and extend to the ventral wall of the urethra. Note the typical H- or butterfly-like shape of the vagina *(V)* and the close apposition of the puborectalis muscle to the vaginal wall. *PS* = pubic symphysis, *R* = rectum.

The posterior compartment contains an important anchoring structure for muscles and ligaments, called the perineal body or central tendon of the perineum, which lies within the anovaginal septum and prevents the expansion of the urogenital hiatus (Fig 5). The rectovaginal fascia is a portion of the endopelvic fascia that extends from the posterior wall of the vagina to the anterior wall of the rectum and attaches to the perineal body, preventing posterior prolapse. A tear in the rectovaginal fascia can be inferred from the presence of an anterior rectocele or enterocele.

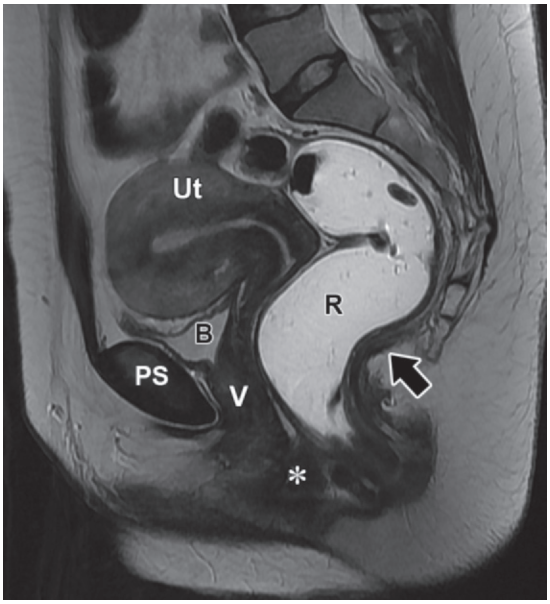
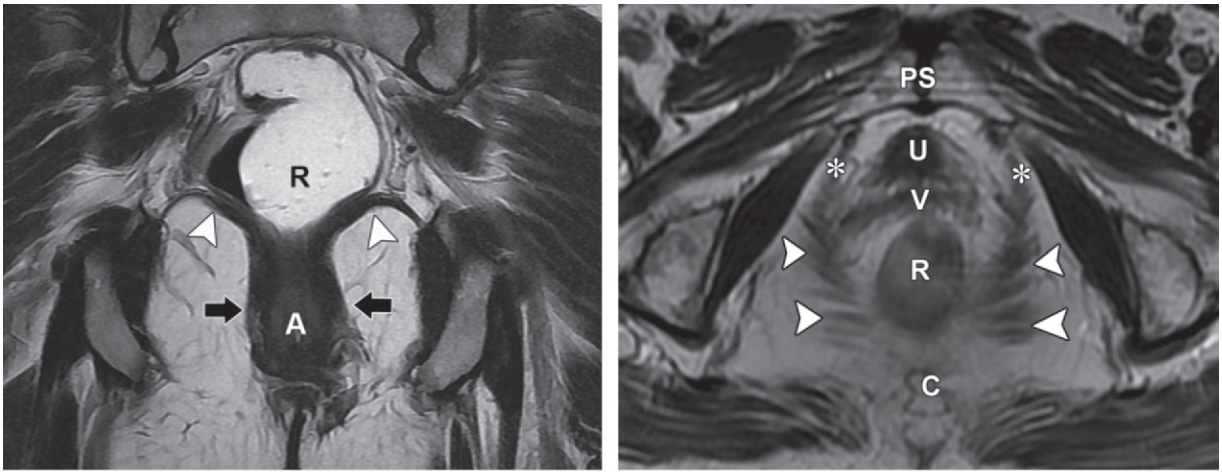


Figure 5. Normal female pelvic floor anatomy. Sagittal T2-weighted MR image shows the location of the perineal body (*) in the anovaginal septum and the levator plate (arrow). *B* = bladder, *PS* = pubic symphysis, *R* = rectum, *Ut* = uterus, *V* = vagina.



a. b.

Figure 6. Normal female pelvic floor anatomy. Coronal **(a)** and axial **(b)** T2-weighted MR images show the normal configuration of the iliococcygeus (arrowheads) and pubococcygeus (*) muscles. Arrows in **a** indicate the external anal sphincter. *A* = anal canal, *C* = coccyx, *PS* = pubic symphysis, *R* = rectum, *U* = urethra, *V* = vagina.

Pelvic Diaphragm

Teaching Point

The pelvic diaphragm lies deep to the endopelvic fascia and is formed by the ischiococcygeus muscles and the levator ani, which is composed of the iliococcygeus, puborectalis, and pubococcygeus muscles (Fig 3a). In healthy people these muscles continuously contract, providing tone to the pelvic floor and maintaining the pelvic organs in the correct position. The two most important components of the levator ani are the iliococcygeus and puborectalis muscles. The iliococcygeus muscle has a horizontal orientation; it arises from the external anal sphincter and fans out laterally toward the arcus tendineus (Fig 6). The posterior condensation of the iliococcygeus muscles forms a firm midline raphe known as the levator plate (21) (Fig 5). The puborectalis muscle likewise has a horizontal orientation; it forms a U-shaped sling around the rectum and inserts anteriorly in the parasymphyseal area, passing beside the urethra, vagina, and anorectum (22) (Fig 4). This muscle plays an important role in elevating the bladder neck and compressing it against the pubic symphysis.

Urogenital Diaphragm

The location of the urogenital diaphragm is caudal to the pelvic diaphragm and anterior to the anorectum (Figs 2, 3b). The urogenital diaphragm is composed of connective tissue and the deep transverse muscle of the perineum, which originates at the inner surface of the ischial ramus. It has multiple attachments to surrounding structures, including the vagina, perineal body, external anal sphincter, and bulbocavernosus muscle (17).

Imaging Techniques: Dynamic Cystoproctography, MR Defecography, and Ultrasonography

Conventional imaging techniques such as dynamic cystoproctography are still widely used for assessing pelvic dysfunction, and there is no single imaging technique that is considered the reference standard. Dynamic cystoproctography is performed with the patient in a more physiologically advantageous position (standing or sitting) but also has disadvantages: it is invasive, does not allow simultaneous evaluation of all three pelvic compartments, and exposes the patient to ionizing radiation.

Since Yang et al described the use of dynamic MR imaging for the evaluation of pelvic organ prolapse in 1991 (23), the method has proven useful also for evaluating pelvic floor weakness because it provides anatomic information about the muscles, ligaments, and sphincters, as well as functional information. MR imaging allows noninvasive dynamic evaluation of all the pelvic organs in multiple planes, with high temporal and spatial resolution of the soft tissues and without radiation (7,24–26). MR defecography is a dynamic study in which the pelvic organs are evaluated in real time while the patient is at rest and performing maneuvers such as defecation after filling of the distal rectum with a substance such as US gel. It is usually performed to evaluate the posterior pelvic compartment when the presence of a rectocele, intussusception, or anismus is suspected because of obstructed defecation or findings at clinical examination. Teaching Point The results of several studies have shown not only that MR defecography improves the evaluation of the posterior compartment but also that it increases the detection of prolapse in other compartments (27–29). Thus, we think it essential to perform MR defecography not only in patients with a defecation dysfunction but also in those in whom the presence of pelvic organ prolapse is suspected. The pelvic floor is subjected to maximum stress levels during rectal emptying, which results in complete relaxation of the levator ani, improving the detection of prolapse in any pelvic compartment.

MR defecography can be performed with the patient supine in a closed-magnet system or sitting in an open-magnet system. The use of an open-magnet MR imaging system allows a more functional position that is more proximate to that at conventional defecography (30), accentuating physiologic abnormalities caused by pelvic floor weakness, but provides images with lower signal-to-noise ratio and lower soft-tissue resolution (25). MR defecography is therefore performed more often in a closed-magnet device with the patient supine, although the less physiologic position may be a substantial disadvantage (31). The results of studies on patient positioning are contradictory, leading some investigators to conclude that the lack of gravity leads to underestimation of prolapse in all pelvic compartments (32), whereas others have found no statistically significant or clinically relevant difference between the two positions (33,34).

Several studies in which conventional cystoproctography was compared with MR defecography showed that the two methods have similar effectiveness for the detection and staging of pelvic organ prolapse (30,32,35). In other studies, there was less agreement between the two methods with regard to findings in the posterior compartment, with fewer enteroceles, rectoceles, and intussusceptions reported at MR defecography than at evacuation proctography (28,36). This result suggests that the diagnosis of these entities can be made more confidently with evacuation proctography (7,30,32,35–37). In fact, some authors who initially favored MR imaging reverted to advocacy of conventional dynamic cystocolpoproctography (31).

High variability among readers in anatomic measurements of the pelvic floor at MR imaging despite centralized training is another important drawback to MR defecography (38). By contrast, higher interobserver agreement in the interpretation of images from dynamic cystocolpoproctography indicates its apparently greater reliability and replicability (39).

Despite its acknowledged limitations, dynamic MR imaging nevertheless allows intuitive noninvasive dynamic evaluation of the three pelvic compartments in multiple planes, with high temporal and soft-tissue resolution, without radiation, and with anatomic detail equivalent or superior to that provided by cystoproctography. The results of dynamic MR imaging with regard to the diagnosis of enteroceles and peritoneoceles correlate well with the results obtained with traditional diagnostic methods and are superior to those obtained with clinical evaluation.

In recent years, US has emerged as an alternative method for evaluating the pelvic floor in patients with symptoms of urinary incontinence, pelvic organ prolapse, fecal incontinence, or obstructed defecation. The technique most widely used for this purpose is translabial (transperineal) US, but transvaginal and endoanal approaches also may be used for sonographic evaluation of the pelvic floor (40–43). A recently developed three-dimensional dynamic anorectal US technique called echodefecography involves the use of a 360° transducer to identify the cause of an evacuation disorder affecting the posterior compartment, which may include an enterocele (44). In a recent study in which this technique was compared with conventional defecography, the investigators found echodefecography a reliable technique for assessing patients who were believed to have obstructed defecation (45). There have been few studies in which US was compared with MR defecography. In a prospective study comparing dynamic anorectal endosonography, dynamic MR imaging defecography, and conventional defecography, Vitton et al (46) found equivalent diagnostic performance with the use of each of these techniques for pelvic floor assessment; however, only the posterior compartment was evaluated in this study.

US is easy to perform, is cost-effective, and does not expose the patient to ionizing radiation, but the field of view is confined. In addition, extensive training and experience are needed for accurate interpretation of US images. Moreover, when US defecography is performed with the patient in a dorsal lithotomy position or a lateral decubitus position, it has the same disadvantages as MR defecography performed with a closed-magnet system.

Role of Pelvic Floor Imaging in Surgical Management

The assessment and treatment of women with pelvic floor weakness require a multidisciplinary team of urologists, gynecologists, proctologists, psychologists, physical therapists, and radiologists. The diagnosis must be based on findings at physical examination, functional testing, and imaging. When the symptoms of pelvic floor weakness are mild, the results of physical examination and imaging with conventional techniques such as urodynamics, voiding cystourethrography, evacuation proctography, or cystocolpodefecography may suffice for diagnosis. However, reliance on a routine clinical examination in patients with moderate to severe symptoms frequently leads to underestimation of the number of compartments involved and inaccurate identification of the site of prolapse (11,22). The recurrence of symptoms in 10%–30% of patients after surgery may be indicative of involvement of one or more compartments not identified at the time of the initial diagnosis of pelvic floor weakness (47). In patients in whom multicompartmental involvement is suspected, MR imaging is a highly useful method allowing the assessment of all compartments for preoperative planning.

Concordance between findings at clinical evaluation and findings at dynamic MR imaging for disease staging has been evaluated in several studies and has been shown to be good overall, with somewhat weaker correlation for findings in the posterior compartment (48,49). Furthermore, MR defecography has been shown to demonstrate more extensive abnormalities than physical examination alone (30,32,35).

According to several reports, dynamic pelvic floor MR imaging may lead to a change in surgical therapy in as many as 67% of cases (25,30,33,49–53), compared with 40% with fluoroscopic studies (54). For example, an uncomplicated cystocele is treated with retropubic colposuspension, whereas fascial repair is required when the paravaginal fascia is detached. The detection of a previously undiagnosed enterocele might result in a change from a transvaginal to a transabdominal surgical approach (31). Surgical repair of an anterior rectocele, which includes repair of the rectovaginal fascia, may be performed with a transanal or transvaginal approach. It may also include posterior fixation of the rectum or rectal resection if rectal intussusception is present (29).

The incidental detection of pathologic conditions such as urethral diverticula, fibroids, and malignant lesions is also useful for treatment planning, and such conditions are better evaluated with MR imaging than with modalities such as cystoproctography and US.

MR Defecography Technique

It is important to explain the procedure and its diagnostic importance to the patient beforehand and to respect the patient's dignity in the unfamiliar and artificial environment of the examination room. Technicians should provide patients with simple instructions to achieve satisfactory results. The patient's cooperation while at rest and during the dynamic study is crucial for the success of the examination. It is particularly important to instruct patients to maximize their strain effort without moving the pelvis during the straining and defecation phase. The patient should practice several times before entering the examination room and at least once more while lying on the MR imaging table before the test is performed.

There is no consensus on a standardized protocol for MR defecography (48). At our institution, a conventional 1.5-T MR imaging unit (Signa Excite; GE Healthcare, Milwaukee, Wis) is used with the patient in a supine position and with a multicoil pelvic or torso array wrapped low around her pelvis.

We instruct patients to try to empty their bladders before the study so as to avoid discomfort during straining. A fully distended bladder may inhibit both the degree of straining and the descent of pelvic organs (31).

Table 1: Suggested Protocol for MR Imaging Evaluation of Pelvic Floor Weakness

Pulse Sequence	Imaging Plane	TR/TE (msec)	FOV (cm)	Section Thickness (mm)	Matrix	AT	Study Phase
T1-weighted localizer	…	…	Large	…	…	…	Rest
T2-weighted fast spin-echo	Axial, coronal, sagittal	4800/100	25 × 25	5	384 × 224	3–4 min	Rest
FIESTA	Midsagittal	4.8/2.2	40 × 40	8	384 × 256	18 sec	Straining
FIESTA	Midsagittal	4.8/2.2	40 × 40	8	384 × 256	18 sec	Squeezing
FIESTA	Midsagittal	4.8/2.2	40 × 40	8	384 × 256	40–60 sec	Defecation

Note.—The dynamic FIESTA sequence is applied during straining (from rest to maximal strain), squeezing, and defecation phases. For the defecation phase, 40–60 seconds are usually sufficient. If defecation is difficult, the sequence is repeated over a prolonged interval of 80–120 seconds. These parameters were established by using a 1.5-T MR imaging system (Signa Excite; GE Healthcare, Milwaukee, Wis). AT = acquisition time, FOV = field of view, TE = echo time, TR = repetition time.

US coupling gel and mashed potatoes mixed with a gadolinium compound have been used by some who perform MR defecography. For reasons of cost, availability, and cleanliness, we fill the distal rectum with 120–150 mL of warm US gel that is easily introduced with a flexible tube or directly with the syringe just before the patient is moved onto the gantry. We do not fill the vagina with US gel at our institution, but the introduction of 50 mL of gel into the vagina can improve the visibility of anatomic landmarks and the detection of prolapse in the middle compartment.

The patient is wrapped in an incontinence pad, and the table is covered with an absorbent towel to minimize discomfort from the eventual loss of urine and/or feces. The patient's knees should be slightly bent over a pillow with the legs slightly parted so as not to interfere with organ prolapse, especially during the straining and defecatory phases of the study.

The MR imaging protocol begins with a T1-weighted localizer sequence with a large field of view to identify the midline sagittal section, including the pubic symphysis, bladder neck, vagina, rectum, and coccyx. This sequence is followed by T2-weighted turbo spin-echo sequences applied in the sagittal, axial, and coronal planes for thin-section anatomic evaluation (repetition time msec/echo time msec = 4800/100; field of view, 25 × 25 cm; matrix, 384 × 224; 25 sections, each 5 mm thick; total imaging time, 3–4 minutes).

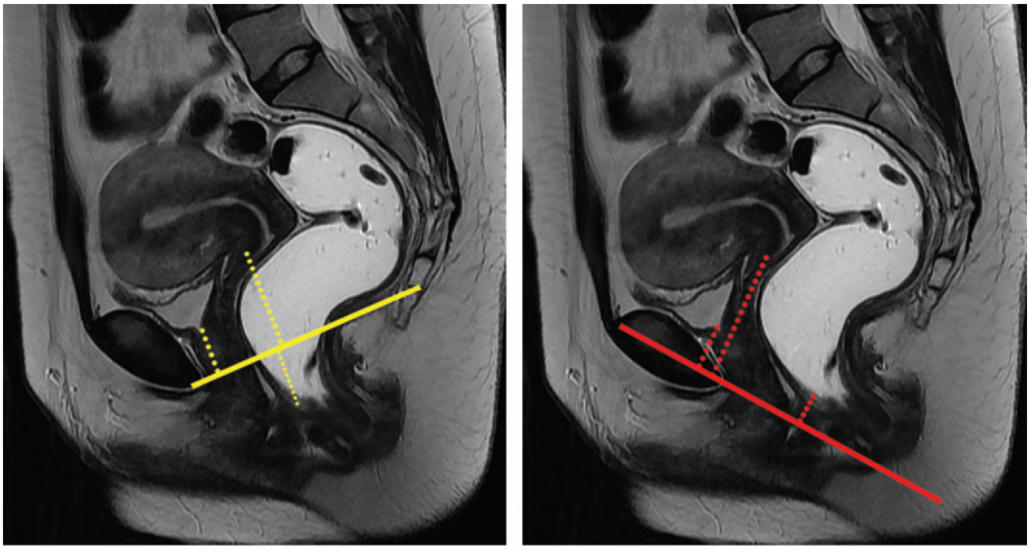
The dynamic study, which is performed after a baseline resting study is completed, involves pelvic image acquisition while the patient alternately strains, squeezes the anal sphincter, and defecates. For the dynamic study, we apply a steady-state sequence in the midsagittal plane (fast imaging employing steady-state acquisition [FIESTA; GE Healthcare], 4.8/2.2; field of view, 40 × 40 cm; matrix, 384 × 256; section thickness, 8 mm), acquiring one section per second. For straining and squeezing maneuvers, the sequence time is 18 seconds; the patient is asked to count for 6–8 seconds from the start of the sequence and to strain or squeeze for the remainder of it. The straining phase of the study provides information about the competence of internal and external sphincters, and the squeezing phase (Kegel maneuver) provides information about pelvic floor muscle strength, particularly puborectalis muscle function (55). In healthy patients the anorectal junction rises 1–2 cm from its resting position and the anorectal angle closes during squeezing (24).

For the defecation phase, a period of 40–60 seconds usually suffices. As with the straining and squeezing phases of the study, the patient is at rest for the first 6-8 seconds of imaging. If defecation is difficult, the sequence is repeated and the defecation phase may be prolonged to 80–120 seconds. Once the study is completed, we ask the patient if she has the feeling of having completely evacuated the rectal gel introduced.

All the dynamic sequences are then analyzed in cine loop mode. A suitable protocol for MR imaging of pelvic floor weakness is summarized in Table 1.

Coronal and axial dynamic imaging, although not routinely performed, may help improve the sensitivity of the MR imaging study, because static MR images often do not depict all the relevant findings. When the presence of a lateral rectocele or lateral prolapse is clinically indicated, coronal and axial dynamic sequences must be added to the protocol (28). These sequences can be applied after the defecation sequences during maximal strain maneuvers, at the level of the

Teaching Point



a. b.

Figure 7. Midsagittal T2-weighted MR images obtained in a female patient with normal anatomy during rest show the reference lines most frequently used for the evaluation of pelvic floor weakness: the PCL (solid line in **a**) and MPL (solid line in **b**). Perpendicular dotted lines drawn from anatomic reference points in the anterior, middle, and posterior pelvic compartments to the PCL and MPL for the assessment of organ prolapse also are shown.

pelvic hiatus in the axial plane and at the level of the anal canal in the coronal plane. The axial dynamic images can demonstrate puborectalis muscle defects and ischiorectal fossa hernias, and the coronal images may show iliococcygeus muscle defects and lateral prolapses (26,56)).

Steady-state imaging sequences such as FIESTA, true fast imaging with steady-state precession (TrueFISP; Siemens, Erlangen, Germany), and balanced fast field echo (balanced FFE; Philips, Einthoven, the Netherlands) provide images of fluid-filled structures within very short acquisition times. These sequences rely on the steady-state T2 contrast mechanism to provide images with a high signal-to-noise ratio due to increased signal strength from fluid within the tissues while suppressing background tissue contrast and anatomic detail of small structures. In fact, they provide the highest signal-to-noise ratio per unit of time among all known sequences (57). Steady-state sequences have become the standard for functional anatomic cardiac imaging and are useful also in abdominal and fetal imaging because they allow the study of rapid physiologic processes with breath-hold acquisitions reducing motion artifacts such as respiration and peristalsis (58). Steady-state sequences have replaced the previously used rapid T2-weighted sequences such as half-Fourier acquisition turbo spin-echo and single-shot fast spin-echo performed while the patient is at rest and straining, as they permit a more intuitive functional evaluation (7,29,33,56,59). Furthermore, greater degrees of organ prolapse have been observed in the three pelvic compartments with dynamic steady-state sequences (eg, TrueFISP) than with sequential half-Fourier rapid acquisition with relaxation enhancement (or RARE) sequences (eg, half-acquisition single-shot turbo spin-echo [HASTE]; Siemens) (60).

Interpreting MR Imaging Findings

There is no standardized method for evaluating pelvic organ prolapse at MR imaging, but, as with cystoproctography, different points of reference for measurements are required to assess the presence or absence and the severity of pelvic organ prolapse. Several points and lines for measuring and staging pelvic organ prolapse at MR imaging have been proposed. The two most commonly used are the pubococcygeal line (PCL), which is drawn from the inferior border of the pubic symphysis to the last coccygeal joint (34,59,61); and the midpubic line (MPL), which is drawn caudad along the long axis of the pubic symphysis (13,48,62) (Fig 7). The PCL represents the approximate line of attachment of pelvic floor muscles and thus the level of the pelvic floor. It is the reference line most frequently used for measuring organ prolapse. Radiologists at our institution, in agreement with the urologists, gynecologists, and proctologists, use the PCL as the reference line in their reports. The perpendicular distance from the reference points to the PCL or MPL must be measured both at rest and at maximal strain, usually during the defecation phase. In the anterior compartment, the

Teaching Point

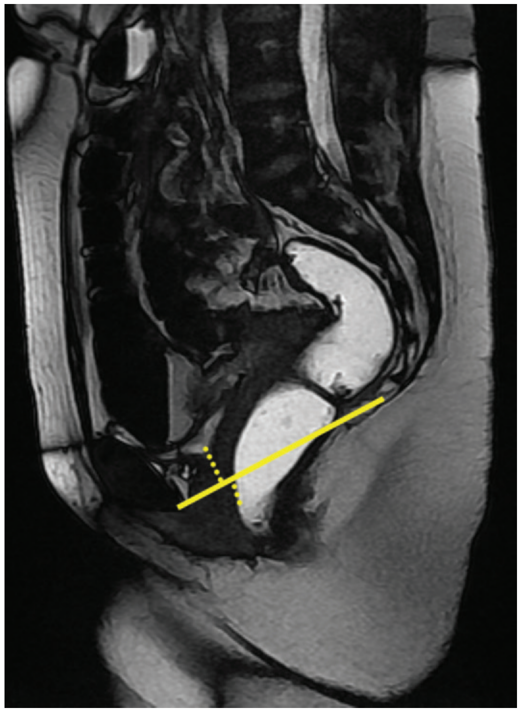


Figure 8. Normal pelvic floor anatomy in a 37-year-old woman who was unable to defecate during a dynamic MR imaging study. Sagittal FIESTA MR image obtained at maximal strain shows minimal descent of the pelvic organs. The distances from reference points (dotted yellow lines) in the anterior and posterior compartments to the PCL (solid yellow line) are shown. The uterus is not well visualized because of its paramedian position. The levator plate shows minimal angulation, and the urethral axis remains vertical.

Table 2: Grading Cystocele and Uterine Prolapse with the PCL

Grade	Distance from the PCL
Mild	1–3 cm below
Moderate	3–6 cm below
Severe	>6 cm below

Table 3: Grading Cystocele, Uterine Prolapse, and Anorectal Junction Descent with the MPL

Stage	Distance from the MPL
0	>3 cm above (TVL* – 2 cm)
1	>1 cm to 3 cm above
2	≤1 cm above or below
3	>1 cm below
4	Complete organ eversion

* Total vaginal length (TVL) is the greatest vertical measurement from the posterior vaginal fornix to the level of the introitus in patients with a cervix at physical examination or on sagittal MR images. In patients without a cervix, the TVL is measured from the farthest superior aspect of the vaginal cuff to the level of the introitus.

reference point is the most posterior and inferior aspect of the bladder base. In the middle compartment, the reference point is the most anterior and inferior aspect of the cervix (or posterosuperior vaginal apex in patients who have undergone a hysterectomy). In the posterior compartment, the anterior aspect of the anorectal junction is the reference point (22,32,63) (Fig 7a). In healthy subjects, minimal descent of the pelvic organs is observed during defecation (59) (Fig 8, Movie 1). The severity of prolapse can be easily graded according to the "rule of three": descent of an organ below the PCL by 3 cm or less is considered mild, descent by 3–6 cm is considered moderate, and descent by more than 6 cm is considered severe (35,59,61) (Table 2).

The concept of the MPL was introduced by Singh et al (62). The MPL corresponds to the level of the vaginal hymen, the landmark for clinical staging. The same reference points within the three anterior-to-posterior compartments are used for measurement with the MPL as are used with the PCL; measurements are made by drawing perpendicular lines from each reference point to the MPL (63) (Fig 7b). With this method, the severity of prolapse is graded in five stages, from stage 0 to stage 4 (Table 3).

To date, there is no agreement about which of these methods is best for grading pelvic organ prolapse at MR imaging; neither method has been proven superior to clinical staging (64). However, measurement with the PCL is the method most widely used. Woodfield et al (13) found fair agreement between disease staging in the three compartments with use of the MPL at MR imaging and clinical staging, and fair to poor agreement between disease staging with use of the PCL at MR imaging and clinical staging. Some authors have suggested that the MPL should be used only

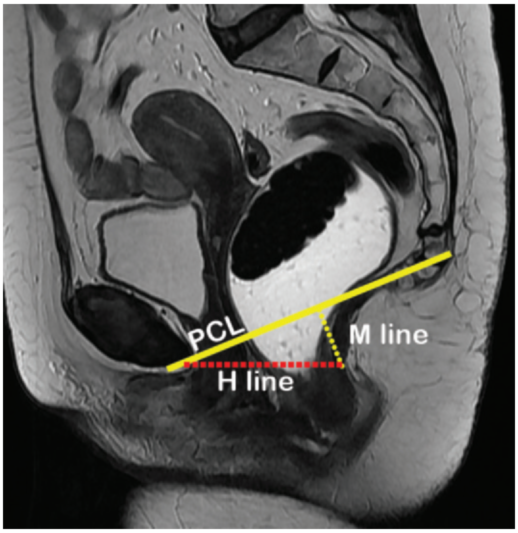


Figure 9. Normal pelvic floor anatomy in a 42-year-old female patient. Midsagittal T2-weighted MR image obtained with the patient at rest shows the PCL (solid yellow line), *H* line (dotted red line), and *M* line (dotted yellow line). The puborectalis muscle is located just posterior to the anorectal junction, and the levator plate is parallel to the PCL.

Table 4: Grading of Pelvic Floor Relaxation with *H* and *M* Lines

Grade	Hiatal Enlargement (*H* line)	Pelvic Floor Descent (*M* line)
Normal	<6 cm	<2 cm
Mild	6–8 cm	2–4 cm
Moderate	8–10 cm	4–6 cm
Severe	>10 cm	>6 cm

for posterior compartment evaluation and that the PCL is a useful reference line for measuring descent only in the anterior compartment (63).

Grading systems are used to determine which patients are candidates for surgery. Mild cases of cystocele do not usually require surgical treatment. On the other hand, moderate and severe cystoceles categorized by using the PCL and cystoceles graded as stage 2 to 4 by using the MPL are usually symptomatic (30) and require surgical treatment (26).

To continue the analysis, the *H* and *M* lines must be measured (Fig 9). The *H* line is drawn on a midsagittal image from the inferior border of the pubic symphysis to the posterior wall of the rectum at the level of the anorectal junction, which is defined as a focal angulation between the inferior aspect of the levator plate and superior aspect of the puborectalis muscle. The *M* line is a vertical line drawn perpendicularly from the PCL to the posterior aspect of the *H* line. The *H* line represents the anteroposterior width of the levator hiatus, and the *M* line represents the distance of its descent. Measurement of the *H* and *M* lines, which are normally no longer than 5 cm and 2 cm, respectively, is used to grade the severity of pelvic floor relaxation on MR images obtained at maximal strain during defecation (65) (Table 4).

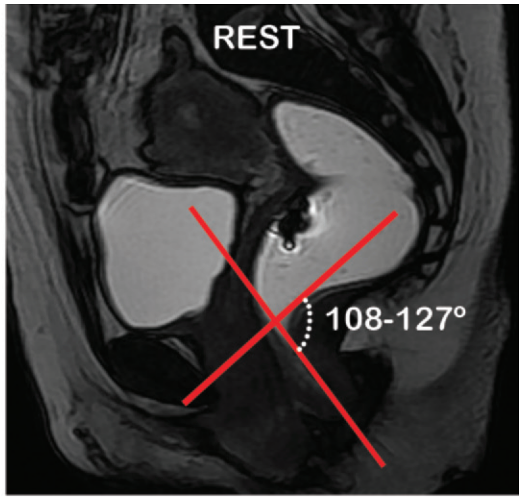
In the normal female pelvis, the levator plate is parallel to the PCL on midsagittal images even at maximal strain (66) (Fig 5). Caudal inclination of the levator plate by more than 10° with respect to the PCL is an indicator of pelvic floor relaxation (67,68).

In the normal anatomy, the urethral axis on sagittal images remains vertical even at maximal strain during defecation (Fig 8, Movie 1). Anterior angulation of the urethra by more than 30° from its resting axis on sagittal images obtained during straining or defecation is indicative of urethral hypermobility (25).

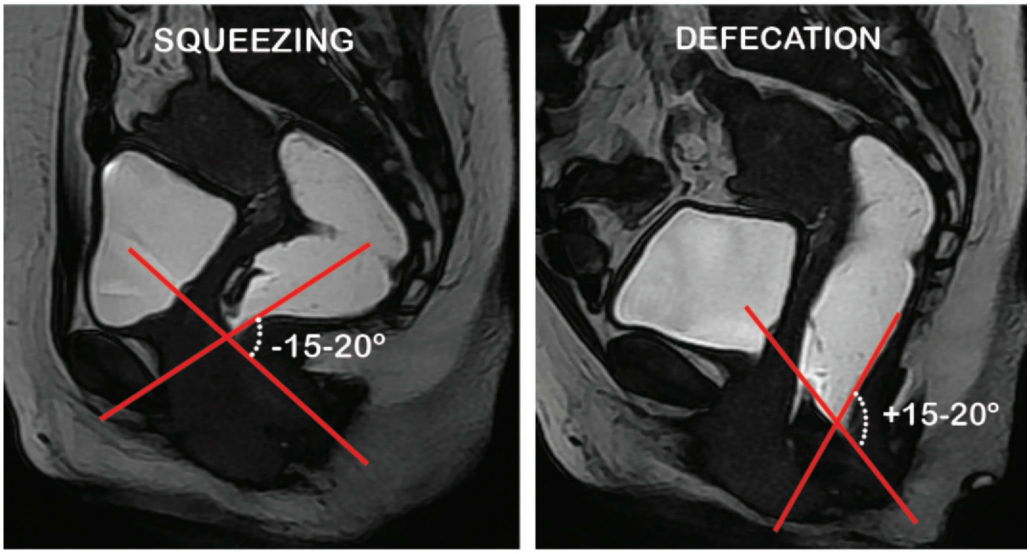
The anorectal angle is defined as the angle between the posterior border of the distal part of the rectum and the central axis of the anal canal, and it normally measures 108° to 127° at rest. This angle decreases by approximately 15° to 20° during squeezing and increases by about the same amount during straining and defecation (52,61,69) (Fig 10).

In the axial plane, the normal configuration of the periurethral ligaments, vagina, puborectalis muscle, and anal sphincter must be assessed. The normal vagina has a characteristic H- or butterfly-like shape, and close apposition of the lateral vaginal walls to the puborectalis muscle can be observed (Fig 4). Although the pelvic fascia is not well visualized with conventional MR

Figure 10. Anorectal angle. Sagittal T2-weighted MR images show a normal anorectal angle in a female subject at rest **(a)**, while performing a squeeze maneuver **(b)**, and during defecation **(c)**. The anorectal angle (dotted white curve) is measured between two intersecting lines (solid red lines), one representing the central axis of the anal canal and the other passing by the posterior wall of the distal rectum. Notice that the angle becomes more acute during squeezing and more obtuse during defecation.



a.



b. c.

imaging, paravaginal fascial tears can be inferred from posterior displacement of the vaginal fornix. However, alterations in the normal shape of the vagina at MR imaging may be observed indirectly also in asymptomatic women (Fig 11a). Hence, a diagnosis of weakened vaginal support should not be made solely on the basis of vaginal shape (70). Paravaginal fascial defects can also be inferred from sagging of the posterior wall of the bladder, known as the "saddlebag" sign (56,71) (Fig 11b).

The components of the levator ani muscles are clearly evident on T2-weighted MR images and should be of similar thickness, with homogeneous low signal intensity. In the coronal plane, the iliococcygeus and pubocoggygeus muscles can be easily assessed because of their horizontal position and upward convexity (Fig 6a). Thinning, tears, and avulsions from their insertion points should be noted (Fig 12). The puborectalis muscle can be better assessed in the axial plane, in which it forms a U-shaped sling around the rectum, inserting near the pubic symphysis (Fig 4). Apparent asymmetry of the puborectalis muscle, with the left side thicker than the right, has been described as a normal variation observed on MR images (72) and is probably due to chemical shift artifact (73).

The anal sphincters may be variably visualized in the axial and coronal planes. The internal anal sphincter has uniform intermediate signal intensity on T1- and T2-weighted images, whereas the signal intensity of the external anal sphincter is usually lower on T2-weighted images (Fig 13). An anterior or posterior disruption of the external sphincter seen on axial views may be a normal anatomic variant and not a muscle defect (17).

Pathologic Conditions Resulting from Pelvic Floor Weakness

Pelvic organ prolapse and pelvic floor relaxation are related and often coexistent components of pelvic floor weakness that must be differentiated.

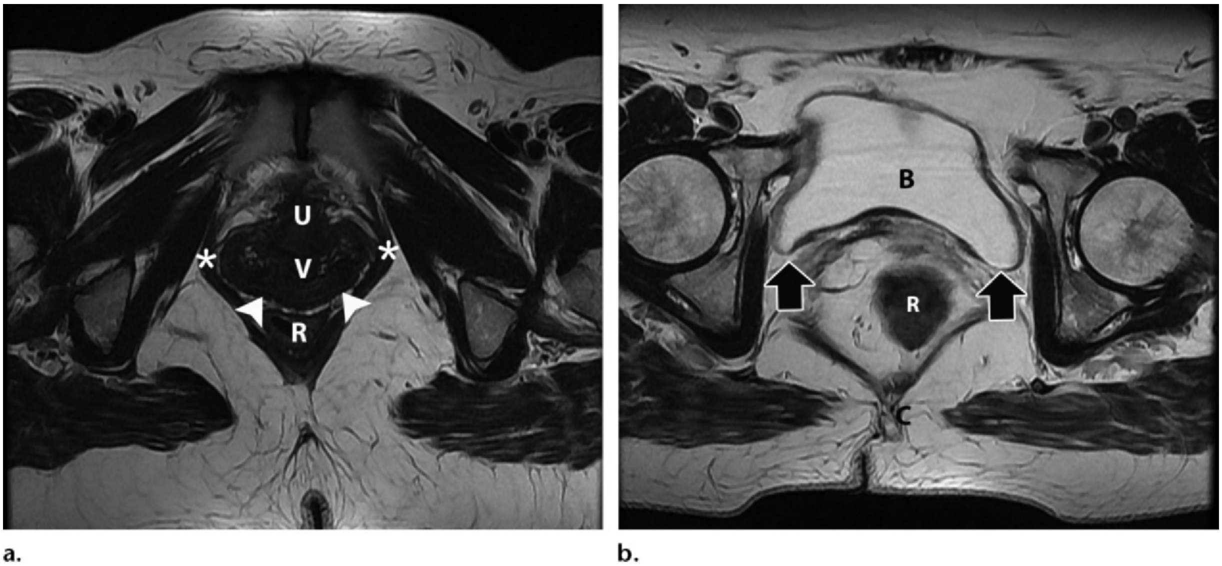


Figure 11. Indirect signs of paravaginal fascial tear. **(a)** Axial T2-weighted MR image shows loss of the normal H- or butterfly-like shape of the vagina *(V)* with deformation of the posterior vaginal wall (arrowheads) and thinning of the puborectalis muscles (*). **(b)** Axial T2-weighted MR image shows bilateral sagging (arrows) of the posterior wall of the bladder *(B)*. *C* = coccyx, *R* = rectum, *U* = urethra.

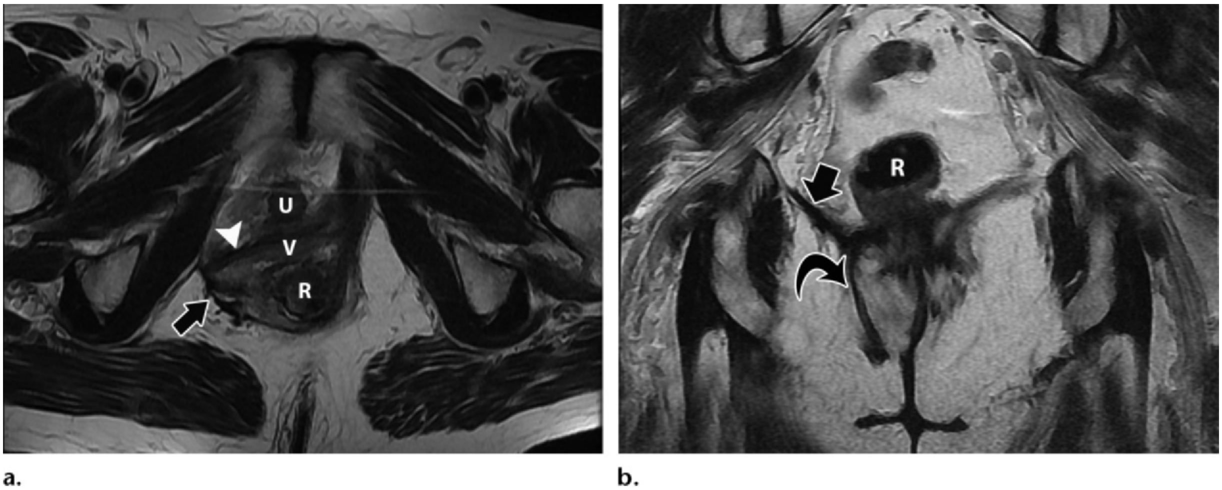


Figure 12. Pelvic muscle defects in a 54-year-old woman with fecal incontinence. **(a)** Axial T2-weighted MR image shows disruption and fibrosis of the right puborectalis muscle (arrow), distortion of the normal H-like shape and displacement of the right lateral wall (arrowhead) of the vagina *(V)*, and poor definition of the urethral ligaments because of disruption. Note the hyperintensity of the right posterolateral aspect of the internal anorectal canal *(R)*, an appearance associated with damage to the muscle. *U* = urethra. **(b)** Coronal T2-weighted MR image shows a tear and fibrosis of the iliococcygeus muscle (straight arrow) with loss of its typical upward convexity. The tear extends through the right ischiorectal fossa (curved arrow). *R* = anorectal canal.

Pelvic organ prolapse is the abnormal descent of a pelvic organ through its respective hiatus. The bladder (cystocele), vagina (vaginal prolapse), uterus (uterine prolapse), mesenteric fat (peritoneocele), and small intestine or sigmoid colon (sigmoidocele) may prolapse. In pelvic floor relaxation, active and passive pelvic floor support structures become weakened and ineffective, allowing excessive descent and widening of the entire floor at rest and/or during evacuation. Pelvic floor relaxation can occur with or without organ prolapse.

Pelvic Organ Prolapse

Anterior Compartment.—Abnormal descent of the bladder at rest or when straining, referred to as a cystocele, results from tearing of the pubocervical fascia or levator ani muscle. At MR imaging, a cystocele is diagnosed when the bladder descends more than 1 cm below the PCL. Cystoceles are graded as mild, moderate, or severe, depending on the distance of the bladder base from the PCL (22) (Table 2). They are usually

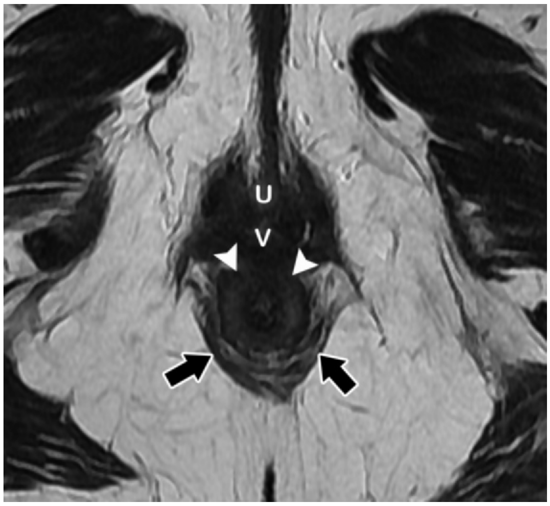
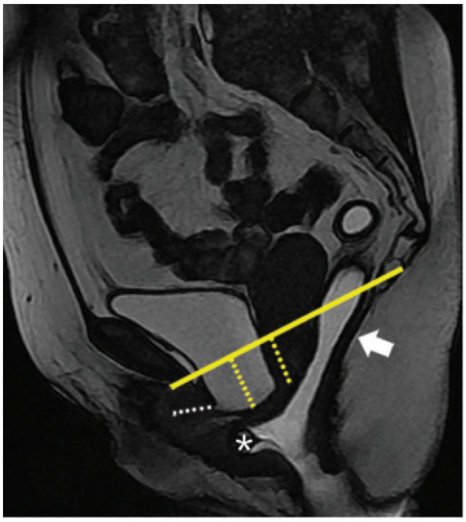
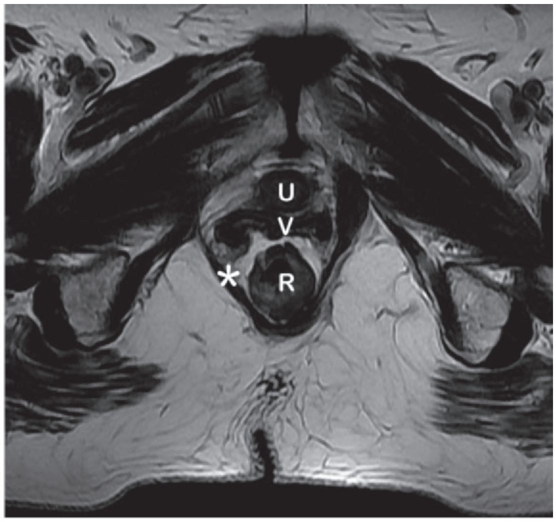


Figure 13. Normal appearance of anal sphincters. Axial T2-weighted image shows an internal anal sphincter (arrowheads) with uniform intermediate signal intensity, whereas the signal intensity of the external anal sphincter (arrows) is more variegated. *U* = urethra, *V* = vagina.





a. b.

Figure 14. Pelvic organ prolapse in a 47-year-old woman with stress urinary incontinence. **(a)** Sagittal FIESTA MR image at defecation shows a moderate cystocele and mild uterine prolapse (dotted yellow lines) with respect to the PCL (solid yellow line). Angulation of the urethral axis (dotted white line) results in urethral hypermobility in the anterior and middle compartments. In the posterior compartment, descent of the anorectal junction with consequent elongation of the *H* and *M* lines (not marked), angulation of the levator plate, and a moderate anterior rectocele (*) are present. **(b)** Axial T2-weighted image at the level of the proximal urethra shows thinning of the right aspect of the puborectalis muscle (*), which is nearly detached from the pubic bone. *R* = rectum, *U* = urethra, *V* = vagina.

larger after rectal evacuation, causing posterior displacement of the middle and posterior compartments and thereby elongating the *H* and *M* lines (Fig 14, Movie 2). A beaklike appearance ("beaking") of the bladder neck on sagittal views obtained while the patient is at rest or straining is common and is not indicative of incontinence (34). In the presence of a severe cystocele, kinking of the urethrovesical junction may obstruct voiding (29) (Fig 15, Movie 3).

Urethral hypermobility is a functional condition involving rotation of the urethral axis in the horizontal plane when intraabdominal pressure increases (Fig 14a). This condition, a consequence of the loss of urethral sphincter and fascial support, is mainly due to the distortion of periurethral and paraurethral ligaments (16). Correct diagnosis of this condition is important because adequate repair requires a pubocervical sling procedure.

Middle Compartment.—Weakness of the supporting structures of the middle compartment, such as the pubocervical fascia, rectovaginal fascia, paracolpium, and parametrium, causes uterine and vaginal vault prolapse. On sagittal

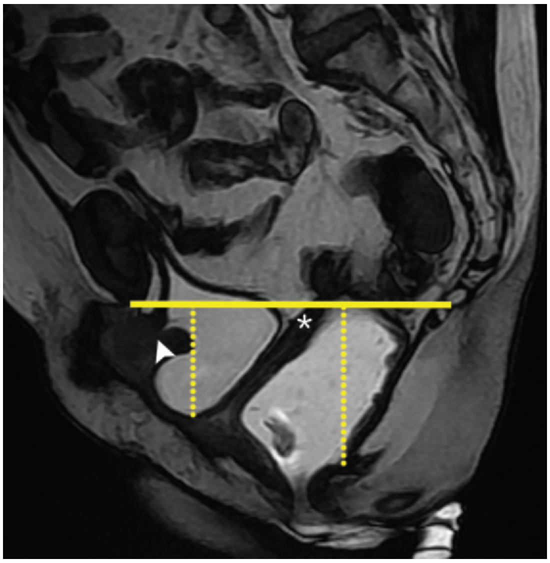


Figure 15. Pelvic organ prolapse in a 68-year-old woman with stress urinary incontinence and a bulging perineal mass. The patient had a history of hysterectomy. Sagittal FIESTA MR image obtained at maximal effort during defecation shows a severe cystocele (short dotted line) and angulation of the urethral axis (arrowhead) with resultant urethral hypermobility in the anterior compartment. In the middle compartment, an apical prolapse is seen (*). In the posterior compartment, marked signs of pelvic floor relaxation include descent of the anorectal junction (long dotted line) and angulation of the levator plate. A small asymptomatic anterior rectocele also is present. Solid line = PCL.

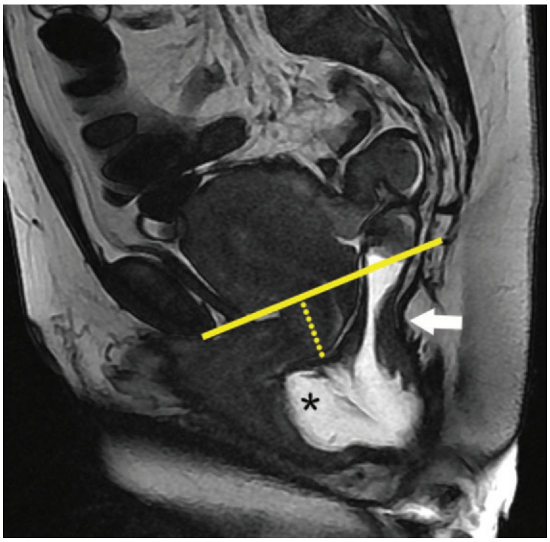


Figure 16. Pelvic organ prolapse in a 52-year-old woman with a bulging perineal mass. Sagittal FIESTA MR image obtained at maximal effort during defecation shows moderate uterine prolapse in the middle compartment (dotted line). In the posterior compartment, a moderate anterior rectocele (*) and caudal angulation of the levator plate (arrow) can be seen. Solid line = PCL.

MR images, this type of prolapse is normally measured perpendicularly from the PCL to the most anteroinferior aspect of the cervix (Fig 16, Movie 4), or, in a patient with a hysterectomy, to the posterosuperior vaginal apex, and is graded by using the same criteria used to grade bladder prolapse (Table 2). In cases of complete uterine prolapse, or procidentia, the vaginal walls are everted and the uterus is visible as a bulging mass outside the external genitalia. In middle compartment weakness, the *H* and *M* lines are elongated, and the vagina acquires a more horizontal disposition on sagittal images and may appear shortened because of partial eversion of the vault.

In women who have undergone a hysterectomy, the vaginal apex should remain at least 1 cm above the PCL (Fig 17, Movie 5). Damage to the paracolpium can result in prolapse of the vaginal apex (ie, apical prolapse) (Fig 15, Movie 3). A large uterine fibroid may prevent the descent of the uterus, leading to underestimation of the true extent of pelvic floor dysfunction (74).

Cul-de-Sac.—A portion of the pelvic peritoneal sac that herniates into the rectovaginal space below the proximal (apical) one-third of the vagina may be referred to as an enterocele if it contains a portion of the small bowel (36). It is called a peritoneocele if it contains only fatty tissue or a sigmoidocele if it contains a portion of the sigmoid colon. Because of the space occupied by the distended rectum during defecation, the hernia becomes evident only at the end of evacuation (75). MR imaging is more useful than conventional defecography for accurately identifying an enterocele because it is capable of depicting peritoneal content (Fig 18, Movie 6). Enteroceles may result from defects in the supporting ligaments, rectovaginal fascia, and iliococcygeus muscle that lead to widening of the rectovaginal space. A previous hysterectomy may have disrupted the rectovaginal fascia, increasing the likelihood of enterocele formation (74) (Fig 19, Movie 7). Large enteroceles that bulge into the introitus may compress the distal part of the anorectum, causing incomplete evacuation and obstructing defecation (Fig 20, Movie 8). Stretching or tearing of the mesentery also may cause pain in the lower abdomen or back (51). An enterocele

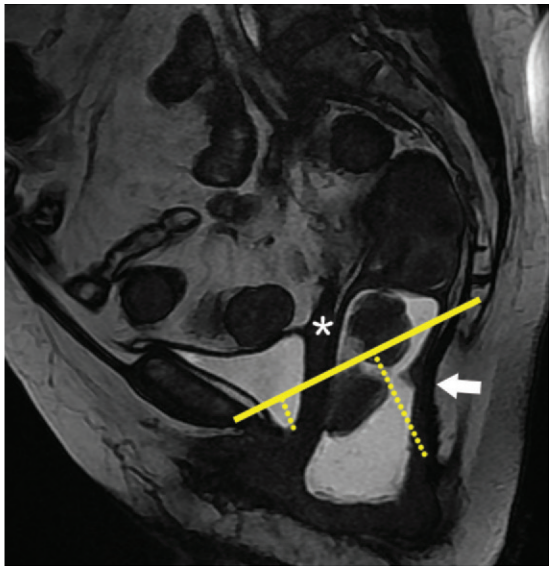


Figure 17. Sagittal FIESTA MR image obtained in a 56-year-old woman with chronic constipation and a history of hysterectomy shows the vaginal apex (*) above the PCL (solid line) even at maximal effort during defecation. A mild cystocele in the anterior compartment (short dotted line) and descent of the anorectal junction (*M* line) in the posterior compartment (long dotted line) are seen. Note the almost vertical position of the levator plate (arrow) and the small anterior rectocele.

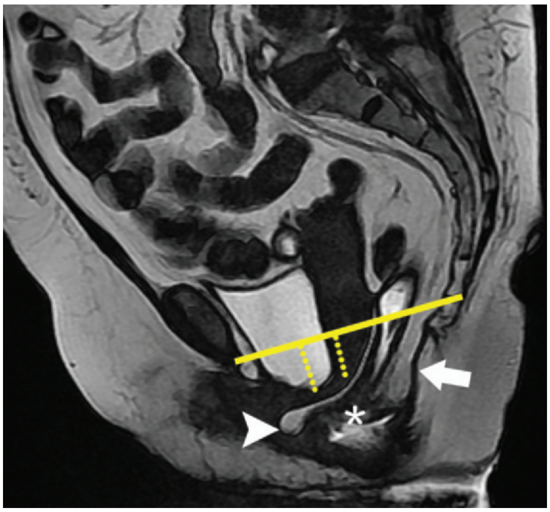


Figure 18. Peritoneocele in a 60-year-old woman who had a history of surgical treatment for urinary incontinence. Sagittal FIESTA MR image obtained at maximal effort during defecation shows herniation of a small amount of mesenteric fat into the rectovaginal space (arrowhead). In the anterior and middle compartments, a mild cystocele (left dotted line) and mild uterine prolapse (right dotted line) are seen in relation to the PCL (solid yellow line). Intrarectal intussusception (*) is seen in the posterior compartment. Note the caudal angulation of the levator plate (arrow) and descent of the anorectal junction. The recognition of a peritoneocele is important because it predisposes to enterocele formation and suggests the need for surgical closure of the cul-de-sac if reconstructive surgery of the pelvic floor is undertaken.

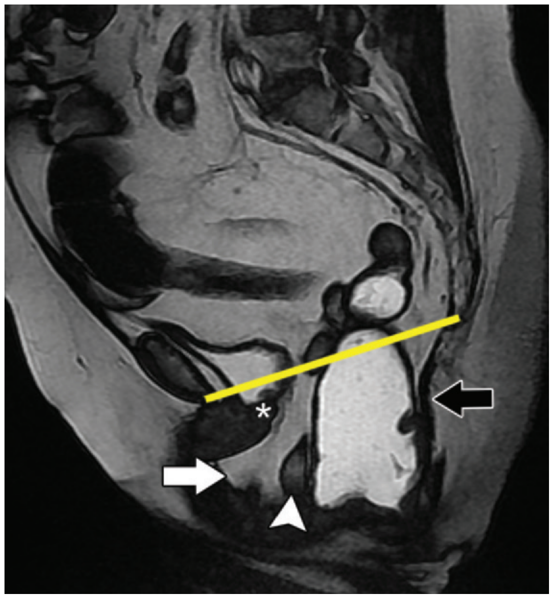


Figure 19. Peritoneocele and enterocele in a 63-year-old woman with a bulging perineal mass and a history of hysterectomy. Sagittal FIESTA MR image obtained at maximal effort during defecation shows herniation of mesenteric fat (white arrow) and small intestine (arrowhead) into the rectovaginal space. In the anterior compartment, no substantial cystocele is seen in relation to the PCL (yellow line). In the middle compartment, an apical prolapse (*) and horizontal angulation of the vagina are depicted. Note the caudal angulation of the levator plate (black arrow) and the descent of the anorectal junction, features indicative of pelvic floor relaxation.

that does not spontaneously reduce is also known as a perineal hernia.

Posterior Compartment.—An anterior rectocele is created by the abnormal bulging of the anterior wall of the rectum into the posterior vaginal wall because of damage to the rectovaginal fascia. This condition may lead to obstructed or incomplete evacuation. An anterior rectocele is quantified by the depth of the protrusion beyond the expected

Figure 20. Peritoneocele and sigmoidocele in a 64-year-old woman with a bulging perineal mass and a history of hysterectomy. Midsagittal FIESTA MR image obtained while the patient performed the Valsalva maneuver, without US coupling gel in the rectum, demonstrates a severe peritoneocele *(P)* and anteroinferior prolapse of the sigmoid colon *(S)* with a resultant sigmoidocele compressing the distal part of the anorectum. Caudal angulation of the levator plate and a mild prolapse of the vaginal apex (*) beneath the PCL (yellow line) also are seen. Detection of the high-grade sigmoidocele allowed simultaneous colonic resection and obliteration of the cul-de-sac in a single surgical procedure.

Figure 21. Anterior rectocele in a 62-year-old woman with chronic constipation and incomplete evacuation. Sagittal FIESTA image from MR defecography shows a large anterior rectocele (arrow)—an outpouching measured from the expected margin of the normal anterior anorectal wall (dotted red line)—bulging into the vagina. Descent of the anorectal junction and pronounced caudal angulation of the levator plate (arrowhead) due to pelvic floor relaxation, along with a mild cystocele and urethral hypermobility, are also seen.

Table 5: Grading of Anterior Rectocele

Grade	Depth of Wall Protrusion*
Small	<2 cm
Medium	2–4 cm
Large	>4 cm

*Rectal wall protrusion is measured as extension beyond the expected margin of the normal anterior anorectal wall.

margin of the normal anterior anorectal wall on sagittal images (Fig 21, Movie 9) and is graded as small (<2 cm), medium (2–4 cm), or large (>4 cm) (32) (Table 5). Anterior rectoceles of as much as 3 cm are commonly seen in asymptomatic women and are not considered clinically significant unless symptoms develop (76). Posterior rectoceles are less common. MR defecography provides information about the size and dynamics of rectocele emptying, retention of contrast medium within the rectocele, and coexistent abnormalities.

The rectal mucosa alone may prolapse, or rectal intussusception may occur with invagination or infolding of the full thickness of the rectal wall (mucosa and muscular layer) into the rectum (intrarectal), into the anal canal (intraanal), or beyond the anus (true complete rectal prolapse) (Fig 22). When referring to the anterior and middle pelvic compartments, the term *prolapse* is used to describe any degree of downward pelvic organ movement. In the posterior compartment, however, *prolapse* is used only to describe the most severe grade of rectal intussusception, in which there is full-thickness wall invagination and eversion of the rectum; this condition must be differentiated from anorectal junction descent without eversion due to pelvic floor relaxation (26). Rectal intussusception causes mechanical obstruction to the passage of stool (Fig 23, Movie 10). MR defecography has the potential advantage of allowing a clear distinction between mucosal intussusception (nonobstructing) and full-thickness rectal intussusception, which is critical

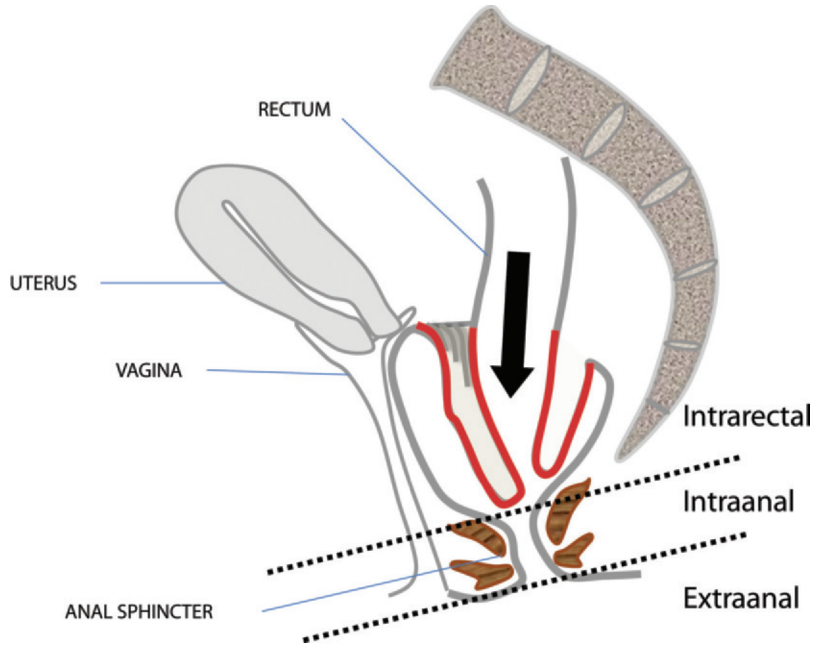


Figure 22. Schematic shows the grading of rectoanal intussusception according to its location and extent: intrarectal intussusception (minimal partial or circumferential rectal wall infolding that remains within the rectum), intraanal intussusception (infolding that extends into the anal canal), and extraanal intussusception or rectal prolapse (full-thickness invagination and eversion of the rectum, which protrudes from the anal canal).

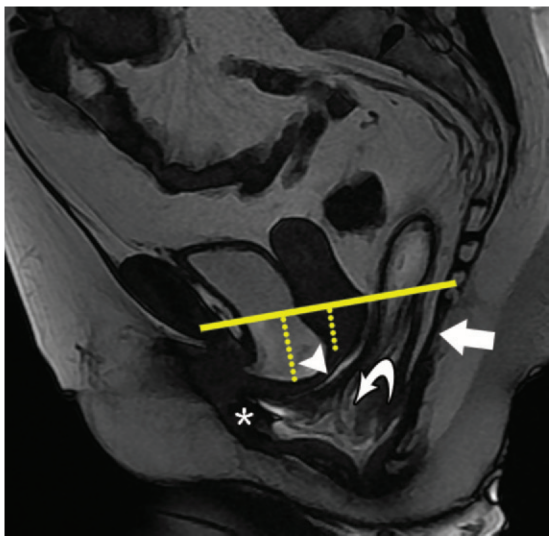


Figure 23. Rectal intussusception in a 48-year-old woman with suspected obstructed defecation. Midsagittal FIESTA MR image obtained during defecation shows intrarectal intussusception of the rectal wall (curved arrow). A large anterior rectocele (*) and pronounced caudal angulation of the levator plate (straight arrow) also are depicted. In the anterior and middle compartments, a moderate cystocele (long dotted line) and mild uterine prolapse (short dotted line) can be seen along with a peritoneocele (arrowhead), a lamella of mesenteric fat extending into the rectovaginal space alongside the upper third of the vagina. The detection of rectal intussusception in this patient altered surgical planning, resulting in the use of a transabdominal approach instead of a transperineal one and the addition of rectopexy to rectovaginal fascia repair.

knowledge for planning surgical treatment (24). Simple mucosal prolapse may be treated with a transanal excision of the prolapsing mucosa, whereas full-thickness rectal invagination might require rectopexy (77).

Pelvic Floor Relaxation

Descending perineal syndrome, or pelvic floor relaxation, is a complex condition caused by a loss of the pelvic muscular tone with resultant excessive descent of the entire floor at rest and/or during evacuation. The level of the anorectal junction at rest is a global indicator of the muscular tone and elasticity of the pelvic floor (75). A low level of the anorectal junction at rest is suggestive of muscle weakness and stretching of the fascia (78). Diffuse bulging of the levator ani muscles results in an increase in the area of the pelvic hiatus (the area enclosed by the levator ani muscles at the level of the pubic symphysis). It may affect only the posterior compartment (Fig 17, Movie 5) but frequently involves the anterior and middle compartments as well, with associated pelvic organ prolapse (Fig 15, Movie 3). On MR images, descending perineal syndrome can be quantified by measuring the descent of the posterior aspect of the anorectal junction from the PCL (ie, the *M* line), with a value of more than 2.5 cm considered indicative (59,61) (Fig 24, Movie 11). The descent of the anterior aspect of the anorectal junction from the PCL and MPL can be also measured. Other characteristics of descending perineal syndrome include elongation of the *H* line, which represents widening of the levator hiatus, and caudal angulation of the levator plate. It is common for the anorectal junction in a

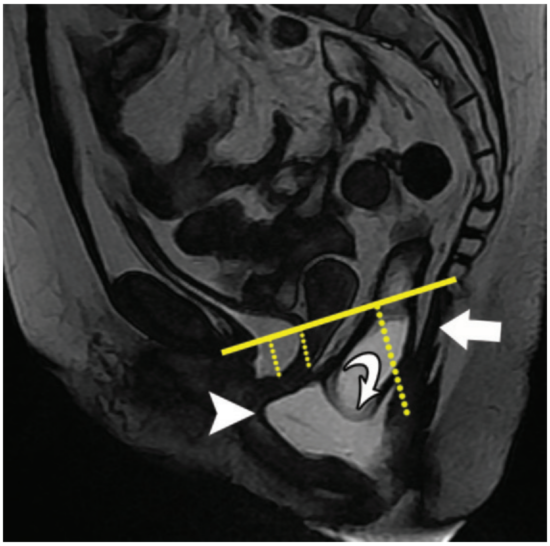


Figure 24. Pelvic floor relaxation or descending perineal syndrome in a 53-year-old woman with pelvic pain and chronic constipation. Midsagittal FIESTA MR image obtained at maximal effort during defecation shows descent of the anorectal junction and consequent elongation of the *M* line (long dotted line in the posterior compartment). Note also the caudal angulation of the levator plate (straight arrow), the moderate anterior rectocele (arrowhead), and the small infolding of the rectal wall indicating intrarectal intussusception (curved arrow). A mild cystocele and uterine prolapse (short dotted lines) are seen in the anterior and middle compartments. Solid line = PCL.

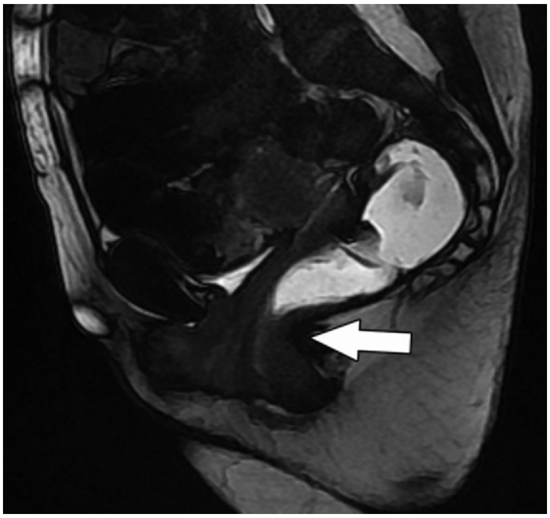


Figure 25. Anismus in a 29-year-old woman with suspected obstructed defecation. The patient was unable to defecate during the study. Midsagittal FIESTA MR image obtained at maximal effort to defecate shows lack of descent of the pelvic floor, a prominent puborectal impression (arrow), and failure of the anorectal angle to open.

patient with descending perineal syndrome not to rise above the PCL during squeezing (53).

Paradoxical Contraction of Puborectalis Muscle

MR defecography allows the evaluation of functional disorders such as inappropriate or paradoxical contraction of the puborectalis muscle, also called dyssynergic defecation or anismus. In this condition, involuntary contraction of striated pelvic floor musculature prevents the normal evacuation of feces. The findings at conventional and MR defecography are lack of descent of the pelvic floor during defecation, prominent puborectal impression, and failure of the anorectal angle to open, with resultant prolonged and incomplete evacuation (Fig 25, Movie 12). The most appropriate findings on which to base the diagnosis of anismus are prolonged and incomplete evacuation (79) and a long interval between opening of the anal canal and the start of defecation (17).

Findings at Dynamic MR Imaging in Asymptomatic Women

Absence of symptoms is not necessarily indicative of the absence of pelvic structural defects or abnormal pelvic organ descent (56). In several studies performed in normal volunteers, defecography and MR imaging showed low-grade pelvic organ prolapse, although such findings were infrequent (59). Fascial defects and muscle tears may be asymptomatic and are not always accompanied by pelvic organ prolapse. In the posterior compartment, the presence of a small anterior rectocele or low-grade intussusception (ie, a rectal mucosal infolding that does not enter the anal canal) is a frequent finding even in the asymptomatic population (17,80). By contrast, no enterocele has been detected in any asymptomatic volunteer. Some degree of pelvic floor descent during defecation is expected, but the established norm was exceeded in one-fourth of asymptomatic patients (81).

Radiologist's Report

Assessment of pelvic floor weakness is a multidisciplinary task in which the radiologist plays a crucial role. The radiologist's report should include all the information that might be useful to surgeons, including the location and number of compartments affected. At our institution, a consensus has been established among urologists,

Table 6: Template for Structured Reporting of Findings at Pelvic Floor MR Imaging and MR Defecography

A: Measurements

	Study Phase	
Parameter	Rest	Defecation
H line (cm)		
M line (cm)		
Levator plate angulation (degrees)		

B: Organ Prolapse

Location and Type	Grade	Contents
Anterior compartment		
Cystocele	Mild/moderate/severe	...
Middle compartment		
Uterine prolapse	Mild/moderate/severe	...
Vaginal apex prolapse (posthysterectomy)	Mild/moderate/severe	...
Cul-de-sac		
Enterocele	Mild/moderate/severe	Small intestine
Peritoneocele	Mild/moderate/severe	Mesenteric fat
Sigmoidocele	Mild/moderate/severe	Sigmoid colon
Posterior compartment		
Rectocele	Small/medium/large	...
Intussusception	Intrarectal/intraanal/extraanal	...

C: Other Functional Abnormalities

Type of Abnormality	Present?
Paradoxical puborectal contraction	Yes/no
Anismus	Yes/no

D: Pelvic Floor Relaxation

Present?	Degree
Yes/no	Mild/moderate/severe

E: Defects in Supporting Structures

Structure	Type of Defect	Side of Defect
Iliococcygeus muscle		
Puborectalis muscle		
Urethral ligament		
Fascia		
Anal sphincter		

gynecologists, surgeons, and radiologists with regard to the contents of the radiologist's report. Every report should include measurements of the position of the pelvic organs in relation to the PCL, obtained with the patient at rest and at maximal strain during defecation; the *H* and *M* lines; and the angulation of the urethra and levator plate. In addition, the report should include the grading of any cystocele, uterine prolapse, enterocele, or rectocele observed, as well as a description of enterocele content. The presence of a defecatory disorder (anismus, intussusception), presence and degree of pelvic floor relaxation, and locations of any inferred fascial tears and muscle abnormalities should also be reported (Table 6).

Summary

Pelvic floor weakness is an important problem for many women, and basic knowledge of the anatomy of the female pelvic floor is needed to detect it and evaluate its severity. Pelvic floor weakness may occur with or without prolapse but frequently involves multiple compartments and may require surgical treatment. A complete survey of the pelvis is necessary before surgical repair should be considered. MR imaging is an excellent tool for noninvasive evaluation of the pelvic floor. Thin-section MR imaging allows a careful assessment of the ligaments and muscles, and dynamic MR imaging with steady-state sequences may play a complementary role in evaluating functional disorders. However, the latter method has not yet been validated for use in anorectal functional evaluation, and a consensus-based standard protocol is lacking. Currently, dynamic cystocolpoproctography and dynamic MR imaging are performed as complementary examinations in the female pelvis.

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MR Imaging–based Assessment of the Female Pelvic Floor

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Page 1418–1419

Over the past decade, magnetic resonance (MR) imaging with dynamic sequences has been proven accurate and reliable for identifying pelvic floor weakness, especially when multiple compartments are involved, because it allows all three compartments to be visualized simultaneously.

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The pelvic diaphragm lies deep to the endopelvic fascia and is formed by the ischiococcygeus muscles and the levator ani, which is composed of the iliococcygeus, puborectalis, and pubococcygeus muscles. In healthy people these muscles continuously contract, providing tone to the pelvic floor and maintaining the pelvic organs in the correct position. The two most important components of the levator ani are the iliococcygeus and puborectalis muscles.

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The results of several studies have shown not only that MR defecography improves the evaluation of the posterior compartment but also that it increases the detection of prolapse in other compartments.

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When the presence of a lateral rectocele or lateral prolapse is clinically indicated, coronal and axial dynamic sequences must be added to the protocol.

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Several points and lines for measuring and staging pelvic organ prolapse at MR imaging have been proposed. The two most commonly used are the pubococcygeal line (PCL), which is drawn from the inferior border of the pubic symphysis to the last coccygeal joint; and the midpubic line (MPL), which is drawn caudad along the long axis of the pubic symphysis.