Disorders of the pelvic floor generally refer to the problems of urinary incontinence, fecal incontinence, and pelvic organ prolapse and affect an estimated 23.7% of women in the United States [1]. Approximately 10–20% of these patients are symptomatic and by the age of 70 years, an estimated 1 in 10 undergo pelvic floor surgical repair. In addition, over the next 30 years, the population of women over the age of 60 years is expected to increase at a higher rate than the general population, resulting in a projected 45% increase in the demand for all services related to treating patients with pelvic floor disorders [2]. This demographic shift also may translate into an increased demand for imaging of these patients.

Although pelvic floor disorders are relatively common conditions, the development of these disorders is often a complex and multifactorial process. Weakness, tears, or both of the structures that support the pelvic organs (i.e., the pelvic fascia, ligaments, and levator ani muscles) variably contribute to increased pelvic organ mobility; to prolapse; and, ultimately, to a variety of symptoms ranging from pelvic pain and pressure to urinary and fecal incontinence, urinary and fecal retention, and defecatory dysfunction. There are numerous risk factors for developing a pelvic floor disorder, although the greatest risk factor is female sex. Additional risk factors include but are not limited to increasing age, parity, prior pelvic surgeries, and chronic increased intraabdominal pressure [3].

Evaluation of patients with pelvic floor complaints begins with a thorough history and physical examination, but the degree and presence of pelvic organ prolapse may not always be apparent on clinical examination [4]. Furthermore, surgical correction of pelvic floor disorders is a common treatment plan, and accurate preoperative assessment of the entire pelvis is important to guide an optimal surgical repair in an effort to avoid the need for repeat surgery [5, 6]. Therefore, many patients benefit from further assessment with adjunctive tests, including imaging.

There are a variety of options for imaging these patients including ultrasound, fluoroscopy, and MRI examinations. This article will review the anatomy and imaging of patients with pelvic floor disorders with an emphasis on the use of a comprehensive MR examination to assess pelvic organ prolapse, defecatory function, and pelvic floor support structure integrity.
ly with regard to visibility on imaging, are still under investigation [7–17]. In addition, the endopelvic fascia is not a true fascia on histology and may be better described as endopelvic connective tissue. However, the term “endopelvic fascia” is still in general use and refers to the tissue plane that attaches to the bony pelvis and covers the levator ani muscles and pelvic viscera in a continuous sheet [18]. This fascia is referred to as the pubocervical fascia between the bladder and the vagina and as the rectovaginal fascia between the vagina and rectum. The fascia extending from the cervix to the pelvic sidewall is termed the “parametrium” and superiorly it forms the cardinal and uterosacral ligaments [19]. The paracolpium is the fascia extending from the vagina to the pelvic sidewall.

Lateral condensations of the fascia unite to form the arcus tendineus, which provides lateral pelvic organ support and a site of attachment for the levator ani muscles. The pubocervical fascia also extends to the arcus tendineus laterally and the pericervical ring superiorly. The rectovaginal fascia extends to the perineal body inferiorly and to the arcus tendineus laterally and unites with the uterosacral ligaments superiorly. Additional supportive ligaments of the pelvic floor include the periurethral, paraurethral, and pubourethral ligaments, which provide support to the urethra and bladder neck [12, 14, 17] (Fig. 1).

Pelvic Diaphragm

The pelvic diaphragm is composed of four muscular groups, the ischiococcygeus muscle and the levator ani, which is composed of the pubococcygeus, puborectalis, and iliococcygeus, muscles. These muscles are an integral part of the pelvic floor and together provide continuous tone. The ischiococcygeus muscle is located posterior to the levator ani and extends from the ischial spines to the lateral margins of the sacrum and coccyx. The pubococcygeus muscle forms a “U” arising from the pubic bones anteriorly and forming a sling around the rectum (Figs. 2A and 2B). The iliococcygeus originates from the arcus tendineus along the lateral pelvic sidewalls and extends posterior to the rectum, in a horizontal fashion, to insert on the coccyx (Fig. 2C). The pubococcygeus muscle also has a horizontal orientation, arising from the superior ramus of the symphysis pubis and inserting on the arcus tendineus and coccyx [8]. This muscle also has attachments to the vagina and the perineal body [8].

Urogenital Diaphragm

The most caudal layer of the pelvic floor is the urogenital diaphragm (Fig. 2D). This diaphragm is composed of connective tissue and the deep transverse perineal muscle. The diaphragm runs horizontally between the ischial rami and extends to the perineal body and external anal sphincter (EAS) (Figs. 2B, 2D, and 2E). The perineal body is located between the anal canal and the vaginal introitus and is also referred to as the central tendon of the perineum and is the site of attachment for many structures including the endopelvic fascia, the EAS, the urogenital diaphragm, the bulbocavernous muscle, and the puborectalis muscle [20].

Pelvic Floor Compartments

For the purposes of evaluating and describing pelvic floor disorders, the pelvis is divided into three compartments: an anterior compartment containing the bladder and urethra, a middle compartment containing the uterus and cervix or the vaginal cuff in women who have undergone a hysterectomy, and a posterior compartment containing the rectum and anal canal. Patients can have symptoms and pelvic floor findings that involve one or more compartments.

In the anterior compartment, loss of fascial and ligamentous support to the urethra and bladder can allow urethral hypermobility and ultimately bladder prolapse, which is referred to as a cystocele. Patients may present with feelings of a vaginal bulge. Hypermobility of the urethra also frequently leads to stress urinary incontinence, and kinking at the vesicourethral junction can result in urinary retention.

In the middle compartment, abnormalities of the pubocervical fascia, parametrium, paracolpium, or uterosacral ligaments allow mobility and descent of the uterus, cervix, or vaginal cuff, creating a sensation of vaginal bulge, and may contribute to voiding and defecatory dysfunction. Uterine prolapse is also referred to as procidentia and vaginal prolapse, as a vaginocoele.

In the middle and posterior compartments, defects of the rectovaginal fascia permit descent of peritoneal contents between the vagina and rectum as well as bulging of the rectal wall, which can again create a swelling sensation, and be a cause of either fecal incon tinence or obstructive defecation. Rectal bulges are also referred to as rectoceles. Atrophy or defects of the levator ani muscle can result in a pelvic diaphragm that is unable to compensate for weakened fascia and ligaments, and ultimately lead to global descent of the pelvic organs and urinary or defecatory dysfunction.

The term “prolapse” is commonly used to describe any degree of downward pelvic organ movement. However, by definition prolapse refers to complete organ erosion. To remain consistent with most prior publications, we are using “prolapse” in its more general form in this article to describe any degree of pelvic organ descent, except in the posterior compartment where a distinction is more commonly made between true rectal prolapse (invagination and eversion of the rectum) and rectal descent without eversion due to pelvic floor weakness.

Imaging

Conventional imaging techniques for patients with pelvic floor symptoms include ultrasound evaluation of the bladder and anal sphincter, urodynamic testing with or without voiding cystourethrography, and evacuation proctography or cystocolpodefecography. More recently, there has been increasing interest and research in the use of MRI to evaluate patients with pelvic floor disorders.

Ultrasound

Ultrasound may be used to further evaluate patients with symptoms of urinary incontinence or retention and fecal incontinence. Transabdominal, transvaginal, endoanal, transperineal, and 3D techniques can be used to evaluate the pelvic floor sonographically. Ultrasound evaluation of the pelvic floor has the advantages of being readily available and
relatively easy to perform, without the use of ionizing radiation. However, the transducer can compress pelvic structures such as the urethra, bladder, and vaginal canal, thereby resulting in inaccurate assessment of organ morphology and position. Ultrasound’s confined field of view also limits global sonographic assessment of the pelvic floor.

In patients with urinary incontinence or retention, pre- and postvoid bladder volumes can be readily calculated using transabdominal ultrasound [21]. The morphology of the bladder wall and mobility at the urethrovaginal junction can also be assessed sonographically [22–24]. Urethral pressure measurements on urodynamic testing reportedly correlate with the calculated urethral volume on transvaginal ultrasound [25]. Ultrasound has also been used to evaluate patients after they have undergone treatment of urinary incontinence. Synthetic implants, such as suburethral slings, surgical mesh, and periurethral injections, can all be readily visualized sonographically [26–28].

Endoanal ultrasound can be used to evaluate the integrity of the internal anal sphincter (IAS) and the EAS muscles in patients with fecal incontinence. The mucosa and submucosa of the anal canal are usually hyperechoic. The normal IAS is uniformly hypoechoic and is 2–3 mm in thickness. The normal EAS is more heterogeneous in echotexture and is variable in thickness (Fig. 3). Anal sphincter defects appear as muscular interruptions, and ultrasound has reported sensitivities and specificities up to 90% for these findings [29, 30] (Fig. 4).

More recently, sonographic evaluation of pelvic organ prolapse has been described with the use of 3D and 4D ultrasound. With the pubic symphysis as a landmark, the transducer is positioned in a mid sagittal orientation at the level of the vaginal introitus. At least a 70° volume field of view is needed to visualize the urethra, vagina, anorectum, and puborectalis at rest. Real-time acquisitions of 3D cine loops are then obtained during various maneuvers including rest, squeeze, and

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**Fig. 2**—45-year-old woman with chronic constipation. MRI reveals normal-appearing levator ani and anal sphincter muscles.

A, Axial T2-weighted turbo spin-echo (TSE) image at level of anorectal junction shows intact puborectalis muscle (arrows) forming sling around rectum (R). Note right puborectalis muscle is thinner than left.

B, Coronal T2-weighted TSE image at level of rectum shows relationship between internal anal sphincter (arrowheads), external anal sphincter (black arrows), and puborectalis muscle (white arrows).

C, Coronal T2-weighted TSE image at level of rectum shows normal iliococcygeus muscles (arrows) with upward convexity.

D, Coronal T2-weighted TSE image at level of rectum shows urogenital diaphragm (white arrows) as most caudal layer of pelvic floor with attachment to external anal sphincter (black arrows). Note right side of diaphragm is thinner than left. This difference in thickness was attributed to atrophy rather than volume averaging given that asymmetry was contiguous on subsequent images.

E, Axial T2-weighted TSE image at level of anal canal illustrates normal internal (arrowhead) and external (arrows) anal sphincter muscles.
strain. Visualization of organ prolapse and of avulsion of the puborectalis muscle during stress has been reported [31, 32]. The role of ultrasound in evaluating pelvic organ prolapse is still under investigation. In a study of 145 women with pelvic organ prolapse, Dietz et al. [33] found that translabial ultrasound had good correlation with the clinical staging of prolapse in all three compartments. However, in a more recent study of 31 women with obstructed defecation, translabial ultrasound had poor agreement with evacuation proctography in the detection of rectoceles, and rectal intussusception, and true rectal prolapse [34].

**Fluoroscopy**

Several fluoroscopic examinations can be used to assess patients with pelvic floor symptoms including voiding cystourethrography (VCUG), with or without urodynamic testing; evacuation proctography; cystocolpoproctography. The advantages of using fluoroscopy to evaluate patients with pelvic floor abnormalities include the ability to image patients in more physiologic standing or seated positions, study availability, and the relative ease of study performance. The disadvantages include the more invasive nature of fluoroscopic studies, which require organ opacification for visualization; the inability to simultaneously evaluate all three pelvic compartments; and the use of ionizing radiation.

**Voiding Cystourethrography**

VCUG is primarily used to detect cystoceles in patients with a history of urinary incontinence. After filling the bladder with iodinated contrast material, patients are imaged in the lateral standing position during rest, stress, and voiding to detect maximal bladder descent. The mobility of the urethrovaginal junction and other coexisting conditions such as urethral diverticula and vesicoureteral reflux can also be seen [35, 36]. VCUG has a reported accuracy of 65% for detecting urethral diverticula and 58%, compared with the clinical Q-tip test, for diagnosing urethral hypermobility [37, 38]. Evaluation of detrusor instability in patients with symptoms of urge urinary incontinence requires assessment of urodynamics [39].

**Evacuation Proctography**

Evacuation proctography, also termed “defecography,” refers to the fluoroscopic assessment of rectal evacuation and prolapse. The
Pelvic floor descent can be further quantified by measuring the distance from the chosen fixed bony landmark for the pelvic floor to the level of the anorectal junction during evacuation [42]. In addition, various reference lines based on bony pelvic landmarks, including a line extending from the symphysis pubis to the last coccygeal joint (the pubococcygeal line [PCL]) or a line extending along the long axis of the symphysis pubis (the midpubic line [MPL]), can serve as lines of reference for fluoroscopic assessment of pelvic organ descent or prolapse. The PCL is one of the more commonly reported reference lines for fluoroscopic examinations [43].

Before evacuation, the anorectal junction should be at or above the PCL. The anorectal junction is the distally tapered point of the rectal contrast column caused by posterior impression of the puborectalis muscle. The anorectal angle is the angle formed at the anorectal junction by the posterior aspect of the distal rectum and the long axis of the anal canal. This angle is normally 90°–110° at rest. With normal complete evacuation, the pelvic floor descends, the puborectalis and sphincter muscles relax, the puborectalis impression on the posterior rectal wall decreases, the anorectal angle becomes more obtuse, and the anal canal shortens and widens (Fig. 5). After evacuation, anal sphincter tone and levator ani muscle tone increase, resulting in a more acute anorectal angle and return of the structures to their preevacuation positions [40].

In addition to assessing rectal evacuation, evacuation proctography can also show rectal intussusception, rectal prolapse, and rectoceles. Intussusceptions manifest as invaginations of the rectum into itself, the anal canal, or extraanally (i.e., true, complete prolapse) [44]. Rectoceles are most commonly directed anteriorly and are diagnosed if the anterior margin of the rectal wall bulge is more than 2 cm anterior to a line drawn along the long axis of the anterior anal canal [43] (Fig. 6).

Rectal intussusception, rectal prolapse, and rectoceles are all potential reasons for difficult rectal evacuation. Another cause of constipation is failure of the puborectalis muscle to relax during attempted evacuation, also referred to as paradoxical contraction of the puborectalis muscle, anismus, or pelvic dyssynergy. Absent or slow rectal emptying (> 66% of rectal contrast material not evacuated by 30 seconds) has been reported to have up to a 90% positive predictive value for pelvic dyssynergy [45].

Evaluation of coexisting anterior compartment and middle compartment weak-
methods: It allows relatively noninvasive, dy-

mamic evaluation of all pelvic organs in mul-
tiple planes with high soft-tissue and temporal
resolution without the use of ionizing radia-
tion. In addition, MRI can directly visualize
the muscular and ligamentous pelvic floor
support structures. Disadvantages of using
MRI to evaluate the pelvic floor include the
less physiologic supine positioning of patients
during imaging if an open seated magnet is
available, higher costs, and potentially
limited radiologist experience.

Using MRI to evaluate pelvic floor disorders
may be most helpful in patients with multi-

compartment physical examination findings or
symptoms, posterior compartment abnormalities, severe prolapse, or recurrent pelvic floor
symptoms after prior surgical repair. Several
studies have shown that MRI is a useful meth-
od for diagnosing and staging pelvic organ prolapse, with detection rates similar to fluoro-
scopic techniques, and that MRI is often able
to reveal more extensive organ prolapse than
physical examination alone [43, 50–52]. In a
study of 10 patients who underwent both dy-
namic MRI and fluoroscopic cystocolpoproc-
tography, the MRI and fluoroscopic results

MRI

MRI is the newest technique used to evalu-
ate patients with pelvic floor disorders. There
are several advantages of MRI over the more
traditional fluoroscopic and sonographic
methods: It allows relatively noninvasive, dy-

ness with fluoroscopy requires opacification
of additional pelvic organs. In the middle
compartment, rectovaginal fascial defects
allow the abdominal contents to descend into
the rectovaginal space during evacuation or
strain. Large-bowel descent is referred to as
a sigmoidocele; small bowel, as an enteroce-
le; and peritoneal fat, as a peritoneocele.

If retrograde rectal contrast medium reaches
the sigmoid colon, sigmoidoceles may be
detected fluoroscopically. To reliably detect en-
teroceles, the small bowel can be opacified
with an oral contrast preparation 1–2 hours
before the study. Displacement of the vagina
during evacuation and strain can be shown by
opacifying the vagina with barium paste or
contrast medium mixed with ultrasound
gel [46]. Finally, to assess for weakness in
the anterior compartment, the bladder can be
catheterized, drained, and then opacified
with water-soluble contrast material. The po-

position of the bladder at rest and during maxi-
mal strain can then be determined. The blad-
der base should normally remain above the
PCL. Fluoroscopic evaluation of the opaci-
fied bladder and the rectum is referred to as
cystocolpoproctography and evaluation of the
opacified bladder, vagina, and rectum, as
cystocolpoproctography [47].

Fluoroscopic studies are often considered
the gold standard for the diagnosis of pelvic
floor abnormalities when newer techniques
are introduced because fluoroscopic studies
have been widely used for the past 20 years.
However, there is really no true gold standard
against which fluoroscopy can be compared.
Patient symptoms and clinical and surgical
findings of pelvic floor abnormalities are of-
ten variable and inconsistent. Fluoroscopic
studies have been shown to reveal more exten-
sive pelvic floor abnormalities than physical
examination alone with high observer accu-

Fig. 10—67-year-old woman with incomplete
defecation. Sagittal T2-weighted HASTE image
obtained during Valsalva maneuver reveals descent of
rectum (white arrow) 5.5 cm below pubococcygeal line
(PCL) (dashed line) and 1.2 cm below midpubic (MPL)
(solid line); these findings are consistent with moderate
(PCL staging) or stage 3 (MPL staging) rectal descent.

Also, note 4-cm anterior rectocele (long black arrow)
and mild, stage 1, bladder prolapse (short black arrow).

Fig. 11—72-year-old woman with question of
rectocele on physical examination. Sagittal T2-
weighted HASTE image obtained during Valsalva
maneuver reveals descent of sigmoid colon (white
arrows) into rectovaginal space. Also note rectal
descent (black arrow) and anterior rectocele (double-
headed arrow). V = vaginal canal, R = rectum.

Fig. 12—37-year-old woman with chronic constipation.
A and B, Sagittal true FISP images obtained with patient at rest (A) and during evacuation (B) show normal
change in anorectal angle with evacuation, 100–145°. Also, note anal canal (arrows) is shorter and wider during evacuation. Patient evacuated rectal contrast material without difficulty.
were similar. Ten rectoceles and nine cystoceles were shown on both studies. Seven enteroceles were diagnosed on fluoroscopy, one of which was not initially seen on MRI, and two sigmoidoceles were diagnosed on MRI, one of which was not identified fluoroscopically [43]. In a more recent study of 50 patients with fecal incontinence, MRI also reportedly changed the surgical approach in 22 (67%) of 33 patients who underwent surgery [50]. Accurate assessment of all three compartments is important to help guide management, particularly in women considering surgical treatment.

**MRI Protocol**

There is no standardized protocol for MRI of patients with pelvic floor disorders. However, the key element of any protocol is to image the patient during maximal strain or rectal evacuation in one or more planes. The protocol for MRI of the pelvic floor used at Women and Infants Hospital and the reason for performing each sequence are outlined in Table 1. Patients are asked to void immediately before the study. They are then positioned on the MR table on a water-resistant pad. Using 60-mL syringes, 120 mL of ultrasound gel is placed into the rectum. The patient is then turned into the supine position and the pad is secured around the pelvis. A wedge is placed underneath the patient’s knees to help maximize strain maneuvers in the supine position. Imaging is then performed with a pelvic phased-array coil, which is positioned slightly lower than usual to cover the proximal thighs to ensure complete coverage of pelvic organ descent.

Protocols may vary with respect to patient positioning, pelvic organ opacification, patient maneuvers (i.e., rest, Kegel, Valsalva, evacuation), and MR sequences and planes. Bertschinger et al. [53] reported equivalent outcomes for patients imaged in both the seated and supine positions. Our examinations are and most pelvic floor MR studies to date have been performed with supine imaging in a closed magnet [43, 54–56]. Sonography gel, a starch substance mixed with gadolinium, or air has been used to opacify the rectum. In a study of 82 women who underwent supine MRI both with and without rectal contrast material as well as fluoroscopic cystocolpoproctography, MRI without rectal contrast material revealed statistically fewer pelvic floor abnormalities than MRI with rectal contrast material, which had a performance similar to that of cystocolpoproctography [57]. Although we do not find it necessary, ultrasound gel can be used to opacify the vaginal canal and some authors report
catheterizing and filling the bladder with saline to more easily identify bladder descent [56]. Imaging patients during rectal evacuation tends to reveal the greatest degree of pelvic organ descent. Real-time true fast imaging with steady-state precession (FISP) sequences reportedly show greater degrees of organ prolapse than HASTE sequences, which require a short delay between series [58].

**MRI Interpretation**

Interpretation of a pelvic floor MR examination can be broken down into the assessment of three components: pelvic organ prolapse, rectal evacuation, and the pelvic floor support structures.

Pelvic organ prolapse—Pelvic organ prolapse is best evaluated on mid-sagittal true FISP dynamic evacuation sequences and sagittal and coronal HASTE strain imaging planes when pelvic organ descent should be greatest. Similar to cystoproctography, to determine the presence and extent of pelvic organ prolapse, a point of reference for rest and stress measurements is required. Several reference points and lines for measuring and staging pelvic organ prolapse on MRI have been proposed. The two most commonly used lines are a line connecting the inferior aspect of the pubic symphysis to the last coccygeal joint, the PCL; and a line extending caudally along the long axis of the symphysis pubis, the MPL [56, 59–61] (Fig. 7).

On cadaveric dissection, the MPL has been shown to correspond to the level of the vaginal hymen, the landmark used for clinical staging [61]. To date, neither the PCL nor the MPL has been shown to have better agreement with clinical staging [62]. The choice of reference line for MRI interpretation may be dependent on radiologist experience and referring physician preference. At our institution, the MPL is used to stage pelvic organ prolapse on MRI. This reference line was chosen because the urogynecologists at our institution, who refer most of the patients for pelvic floor MR examinations, are more familiar with the MPL and its staging system because it is the same staging system they use clinically. We include a description of the MPL and the MPL staging system at the end of each MR report for physicians who may be less familiar this reference line and staging system.

Once the MR reference line is chosen, staging of pelvic organ prolapse in all three compartments can be performed by measuring the perpendicular distance from the anatomic reference point in each compartment to the reference line (Fig. 7). In the anterior compartment, the reference point is the most posterior and inferior aspects of the bladder base. In the apical compartment, the reference point is the anterior cervical lip or the posterolateral vaginal apex if the patient has undergone hysterectomy. In the posterior compartment, the anterior aspect of the anorectal junction

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Imaging Plane</th>
<th>Patient Position</th>
<th>TR (ms)</th>
<th>TE (ms)</th>
<th>Slice Thickness (mm)</th>
<th>Field of View (cm)</th>
<th>Matrix</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>HASTE</td>
<td>Sagittal*</td>
<td>Rest</td>
<td>1,150</td>
<td>100</td>
<td>7</td>
<td>35</td>
<td>224 × 256</td>
<td>Determine resting organ positions</td>
</tr>
<tr>
<td>HASTE</td>
<td>Sagittal*</td>
<td>Kegel</td>
<td>1,150</td>
<td>100</td>
<td>7</td>
<td>35</td>
<td>224 × 256</td>
<td>Assess Kegel ability</td>
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<tr>
<td>True FISP</td>
<td>Sagittal*</td>
<td>Evacuation</td>
<td>15</td>
<td>2</td>
<td>6</td>
<td>30</td>
<td>224 × 256</td>
<td>Evaluate pelvic organ prolapse, rectal evacuation</td>
</tr>
<tr>
<td>HASTE</td>
<td>Sagittal*</td>
<td>Valsalva</td>
<td>1,150</td>
<td>100</td>
<td>7</td>
<td>35</td>
<td>224 × 256</td>
<td>Evaluate pelvic organ prolapse</td>
</tr>
<tr>
<td>HASTE</td>
<td>Coronal*</td>
<td>Valsalva</td>
<td>1,150</td>
<td>100</td>
<td>7</td>
<td>35</td>
<td>224 × 256</td>
<td>Evaluate pelvic organ prolapse</td>
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<tr>
<td>TSE</td>
<td>Axial</td>
<td>Rest</td>
<td>5,640</td>
<td>120</td>
<td>4</td>
<td>30</td>
<td>300 × 384</td>
<td>Evaluate pelvic support structures</td>
</tr>
<tr>
<td>TSE</td>
<td>Coronal</td>
<td>Rest</td>
<td>5,640</td>
<td>120</td>
<td>4</td>
<td>30</td>
<td>300 × 384</td>
<td>Evaluate pelvic support structures</td>
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Note—Examination performed on a 1.5-T closed magnet. FISP = fast imaging with steady-state free precession, TSE = turbo spin-echo.
*Imaging from femoral head to femoral head.
*True FISP evacuation sequence is performed before the single-shot fast spin-echo Valsalva sequence to ensure that rectal contrast material is not lost before dynamic imaging. The true FISP sequence is a continuous 90-second acquisition along the mid-sagittal slice. Acquisition time per image = 1 second.
serves as the point of reference [43, 47, 63, 64]. The largest measurement during strain or evacuation, defined as the measurement farthest below the reference line or closest to the reference line if located above the PCL or MPL, is used to stage the presence and degree of pelvic organ prolapse (Figs. 8–10). Staging systems for both the PCL and MPL exist [43, 51, 53, 60, 61] (Tables 2 and 3).

**Cul-de-sac defects**—In addition to assessing pelvic organ prolapse, the cul-de-sac should also be evaluated on the evacuation and strain sequences for enterocoeles, sigmoidoceles, and peritoneoceles [43, 65]. Cul-de-sac defects are particularly challenging to diagnose and characterize on physical examination because a posterior vaginal wall bulge could be due to any of these three or the rectum. Because of its excellent soft-tissue resolution, MRI can readily diagnose the contents of a cul-de-sac bulge without the use of oral contrast material as would be required for fluoroscopic studies (Fig. 11).

**Defecatory function**—Next, defecation can be evaluated with the dynamic mid sagittal true FISP images obtained during rectal evacuation. In our facility, if the patient is unable to evacuate the rectal contrast material on the first attempt, the sequence is repeated at least twice to ensure that the inability to evacuate contrast material is not due to a lack of communication or effort. The same criteria for normal defecation on evacuation proctography can be applied to MRI. Normal defecation on MRI is characterized by the ability to evacuate at least some of the rectal contrast material as well as the appropriate changes in the anorectal angle (Fig. 12). Also, similar to evacuation proctography, MRI can reveal additional reasons for abnormal defecation including true rectal prolapse, rectoceles, and rectal intussusception.

Intussusceptions can be difficult to detect on MRI, and fluoroscopy has been shown to reveal more intussusceptions than MRI. The sensitivity for diagnosing rectal intussusception on MRI has been reported to be 70% relative to evacuation proctography [66]. However, the soft-tissue resolution of MRI may allow better differentiation between mucosal-only intussusceptions versus full-wall-thickness intussusceptions [66]. Small rectoceles may also be better seen on fluoroscopy.

Pelvic dyssynergia manifests on MRI as an inability to evacuate rectal contrast material despite multiple attempts. However, the inability to evacuate the rectal contrast material could also be due to difficulty defecating in the supine position. In our experience, most patients are able to evacuate at least some of the rectal contrast material in the supine position if allowed multiple attempts (at least two to three). Assessment of the anorectal angle during attempted defecation may help differentiate between patients with true paradoxical contraction of the puborectalis muscle and patients who have difficulty defecating due to supine positioning. No change in the anorectal angle or a more acute change in the anorectal angle with attempted defecation may suggest pelvic dysynergia, whereas a more obtuse change in the anorectal angle may suggest difficulty defecating supine [67].

Investigators have suggested that the diagnosis of rectal intussusception, true prolapse, and incomplete emptying of rectoceles may be made more confidently with evacuation proctography than with MRI [68]. This may be partly due to the more physiologic seated position of patients with fluoroscopy, which may facilitate defecation, and to radiologist experience. However, up to 30% of patients with rectal intussusception reportedly have associated pelvic organ descent in the anterior, middle, or both compartments [69]. Therefore, MRI may be the first study of choice when there are physical examination findings or the patient has symptoms suggestive of multicompartiment abnormalities.

**Pelvic floor support**—The third step of the MR examination is to assess the pelvic floor support structures. The support structures are best visualized on the axial and coronal T2-weighted turbo spin echo (TSE) sequences. The iliococcygeus and puborectalis muscles are well visualized on MRI. The ischiococcygeus and pubococcygeus are typically not seen separately, and with the use of only a pelvic phased-array coil, the supportive ligaments are variably seen and the endopelvic fascia is not directly visualized. However, there have been several recent reports of high-resolution MRI of cadavers and patients with end urethral and endovaginal coils to better identify and visualize the ligaments of the pelvic floor [10, 11, 13, 14, 16, 17].

The puborectalis muscle is best visualized in the axial plane and thinning and defects can be detected. Asymmetry of the muscle, with the right side being thinner than the left, has been described as a normal variation on MRI [70]. This asymmetry has been proposed to be due to variable chemical shift artifact that can make the muscle appear thicker on the left [9]. In the coronal plane, the ilio coccygeus muscle is well visualized. Normally this muscle is convex upward. Atrophy of the muscle may result in downward convexity. The urogenital diaphragm is also well visualized in the coronal plane [20] (Figs. 2A–2D).

The anal sphincter muscles are well visualized and can be evaluated in both the axial and coronal planes (Figs. 2B and 2E). The IAS is the innermost muscle and is uniformly intermediate in signal intensity on T2-weighted images. The EAS is the outermost muscle and is usually lower in signal intensity on T2-weighted images. The EAS may

### TABLE 2: Staging of Pelvic Organ Prolapse Using Pubococcygeal Line (PCL)

<table>
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<th>Stage</th>
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<tbody>
<tr>
<td>Small prolapse</td>
<td>1 to 3 cm below PCL</td>
</tr>
<tr>
<td>Moderate prolapse</td>
<td>3 to 6 cm below PCL</td>
</tr>
<tr>
<td>Large prolapse</td>
<td>&gt; 6 cm below PCL</td>
</tr>
</tbody>
</table>

Note—Moderate prolapse and large prolapse are usually symptomatic [50].

### TABLE 3: Staging of Pelvic Organ Prolapse Using Midpubic Line (MPL)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&gt; 3 cm to (TVLb – 2 cm) above MPL</td>
</tr>
<tr>
<td>1</td>
<td>Does not meet stage 0, but &gt; 1 cm above MPL</td>
</tr>
<tr>
<td>2</td>
<td>≤ 1 cm above or below MPL</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 1 cm below MPL</td>
</tr>
<tr>
<td>4</td>
<td>Complete organ eversion</td>
</tr>
</tbody>
</table>

Note—Stage 2–4 are usually symptomatic. The MPL reference line and clinical pelvic organ prolapse quantification examination use the same staging system [61].

*Distance of inferior bladder base, anterior cervical lip, and anterior anorectal junction from PCL.

bOn physical examination and sagittal MR images, total vaginal length (TVL) is the greatest vertical vaginal measurement in centimeters from the posterior vaginal fornix to the level of the introitus in patients with a cervix. In patients without a cervix, the measurement is made from the most superior aspect of the vaginal cuff to the level of the introitus [74].
be open anteriorly or posteriorly as a normal variation, and this finding should not be mistaken for a muscular defect [20]. Defects of the sphincter muscles can be difficult to characterize because they are often accompanied by low-signal-intensity fibrosis rather than a clear muscle gap [30, 71]. MRI has been shown to be as accurate (91%) as ultrasound for the detection of anal sphincter defects—in particular, for defects of the EAS—but to be more accurate (93%) than ultrasound for the diagnosis of sphincter atrophy [72, 73].

Visualization and evaluation of the liga-mentous and fascial support of the pelvic organs with MRI are challenging and an area of increasing clinical and research interest [10, 11, 13, 14, 16, 17]. Using an endorectal MR coil and high-resolution MRI, Macura et al. [14] described at least three different ligaments that provide support to the female urethra: the periurethral, paraurethral, and pubourethral ligaments. Imaging with an endo- vaginal coil may also improve visualization of the ligaments supporting the urethra [13].

In another recent article, El Sayed et al. [16] described secondary signs of paravaginal fascial defects including posterior protrusion of the bladder. Knowledge of the exact site of a muscular, ligamentous, or fascial defect of the pelvic floor could allow more tailored management and surgical treatment of patients.

Conclusion
Pelvic floor disorders are a common and complex problem in which imaging plays a key role in effective diagnosis and treatment. Ultra-sound, fluoroscopy, and MRI can all be used to evaluate the pelvic floor. Although research is ongoing, static and dynamic MRI has the advantages of simultaneously and relatively non-invasively evaluating pelvic organ prolapse in all three compartments, rectal evacuation, and various pelvic floor support structures.

References
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