Postoperative Imaging after Surgical Repair for Pelvic Floor Dysfunction

Gaurav Khatri, MD  
Maude E. Carmel, MD  
April A. Bailey, MD  
Melissa R. Foreman, RDMS, RVT  
Cecelia C. Brewington, MD  
Philippe E. Zimmern, MD  
Ivan Pedrosa, MD

Pelvic floor dysfunction encompasses an extremely common set of conditions, with various surgical and nonsurgical treatment options. Surgical options include injection of urethral bulking agents, native tissue repair with or without bioabsorbable or synthetic graft material, placement of synthetic midurethral slings or use of vaginal mesh kits, and mesh sacrocolpopexy procedures. Numerous different synthetic products with varied imaging appearances exist, and some of these products may be difficult to identify at imaging. Patients often present with recurrent or new symptoms after surgery; and depending on the presenting complaint and the nature of the initial intervention, imaging with ultrasonography (US), magnetic resonance (MR) imaging, voiding cystourethrography, or computed tomography (CT) may be indicated. US and MR imaging can both be used to image urethral bulking agents; US is often used to follow potential changes in bulking agent volume with time. Compared with MR imaging, US depicts midurethral slings better in the urethropelvic space, and MR imaging is better than US for depiction of the arms of the sacrospinous ligament (ischioanal fossae) better depicted by the age of 80 in the United States for the treatment of pelvic floor disorders (1). The lifetime risk of undergoing a single surgical procedure for prolapse or incontinence by the age of 80 in the United States is 11% (3), and annual surgical costs for pelvic floor dysfunction in the United States have been shown to surpass $1 billion (4,5). Notably, the rate of reoperation for recurrent prolapse is as high as 29% (3), which may be secondary to a high rate of surgical failure and complications from the initial intervention. Although imaging can play an important role in the initial surgical planning and subsequently for evaluation of complications in the postoperative period, knowledge of the many interventions and their expected imaging appearances is imperative to detect complications in this setting.

Introduction

Pelvic floor disorders affect nearly one in four women in the United States (1) and comprise a complex set of conditions, including pelvic organ prolapse, stress urinary incontinence, pelvic pain, and defecatory dysfunction. Various surgical and nonsurgical management options exist, depending on the specific condition being treated. More than 300,000 surgical procedures are performed annually in the United States for the treatment of pelvic floor disorders (2). The lifetime risk of undergoing a single surgical procedure for prolapse or incontinence by the age of 80 in the United States is 11% (3), and annual surgical costs for pelvic floor dysfunction in the United States have been shown to surpass $1 billion (4,5). Notably, the rate of reoperation for recurrent prolapse is as high as 29% (3), which may be secondary to a high rate of surgical failure and complications from the initial intervention. Although imaging can play an important role in the initial surgical planning and subsequently for evaluation of complications in the postoperative period, knowledge of the many interventions and their expected imaging appearances is imperative to detect complications in this setting.

SA-CME LEARNING OBJECTIVES

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

- List the various surgical treatment options available for pelvic floor disorders and the potential complications of these treatment options.
- Discuss the application of various imaging modalities in the evaluation of complications related to pelvic floor reconstruction procedures.
- Describe normal and abnormal appearances of urethral bulking agents, midurethral slings, and mesh on US and MR images.

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Abbreviations: SE = spin-echo, 2D = two-dimensional, 3D = three-dimensional


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Radiologists must be aware of the expected postsurgical appearances after various pelvic floor interventions in order to be able to evaluate patients for complications such as misplaced or migrated bulking agent material, erosion or extrusion of implanted surgical material, or infection of mesh or slings.

Midurethral slings can be imaged with US or MR imaging. US is generally more revealing than MR imaging when assessing slings in the suburethral space; however, US is limited for imaging of the retropubic space, which is depicted well at MR imaging.

The radiologist plays an important role in the care of patients after pelvic floor repair by helping in the detection of potential normal or abnormal mesh material and by offering a road map for surgical exploration when indicated on the basis of the clinical data. Adequate description should include the location and extent of the suspected mesh body and arms and their relationship to native anatomic structures, because these details may provide important preoperative planning information.

As in the case of urethral slings, vaginal mesh cannot always be readily differentiated from scar tissue at imaging, and this caveat is particularly important when patients have had multiple prior attempts at placement and removal of synthetic material.

Vaginal mesh kits and sacrocolpopexy mesh may be better depicted at MR imaging because the large field of view allows detection of the distant extent of the mesh components. MR imaging may also be more useful for the detection of intrapelvic complications such as infection or abscesses.

The purpose of this review is to describe some of the many available treatment options for pelvic floor disorders, discuss pertinent imaging techniques, and illustrate the utility of imaging in postoperative patients. Three-dimensional (3D) schematic representations of different surgical procedures are presented to allow better understanding of the complex anatomic relationships.

### Treatment of Pelvic Floor Disorders

Pelvic floor disorders can be treated surgically or managed with a number of nonsurgical options, such as (a) observation or pelvic floor muscle training for relatively asymptomatic or mild conditions; (b) biofeedback for pelvic floor dyssynergia or spastic pelvic floor syndrome; or (c) placement of a pessary for prolapse in symptomatic patients who decline surgery or are poor surgical candidates, or in the setting of temporary prolapse (eg, pregnancy). Surgical options also vary on the basis of the particular condition being treated, and surgical treatment can be performed with transurethral, transvaginal, or transabdominal approaches.

Stress urinary incontinence can be managed with the injection of urethral bulking agents, open abdominal retropubic colposuspension, surgical placement of midurethral slings, bladder neck suspension, placement of artificial urinary sphincters in male patients, and laparoscopic colposuspension. Pelvic organ prolapse can be treated surgically with either obliterative or reconstructive techniques. Obliterative techniques such as colpocleisis are generally reserved for elderly patients who are not sexually active and may have other medical comorbidities. Reconstructive options include primary native tissue repairs, placement of biologic or absorbable graft materials, or implantation of nonabsorbable synthetic material. Anterior prolapse can be treated with anterior colporrhaphy or primary repair of paravaginal defects. Anterior vaginal wall suspension, or placement of anterior vaginal mesh. Vaginal apical or uterine prolapse can be treated with vaginal vault sacrospinous ligament fixation, iliococcygeus ligament fixation, high uterosacral ligament fixation, McCall culdoplasty, or placement of vaginal or cervical sacrocolpopexy mesh. Enterocoeles or peritoneoceles may be treated with primary repair of the hernia defect or with sacrocolpopexy. Posterior vaginal wall prolapse and rectoceles can be treated with posterior colporrhaphy, primary defect repairs, placement of posterior vaginal mesh, or augmentation with bioabsorbable material. Total mesh kits have been used to correct combined anterior, apical, and posterior compartment prolapse. Surgical treatment options for other causes of defecatory dysfunction include rectopexy or partial resection of redundant sigmoid colon or rectum in cases of sigmoidocele or rectal intussusception.

Patients may present with recurrent symptoms or complications after surgical treatment of pelvic floor disorders. Complications in the acute postoperative period include bleeding or infection, and delayed or chronic complications may include recurrent incontinence or prolapse in either the same treated compartment or in a different compartment of the pelvis. Recurrent symptoms may result from loss of efficacy of the initial intervention, as in the case of resorption of urethral bulking agents or detachment of a previously placed sacrocolpopexy mesh. Patients may also present with new symptoms related to the placement of synthetic material, such as dyspareunia, discharge, or bleeding related to extrusion of synthetic material into the vagina; or irritative bladder symptoms, voiding dysfunction, or recurrent urinary infection caused by erosion of synthetic material into the bladder or urethra. Chronic pelvic or groin pain is not uncommon after certain types of urethral sling or mesh procedures. Depending on the nature of the prior therapy and the suspected complication, different imaging techniques may be used, and more than one imaging examination may be necessary to provide complementary information.
Imaging Indications

Imaging in the perioperative setting can be used as an objective measure after pelvic floor intervention to document anatomic and functional changes (8–12); however, imaging findings may not always correlate well with the clinical findings and symptoms (13,14). Imaging can play an additional role in the postoperative setting in the evaluation of recurrent symptoms or complications. Knowledge of the original presurgical presenting complaints and the type of subsequent intervention performed is imperative when interpreting imaging in the postintervention setting, although this information may not always be available. Furthermore, radiologists must be aware of the expected postsurgical appearances after various pelvic floor interventions in order to be able to evaluate patients for complications such as misplaced or migrated bulking agent material, erosion or extrusion of implanted surgical material, or infection of mesh or slings.

Failed prolapse surgery may be secondary to the involvement of multiple compartments, a finding which may not have been detected during physical examination before surgery. These patients may present with recurrent or progressive symptoms. For example, a patient treated for a cystocele in the anterior compartment may present with a posterior bulge from an enterocele that was not diagnosed before the initial intervention. This finding may or may not be apparent at physical examination even at the time of subsequent presentation, and dynamic pelvic floor imaging may be more revealing (15).

Imaging may provide important information in patients who have undergone multiple prior interventions at different institutions, because details of the prior interventions are often not available. This scenario is not uncommon, as a large number of patients with mesh complications are known to receive evaluations by physicians other than the implanting surgeon (16). In such a situation, imaging may be able to locate synthetic material and provide a road map for surgical exploration, although differentiation of scar tissue from synthetic material can be difficult. This information, along with the clinical presentation and the findings at physical examination, allows the surgeon to decide whether the patient will benefit from further surgical procedures, such as removal of potentially offending synthetic material. Finally, imaging can be used to detect acute or subacute perioperative complications, such as hematomas or other fluid collections, infection, or vascular injury, or less-common complications such as bladder or ureteral injury and bowel injury or obstruction that may be difficult to detect at clinical examination.

Imaging Techniques

Common imaging techniques used in this clinical setting include ultrasonography (US), magnetic resonance (MR) imaging, voiding cystourethrography, and, less commonly, computed tomography (CT). The choice of the optimal imaging modality depends on the specific nature of the presenting complaint as well as the prior intervention.

Ultrasonography

Endovaginal as well as transperineal/introital and translabial two-dimensional (2D) and 3D US techniques have been used for depiction of implanted slings and mesh in the pelvic floor (17–22). Compared with physical examination and urethrocystoscopic findings, US is more sensitive for locating implanted mesh and slings (21). Investigators from a recent study demonstrated endovaginal US to have a 92% sensitivity for depiction of implanted mesh or slings, with only 72% of the meshes or slings depicted with US being detected at physical examination (23). In addition, US is able to provide anatomic and functional information about native structures, such as the bladder and urethra, after surgery, which may help assess the results of the interventions (11). US offers a particular advantage, compared with current MR imaging techniques, for the characterization of slings and mesh in the sub- or periurethral locations, but MR imaging outperforms US for depiction in the retropubic space (19). Additional advantages of US include its lower cost, wider availability, shorter on-table examination time, potential for real-time correlation of imaging findings and patient symptoms, and portability, which allows for both peri- and intraoperative evaluation. Limitations for the use of US include its small field of view, potential for variability in reconstruction of viewing planes, and dependence on the expertise of not only the radiologist, but also the technologist.

We use 2D and 3D transperineal/introital US by following previously published techniques (18,22,24,25). With the patient in the dorsal lithotomy position, a high-frequency high-resolution 3D end-fire mechanical probe is placed at the perineal surface at the level of the introitus, centered on the urethra in the midsagittal plane. Two-dimensional static images and real-time cine clips are obtained in sagittal, coronal, and axial planes. The probe allows for automatic 3D multiplanar volume acquisition, as opposed to noncalibrated freehand acquisition, thus enabling measurement on the volume images. Three-dimensional images are postprocessed from the volumetric data after completion of the examination. In addition to providing important anatomic and functional information (18,21,24), 3D US and cine US allow...
Figure 1. (a) Sagittal midline 2D US image shows normal anatomic structures from anterior to posterior (left to right): pubic symphysis (PS), urethra (arrows), urinary bladder (UB), vagina (arrowheads), and rectum (R). (b) Coronal 2D US image obtained with the probe in the neutral position shows the urethra (U) as a tubular hypoechoic structure centrally in the near field, as well as a distended urinary bladder (UB) superior to the urethra in the far field.

the image data to be reconstructed and viewed at a later time, thus shortening actual on-table time for the patient. Three-dimensional datasets also provide referring physicians more readily identifiable anatomic landmarks. Normal anatomic landmarks that are depicted on a sagittal transperineal US midline image, from anterior to posterior, include the pubic symphysis, urethra, urinary bladder, vagina, and rectum (Fig 1a) (25). Coronal US images allow depiction of the pubic symphysis when the probe is angled anteriorly, and the urethra is seen as a tubular structure when the probe is in the neutral position (Fig 1b).

MR Imaging

Compared with US, MR imaging is better suited for the evaluation of the retropubic portions of urethral slings (19) because of its larger field of imaging and the inability of the ultrasound beam to penetrate the pubic bone. MR imaging has also been used in the postsurgical setting to evaluate the integrity of sacrocolpopexy mesh and potential associated complications (26). In most studies utilizing MR imaging after placement of vaginal mesh, investigators focus on dynamic or anatomic evaluation of the pelvic floor to assess the outcomes of the surgery, rather than focusing on direct depiction of the actual mesh material, with variable results compared with the findings at clinical examination (8,10,13,27,28). The MR imaging protocols used in these comparisons (8,10) are generally tailored for dynamic evaluation of the pelvic floor, rather than high-resolution (eg, small field of view) imaging of mesh material.

When imaging patients who have undergone multiple prior surgeries for mesh and sling placement or removal, it is important to maximize the likelihood of identification of synthetic materials by using a tailored high-resolution “mesh protocol” (Table 1), which differs from the standard dynamic pelvic floor MR defecography protocol. At our institution, the mesh protocol includes high-resolution 2DT2-weighted fast SE (turbo SE) sequences in the axial, sagittal, and coronal planes; a 2DT2-weighted fat-suppressed fast SE sequence in the sagittal plane to evaluate for inflammation, collections, and bone edema or infection; and a thin-section 3DT2-weighted fast SE sequence in the axial plane centered at the urethra and vagina to enable depiction of mesh and sling components. T1-weighted gradient-echo in-phase and out-of-phase MR images are obtained to evaluate for susceptibility related to surgical sutures and clips. Nonenhanced and dynamic contrast material–enhanced 3DT1-weighted fat-suppressed gradient-echo MR images obtained during the late arterial phase and then at 40, 90, and 120 seconds are used to assess for enhancement corresponding to inflammation of mesh and sling elements. Cranio-caudal coverage of the coronal and sagittal images should extend to at least the L5 vertebral body to include the fixation site of potential sacrocolpopexy mesh at the sacral promontory. This protocol allows for an optimized anatomic evaluation of the lower portion of the pelvis, including both soft-tissue and osseous structures, and we use it for evaluation of patients who present with pelvic or groin pain, dyspareunia, or voiding dysfunction, and those who are suspected of having infection after pelvic floor intervention, rather than recurrent prolapse. In patients with recurrent or persistent prolapse as the major complaint, we use a separate functional MR defecography protocol (29).

Other Imaging Techniques

Voiding cystourethrography and CT are used less commonly in the postoperative setting. Upright voiding cystourethrography with images
obtained with the patient in the lateral and frontal positions can be used for the evaluation of new or recurrent anterior compartment symptoms, such as voiding difficulty, incontinence, or anterior prolapse, because the technique allows dynamic assessment of the bladder and urethra during rest and strain, and permits depiction of the voiding urethra in the upright position (30,31). Although CT does not delineate mesh and slings well against the surrounding pelvic soft tissue, it can be used as the initial imaging modality for diffuse postoperative abdominal or pelvic pain or for evaluation of certain postoperative complications, such as fluid collections (particularly outside the pelvis), bladder or ureteral injury, or bowel obstruction.

The remainder of this review details the specific interventions used in the treatment of pelvic floor disorders, with focus on the expected normal imaging findings, as well as the imaging of potential complications.

### Urethral Bulking Agents

Transurethral or periurethral injection of bulking agents enhances coaptation of urethral mucosa and provides more short-term benefit in the treatment of stress urinary incontinence, compared with conservative therapy. The injection of urethral bulking agents has a better safety profile than that of surgical repair; however, the objective cure rates are lower than those for surgery (7). Various urethral bulking agents have been used (Table 2).

Many of these agents have similar efficacy rates; however, dextranomer–hyaluronic acid compounds have been found to be associated with a significantly higher risk of injection site complications and have subsequently been withdrawn from the market (7,32). Additional retired agents include (a) autologous fat, which was retired because of rapid digestion and migration of the injected material (7), as well as the lack of efficacy data compared with placebo and reports of pulmonary embolism (33,34); (b) polytetrafluoroethylene (Polytef), which was retired because of evidence of particle migration (7); and (c) ethylene vinyl alcohol (Uryx or Tegress), which was retired because of high rates of urethral erosion (7,35). Although collagen has historically been the most commonly used urethral bulking agent (36), injectable collagen formulation is also no longer available in the United States, because the manufacturer ceased production in 2008 (37). Compared with collagen, silicone particles may have a slight advantage in terms of the cure rate (7,38). Collagen is biodegradable and may get resorbed with time, resulting in a recurrence of symptoms, although in the findings from some studies, investigators have shown a relative preservation of volume with time (39).

### Imaging of Urethral Bulking Agents

The varied biochemical properties of these urethral bulking agents lead to unique imaging characteristics. Because of its soft-tissue attenuation, collagen cannot be delineated from the surrounding soft tissue on nonenhanced CT images; however, collagen becomes more discernible because of its lack of enhancement relative to the surrounding soft tissue.

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<table>
<thead>
<tr>
<th>MR Pulse Sequence</th>
<th>Imaging Plane</th>
<th>Field of View (cm)</th>
<th>Section Thickness (mm)</th>
<th>TR (msec)</th>
<th>TE (msec)</th>
<th>Flip Angle (°)</th>
<th>Matrix</th>
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<tbody>
<tr>
<td>2DT2-weighted fast SE</td>
<td>Sagittal</td>
<td>25</td>
<td>4</td>
<td>4575</td>
<td>130</td>
<td>90</td>
<td>356 × 356</td>
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<tr>
<td>2DT2-weighted fat-suppressed fast SE</td>
<td>Sagittal</td>
<td>25</td>
<td>4</td>
<td>4696</td>
<td>130</td>
<td>90</td>
<td>356 × 356</td>
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<tr>
<td>2DT2-weighted fast SE</td>
<td>Axial</td>
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<td>4</td>
<td>7677</td>
<td>130</td>
<td>90</td>
<td>340 × 308</td>
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<tr>
<td>2DT2-weighted fast SE</td>
<td>Axial</td>
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<td>2</td>
<td>1311</td>
<td>200</td>
<td>90</td>
<td>200 × 184</td>
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<tr>
<td>3DT2-weighted fast SE</td>
<td>Axial</td>
<td>18</td>
<td>4</td>
<td>6483</td>
<td>130</td>
<td>90</td>
<td>340 × 308</td>
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<tr>
<td>2DT1-weighted gradient-echo OP/IP</td>
<td>Axial</td>
<td>30</td>
<td>5</td>
<td>149</td>
<td>1.15/2.3</td>
<td>55</td>
<td>256 × 256</td>
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<tr>
<td>3D nonenhanced T1-weighted fat-suppressed gradient-echo</td>
<td>Axial</td>
<td>24</td>
<td>3</td>
<td>5</td>
<td>1.28/2.3</td>
<td>10</td>
<td>200 × 160</td>
</tr>
<tr>
<td>3D gadolinium-enhanced T1-weighted fat-suppressed gradient-echo*</td>
<td>Axial</td>
<td>24</td>
<td>3</td>
<td>5</td>
<td>1.28/2.3</td>
<td>10</td>
<td>200 × 160</td>
</tr>
</tbody>
</table>

Note.—OP/IP = out of phase and in phase, SE = spin-echo, TE = echo time, TR = repetition time.
* Dynamic contrast-enhanced MR imaging was performed (late arterial phase and at 40, 90, and 120 seconds).
enhancing soft tissue on delayed contrast-enhanced images (40,41). Collagen has a variable appearance at MR imaging. In vitro imaging has shown that the signal intensity of collagen is slightly higher than that of saline on T1-weighted MR images and slightly lower than that of saline on T2-weighted MR images (41). In vivo, injected collagen generally appears as a well-circumscribed round or oval mass adjacent to or encircling the urethral lumen, with variable signal intensity depending on the amount of water content within the injectable solution as well as the degree of collagen degradation. Recently injected collagen will appear hyperintense on T2-weighted MR images and may mimic a urethral diverticulum or periurethral collection with a lack of central enhancement (Fig 2). There may be more mass effect on the urethral lumen by the bulking agent than is expected with urethral diverticula; however, knowledge of the prior intervention is important for differentiation. With time, injected collagen will become isointense to slightly hypointense on T1- and T2-weighted MR images because of resorption of the water content and may mimic a solid mass. Nonenhancement of the collagen allows differentiation from a solid mass in this setting (40). We have observed occasional susceptibility artifacts, as manifested by a loss of signal intensity on longer-echo time in-phase MR images in sites of prior collagen injection. Although the cause is unclear, this finding may be attributed to postprocedural changes, hemorrhage, or calcification with time (42). Collagen appears isoechoic to slightly hypoechoic relative to the surrounding tissues on US images (Fig 3). US can be used to help confirm the initial uniform circumferential injection of collagen within the urethral wall and to measure the persistent volume of injected collagen over time at multiple levels through the urethra on 3D volume acquisition images (Fig 3c).

Silicone particles (Macroplastique) appear slightly more hyperechoic than collagen on US images (Fig 4); however, differentiation of these two bulking agents from each other is difficult at imaging. A circumferential distribution and proximal location of the injected material have been shown to be associated with the best short-term outcomes (43). US is used to assess the distribution of the injected bulking agent and to determine the need and location for reinjection. Reformatted 3D images obtained from reconstruction of the volume acquisition may be especially helpful in this regard (Fig 4, Fig E1). At MR imaging, injected silicone particles (Macroplastique) appear hyperintense on T2-weighted images and cannot be readily differentiated from other bulking agents. This agent may also mimic a urethral diverticulum; however, diverticula usually do not cause mass effect on the urethral lumen (Fig 5). Although CT is not typically used for the evaluation of bulking agents, radiologists should be familiar with the expected appearance on CT images, which can range from isoattenuating to slightly hyperattenuating, depending on the particular agent used and the time interval since injection (Fig 6).

Certain formulations of injectable bulking agents have been reported to calcify with time (42,44), which results in better depiction at CT; and other agents, such as calcium hydroxyapatite (Coaptite), are naturally radiopaque and are depicted at CT and radiography immediately after injection (44). Carbon-coated beads (Durasphere) are also high in attenuation and appear radiopaque at CT, with attenuation similar to that of cortical bone, and thus may mimic calcium deposits, stones, or even metal. At MR imaging, these carbon-coated beads appear hypointense on T1- and T2-weighted MR images and, similar to other injectable material, do not enhance (40) (Fig 7a, Table 2: Urethral Bulking Agents

<table>
<thead>
<tr>
<th>Urethral Bulking Agent</th>
<th>Trade Name</th>
<th>Manufacturer or Distributor (Location)</th>
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<tbody>
<tr>
<td>Bovine collagen</td>
<td>Contigen</td>
<td>CR Bard (Covington, Ga)</td>
</tr>
<tr>
<td>Porcine dermal collagen</td>
<td>Permacol</td>
<td>Covidien (Minneapolis, Minn)</td>
</tr>
<tr>
<td>Silicone particles</td>
<td>Macroplastique</td>
<td>Cogentix Medical (Minnetonka, Minn)</td>
</tr>
<tr>
<td>Calcium hydroxyapatite</td>
<td>Coaptite</td>
<td>Boston Scientific (Marlborough, Mass)</td>
</tr>
<tr>
<td>Carbon-coated beads</td>
<td>Durasphere</td>
<td>Coloplast (Minneapolis, Minn)</td>
</tr>
<tr>
<td>Dextranomer–hyaluronic acid compound</td>
<td>Zuidex</td>
<td>Q-Med AB (Uppsala, Sweden)</td>
</tr>
<tr>
<td>Polytetrafluoroethylene</td>
<td>Polytetf</td>
<td>Ethicon (Somerville, NJ)</td>
</tr>
<tr>
<td>Ethylene vinyl alcohol</td>
<td>Uryx or Tegress</td>
<td>CR Bard</td>
</tr>
<tr>
<td>Autologous fat</td>
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</table>

Note.—This list of urethral bulking agents is not all inclusive. Furthermore, some of the listed products may not be currently available on the market.
7b). Although the older formulation of this bulking agent (Durasphere) with carbon-coated beads was opaque enough to be depicted on radiographs, the newer formulation with a graphite coating is less opaque. Although the newer formulation is not depicted on conventional radiographs, it is depicted on CT images, but with diminished beam-hardening and aliasing artifacts compared with those associated with the original carbon coating. The appearance of the newer formulation at MR imaging remains identical to that of the older formulation with the carbon-coated beads (40). At US, both formulations of this bulking agent appear hyperechoic, similar to the appearance of other bulking agents (Fig 7c).

Patients who have undergone injection of urethral bulking agents may present with recurrent incontinence caused by diminished urethral coaptation secondary to resorption of the agent with time or secondary to periurethral or intraluminal extrusion of the injected agent. Periurethral migration may also incite a granulomatous or inflammatory reaction, and patients may present with a pseudoabscess or a sterile abscess days to months or, rarely, years after injection. Symptoms may include pain, dyspareunia, irritative or obstructive urinary symptoms, urge symptoms, urinary tract infection, and a periurethral masslike sensation (34,45–47). True abscess formation has also been reported (48). Imaging with CT in the case of carbon-coated beads (Durasphere) and with MR imaging in the case of nonradiopaque injectable agents may assist in the diagnosis of and treatment planning for complications (45). Periurethral extrusion and intraluminal extrusion can be identified on US images (Fig 8, Fig E2). Because of the high viscosity and the degree of force needed to inject some agents, intravasation into pelvic vessels has also been reported and may be depicted at CT in the case of carbon-coated beads (Durasphere) (40). Additional complications of injectable material, such as urethral erosion, may be difficult to detect at imaging unless associated with extravasation. Late complications such as delayed skin reactions, arthralgia, pulmonary embolism, and osteitis pubis have also been reported (7) but are exceedingly rare.

**Midurethral Slings**

Placement of midurethral slings is the most common surgical intervention for patients with stress urinary incontinence, with cure rates ranging between 75% and 95% (49). The surgical procedure involves the placement of synthetic strips made of polypropylene material to support the midportion of the urethra, to replicate the function of the natural pubourethral ligaments (49). The increased urethral support manifests as decreased urethral mobility at dynamic MR imaging (Movie 1a, 1b). Midurethral slings differ from older bone anchor slings in that they are placed in a “tension-free”
Figure 3. Urethral collagen in a 61-year-old woman with a history of mixed incontinence. (a) Axial reformatted US image from a 3D volume acquisition shows circumferential thickening (bracket) in the wall of the urethra that is due to collagen injection and appears isoechoic to slightly hypoechoic compared with the surrounding soft tissues. Note the anechoic urethral lumen (U) centrally. (b) Coronal 2D US image shows hypoechoic collagen (C) on either side of the urethral lumen (U), causing thickening of the urethral wall. The urinary bladder (UB) is depicted as an anechoic structure in the far field. (c) Coronal (top left), sagittal (top right), and axial (bottom left) US images obtained as part of a 3D volume acquisition through the urethra show the “stacked contour” technique used to measure bulking agent volume. The coronal reconstruction is used as a reference image, with calipers placed at the proximal and distal urethra (+ on top left image) to mark endpoints of area to be included in measurement. Horizontal lines show the location of each section of the “stack” traced in the axial view. The solid white line indicates a section that has been traced and recorded; the orange line indicates the active section being traced; the white dashed lines show remaining sections to be traced. Measurement in green (bottom left image) reflects the distance (Dist) of the urethra that is included within the volume calculation (ie, the distance between the calipers on top left image) on either end of the urethra on the coronal reconstruction.

Figure 4. Injection of silicone particles (Macroplastique) as a urethral bulking agent in a 57-year-old woman with a history of incontinence. Axial reformatted US image from a 3D volume acquisition shows circumferential urethral bulking agent (M) in the wall of the urethra; the agent appears isoechoic to slightly hyperechoic to the surrounding tissue, although differentiation of the various types of bulking agents may be difficult at US. Note the relatively thin area of this agent (+), which yields the nonuniform appearance at approximately the 8–9-o’clock position.
manner; the arms are not anchored into bone but are fixated into soft tissue or adipose tissue with time as a result of scarring. Various proprietary midurethral sling kits exist and can be categorized as retropubic slings, transobturator slings, or single-incision slings. A less-common prepubic approach has also been used.

Retropubic Slings

Retropubic slings are placed around the urethra in a U shape, with the arms extending anteriorly and superiorly into the retropubic space between the pubic bone and bladder (Fig 9, Movie 2). More cranially, the arms traverse the rectus sheath in the suprapubic location. These slings can be placed most commonly with a transvaginal approach or, alternatively, with a suprapubic approach. Transvaginal slings such as tension-free vaginal tape (Gynecare TVT; Ethicon) are placed by way of small midline vaginal incisions. The trocars are introduced through the vaginal incision and then passed into the retropubic space and toward the ventral abdominal wall (“bottom-up” placement) (49,50). After coursing between the bladder and pubic bone, the arms traverse the suprapubic rectus fascia, about 2.5 cm lateral to the pubic symphysis on either side of the midline. In comparison, suprapubic slings such as the SPARC Sling System (American Medical Systems, Minnetonka, Minn) are placed “top-down” by way of suprapubic advancement of trocars into the retropubic space (49,50). The arms of the sling are typically located approximately 1 cm lateral to the pubic symphysis on either side of the midline, which results in a narrower U shape. Comparisons between bottom-to-top approach (eg, Gynecare TVT) and top-to-bottom approach (SPARC) retropubic slings have shown higher objective and subjective cure rates and fewer adverse effects with the bottom-to-top approach (51).

Transobturator Slings

Transobturator slings or transobturator tapes assume a wider hammock-like shape (Fig 10, Movie 3) and are placed by using transmuscular insertion by way of the obturator and puborectals muscles, without violation of the retropubic space. This technique results in a decreased risk for bladder and vascular injury (52). The wide configuration of the transobturator sling is also associated with a lower incidence of postoperative voiding dysfunction; however, the likelihood of

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**Figure 5.** Injection of silicone particles (Macroplastique) as a urethral bulking agent in a 59-year-old woman. (a) Axial T2-weighted fast SE MR image shows hyperintense material (arrows) encircling the urethra. This material cannot be readily differentiated from other bulking agents, such as collagen, at MR imaging. A urethral diverticulum can also have a similar appearance; however, it would not be expected to have mass effect on the urethral lumen (arrowhead), as depicted in this case. (b) Coronal 3D contrast-enhanced T1-weighted fat-suppressed gradient-echo MR image shows the absence of central enhancement of the urethral bulking agent (arrows). A urethral diverticulum can also have a similar appearance; knowledge of prior bulking agent injection is imperative to make the correct diagnosis.

**Figure 6.** Injection of silicone particles (Macroplastique) as a urethral bulking agent in a 93-year-old woman with a history of lymphoma and urinary incontinence. Coronal nonenhanced reformatted CT image obtained for follow-up of lymphoma incidentally shows hyperattenuating material (arrows) in the expected location of the known urethral bulking agent injection. Although some injectable agents may calcify with time, others (Coaptite and Durasphere) demonstrate inherently high attenuation at CT.
groin pain is higher (52). The original transobturator tape technique (53) called for an “outside-in” placement, with percutaneous passage of the tape by using trocars into the obturator foramen and then through a midline vaginal incision (50). Examples of transobturator tapes placed in this manner are reported in Table 3 (49). Multiple authors have reported high rates of vaginal extrusion with one transobturator sling (ObTape); as a result, its use has been discontinued (49,50,54). A modified “inside-out” transobturator technique calls for passage of the trocars initially through a midline vaginal incision and then by way of the obturator foramen to the skin (55). The Gynecare TVT Obturator System is one such sling that is placed by using the inside-out technique. Comparisons of the two transobturator techniques have shown no significant differences in cure rates; however, investigators have reported a significantly lower rate of vaginal perforation with the inside-out technique, albeit without a substantial difference in rates of tape extrusion (52).

In comparisons between retropubic slings and transobturator slings, investigators have shown slightly higher objective and subjective cure rates for retropubic slings but without achieving statistical significance (52,56). Retropubic slings are associated with lower rates of sling erosion, less need to return to the operating room for treatment of sling erosion, lower rates of vaginal perforation, and lower rates of groin or leg pain, when compared with transobturator slings. In comparison, transobturator slings are associated with shorter surgical time, less blood loss, a shorter hospital
stay, fewer bladder or urethral perforations, less perioperative pain, fewer urinary tract infections, fewer overactive bladder symptoms, a lower likelihood of major vascular injury, and fewer voiding dysfunction symptoms than retropubic slings (51,52,56). Transobturator sling placement is also less likely to cause bowel injury, compared with the retropubic technique (49).

**Single-Incision Slings (Mini-slings)**

Single-incision slings are shorter slings that can be placed in either a U shape or hammock shape through a single midline vaginal incision, with the arms directed toward the obturator internus muscle or pubic bone on either side, but not extending into the obturator foramen or retropubic space. There are no skin entry or exit sites, and no trocars are used. In theory, this technique decreases the risk for complications related to the passage of trocars into the obturator or retropubic spaces, complications such as organ, muscle, or nerve injury (49). Although surgical times for placement of single-incision slings are shorter compared with those for retropubic sling placement, single-incision slings are associated with a higher risk of de novo urgency and higher rates of persistent incontinence compared with both retropubic and transobturator slings. Single-incision slings are also associated with higher rates of vaginal mesh exposure, bladder or urethral erosion, and surgical blood loss compared with transobturator slings. Postoperative and long-term pain is less common with single-incision slings (57). Most comparisons between single-incision slings and retropubic or transobturator slings have involved one particular type of single-incision sling (Gynecare TVT-Secur), which has been shown to be considerably inferior in terms of outcomes and adverse complication rates and has been withdrawn from the market (57). In a recent meta-analysis, investigators found that after excluding this type of sling (Gynecare TVT-Secur), no significant difference was demonstrated between single-incision slings and retropubic or transobturator slings in terms of patient-reported or objective cure rates, but single-incision slings did have more favorable recovery times (58).

Some other single-incision sling systems are listed in Table 3 and can be categorized as ones that include a fixation system or hook (MiniArc, Ajust, Needleless, and Solyx) or ones that do not include a fixation system (Gynecare TVT-Secur and Ophira) (57).

**Prepubic Slings**

Another type of sling that uses a prepubic approach (Prefyx PPS system) is placed with trocar passage from a vaginal incision to an exit site anterior to the pubic bone, thus avoiding vascular structures as well as the bladder. The arms of this type of sling may be seen inferior to the pubic bone, extending anteriorly from the urethra. This approach may increase the risk of injury to the neurovascular supply of the clitoris (49). This product is not currently listed on the manufacturer’s Web site and may not be commercially available at this time (59).

**Imaging of Midurethral Slings**

As alluded to earlier in this review, midurethral slings can be imaged with US or MR imaging. US is generally more revealing than MR imaging when assessing slings in the suburethral space; however, US is limited for imaging of the retropubic space, which is depicted well at MR imaging (19). Midurethral slings appear hyperechoic on US images (19) and demonstrate posterior acoustic shadowing (Fig 11). A crosshatch or dot-dash ribbonlike appearance (Fig 11) may help distinguish slings from scarring; however, systematic studies are needed to establish the utility of this finding.
We find the acquisition of cine US images to be particularly helpful to identify and delineate slings from surrounding tissue (Movies 4, 5). US may be able to help differentiate retropubic slings from transobturator or single-incision slings by identifying a more anterior and superior course of the arms of retropubic slings toward the pubic symphysis (more U shaped) (Fig 11) and a wider lateral extension of the arms of transobturator slings (hammock or dovelike shape) (21) (Fig 12, Movie 6). The morphologic structure and position of implanted slings relative to the urethral cross section and urethral length, as well as the bladder neck, can be determined with US (19,21). Ideally, the slings should be located at the level of the mid urethra.

US can be used to assess for anatomic changes in implanted slings and mesh, such as contraction, folding (Fig 12), or disruption with time, findings which may not be evident clinically (12,20,21,60,61). US may help detect malpositioning, erosion, or extrusion of implanted material into the urethral or vaginal walls or into the urinary bladder (17,62,63) (Fig 13) and can provide important information for assessment of the risk of urethral injury during removal, such as the depth of erosion into the urethral wall or the proximity to the urethral lumen. Staack et al (21) showed improved detection of urethral or periurethral erosion with US but no improved detection of vaginal extrusion, when compared with the findings at physical examination. An important caveat is that scar tissue can sometimes mimic true slings. The absence of color or Doppler flow within the sling may help delineate it from surrounding native soft tissue (Fig 14); however,
whether this finding would allow differentiation from fibrotic tissue is unknown. Although 2D US provides excellent evaluation of slings, 3D reconstruction performed from the volume data can help add confidence to the image interpretation and allow the surgeon to visualize the entire sling on a single image and realize its relationship to the native anatomic structures.

Although US more optimally demonstrates slings in the periurethral space, MR imaging is excellent for demonstration of slings in the retropubic space (19). Complications such as hematoma or infection in the retropubic space or suprapubic space cannot be seen with US but may be readily depicted at MR imaging. Synthetic polypropylene appears hypointense on T2-weighted MR images when imaged in phantoms (19). In vivo, normal retropubic sling arms appear as narrow linear hypointense structures coursing between the bladder and pubic bone and then traversing the rectus fascia in the suprapubic space. Axial T2-weighted MR images may depict the periurethral and suprapubic extent of slings and, to some degree, may also allow depiction of the retropubic components of the arms (Fig 15). Sagittal and coronal MR images may better depict slings in the retropubic space and suprapubic region as they traverse the rectus
Figure 13. Midurethral sling erosion in a 46-year-old woman with dyspareunia and pelvic pain after sling placement for incontinence. (a) Sagittal 2D US image shows the hyperechoic sling material (arrow) embedded in the posterior urethral wall (U). UB = urinary bladder. (b) Axial reformatted US image from a 3D volume acquisition shows asymmetric sling material (arrow) embedded in the left side wall of the urethra, protruding into the urethral lumen (U). PS = pubic symphysis.
Figure 15. Anterior and posterior vaginal mesh and retropubic sling in a 47-year-old woman with pain, dyspareunia, and urinary retention. (a–c) Axial T2-weighted fast SE MR images (b is the most caudal; a is more cranial than b; c is the most cranial) show a hypointense band (arrows on a, b) encircling the urethra and extending into the retropubic space. The sling can be seen extending through the rectus muscle fascia more superiorly on the left (arrows on c). The posterior vaginal mesh (arrowheads on a, b) is depicted as a uniform band of hypointense signal intensity along the anterior portion of the rectum, with the arms traversing the levator muscles and ischiorectal fossae. Note the proximity of the posterior vaginal mesh to the anterior rectal wall, a finding that should be reported to minimize the risk of rectal injury during mesh removal. (d) Sagittal T2-weighted fast SE MR image shows subtle buckling along the posterior wall of the midportion of the urethra (arrow) secondary to the midurethral sling, as well subtle dark bands (arrowheads) along the anterior and posterior vaginal wall that are related to the vaginal mesh, although this finding is difficult to differentiate from scar tissue. (e) Right parasagittal T2-weighted fast SE MR image shows the anterior and posterior arms (arrowheads) of the vaginal mesh traversing the levator muscles and extending into the ischiorectal fossa.

Figure 14. Midurethral sling in a 50-year-old woman with a history of prolapse and incontinence. Coronal 2D US image obtained posterior to the urethra shows an absence of power Doppler flow in the hyperechoic synthetic sling material (arrows). Note the diffuse color flow signal intensity secondary to motion artifact depicted in the surrounding native soft tissues (orange) because of high gain settings.

sheath above the level of the pubic symphysis (Fig 16). Sagittal midline MR images may depict the sling as a short hypointense structure parallel to the posterior wall of the midportion of the urethra; at other times, sagittal MR imaging may detect indentation or buckling along the posterior wall of the midportion of the urethra caused by the sling (Fig 15). Scar tissue can also mimic
slings at MR imaging because both structures appear hypointense and linear (Fig 17). The course of the retropubic arms in relation to the bladder should be closely examined because indentation or retraction of the bladder wall may be a sign of erosion (Fig 18a, Fig E3). Occasionally, extruded sling material may be depicted embedded in the bladder wall or within the lumen (Fig 18b). Depending on the site of the erosion, this finding may be better depicted with MR imaging than with US. 3D MR images may be particularly helpful for following the arms of the sling and examining their relationship to surrounding structures in the retropubic space (Fig E3).

Transobturator slings are more difficult to identify at MR imaging; however, when depicted, transobturator slings appear hypointense on T2-weighted MR images and course laterally from the periurethral space into the obturator foramen. They may be seen traveling caudally between the obturator muscles. Depiction of the lateral aspect of the transobturator tape arms at MR imaging is challenging, even when using 3D MR imaging with thin sections (Fig 19a, 19b). On sagittal T2-weighted MR images, transobturator slings may be seen as a short hypointense band of tissue.

Figure 16. Anterior and posterior vaginal mesh and retropubic sling in a 49-year-old woman. (a, b) Sagittal (a) and coronal (b) T2-weighted fast SE MR images show the typical linear hypointense appearance of the sling arms (arrows on a, b) in the retropubic space between the bladder and the pubic bone without evidence for bladder wall erosion. Thick linear hypointense bands (arrowheads on a) seen along the anterior and posterior vaginal walls represent vaginal mesh, although scar tissue can also have this appearance. (c) Axial T2-weighted fast SE MR image also depicts the sling arms (arrows) just deep to the rectus sheath. Anterior and posterior vaginal mesh (arrowheads) is also well depicted.

Figure 17. Persistent severe groin pain in a 41-year-old woman since placement of suburethral tape 3 years previously, with unclear history of partial tape removal since then. Axial T2-weighted fast SE MR image shows a thicker linear hypointense band (arrow) in the periurethral space on the left. US evaluation and surgical exploration failed to demonstrate synthetic material. Moderate scar tissue was found.
Figure 18. Bladder erosion in a 63-year-old woman with a remote history of retropubic sling placement who presented with recurrent urinary tract infections. (a) Axial T2-weighted fast SE MR image shows the sling to be within the wall of the bladder, with retraction along the anterior and posterior bladder base (white arrows). A subtle crosshatch pattern of the sling material (black arrow) can actually be seen coursing through the bladder lumen. Note the more distal arms (arrowheads) of the sling in the suprapubic space anteriorly. (b) Coronal 3D T2-weighted fast SE MR image shows that the sling (arrow) is embedded within the bladder lumen overlying the mucosa on the left, a finding consistent with extrusion, which was confirmed at surgery.

Figure 19. Transobturator sling in a 64-year-old woman. (a) Axial 3D T2-weighted fast SE MR image shows a bandlike hypointense structure (arrows) in the left periurethral space, extending laterally through the puborectalis muscle into the obturator foramen. (b) Axial 3D T2-weighted fast SE MR image shows a similar bandlike hypointense structure (arrows) traversing the right obturator foramen. The arms (arrowheads) of the mesh can also be seen directed caudally between the obturator muscles after extending through the obturator foramina. (c) Axial 3D contrast-enhanced T1-weighted fat-suppressed gradient-echo MR image shows low-grade enhancement along the course of the right arm (arrows) of the transobturator sling.

along the posterior vaginal wall similar to tension-free vaginal tape in the midline; however, on parasagittal MR images, the arms may appear as small comma-shaped structures on either side of the urethra, coursing into the obturator foramen (Fig 20a, 20b). Low-grade enhancement can be depicted along the course of the arms of mid-urethral slings and may be related to associated fibrosis (Fig 19c). Infection or inflammation may be considered in the case of avid or early enhancement; however, the sensitivity and specificity of this finding remain undetermined.

Voiding cystourethrography can be used for patients with prior sling placement who present...
Vaginal Mesh Kits

Various proprietary synthetic polypropylene vaginal mesh kits exist; and depending on the specific kit, mesh may be placed along either the anterior or posterior vaginal wall, or both. The arms of the mesh may be anchored into different portions of the native anatomic structures, such as the arcus tendineus, the coccygeus muscle–sacrospinous ligament complex, the obturator membrane, or the levator or inner thigh muscles, or may extend with recurrent or progressive symptoms or new voiding dysfunction. Sling material is not radiopaque and thus is not depicted at voiding cystourethrography, but malpositioned or overtight slings or slings with excessive scarring may distort the midportion of the urethra and, in extreme cases, can result in luminal obstruction. Voiding images may demonstrate an angulated or kinked urethra with dilatation upstream to the distorted segment (Fig 21). CT generally does not play an important role in the evaluation of urethral slings.

Prolapse Repair Mesh

Repair of pelvic organ prolapse can be achieved surgically with primary repair of the native tissues. For example, vaginal colporrhaphy may be performed for either anterior or posterior vaginal prolapse; sacrospinous ligament fixation or uterosacral ligament fixation can be performed for apical prolapse. In certain cases, surgical repair with biologic or absorbable graft material may be indicated and may accompany native tissue repair. When neither native tissue repair nor use of biologic graft material is feasible or preferred, repair with synthetic material such as vaginal mesh kits or sacrocolpopexy may be performed.
into the ischiorectal fossae (64). A diagram of a combined anterior and posterior vaginal mesh kit is shown in Figure 22 (Movie 7). The varied shapes and appearances of these kits are often a source of confusion among patients and physi-

cians. Awareness of the various types can be helpful in localizing these at imaging. For example, two of the vaginal mesh kits (Apogee and Perigee; American Medical Systems) are placed along the posterior and anterior vaginal walls, respectively. Additional examples of vaginal mesh kits are presented in Table 4. Some of the mesh kits (eg, Gynecare Prolift and Avaulta) have been withdrawn from the market (65), while others (Apogee and Perigee kits and Pinnacle and Uphold systems) are not listed as available products on the manufacturers’ Web sites (66,67).

Although use of vaginal mesh kits has been associated with a decreased incidence of recurrent anterior prolapse relative to primary repair, mesh extrusion rates can be high, ranging from 5% to 20%, and result in a high reoperation rate compared with native tissue repair (65,68). Other potential long-term complications include mesh contraction, vaginal scarring, dyspareunia, infection, pain, and urinary symptoms. Perioperative risks include organ perforation and bleeding (68). Certain anterior prolapse repair mesh kits have also been associated with higher blood loss, longer surgical times, a higher incidence of de novo stress urinary incontinence, and a higher likelihood of recurrence in apical or posterior compartments relative to native tissue repair (65,69). The U.S. Food and Drug Administration has issued updates and safety communications with regard to the potential serious complications related to placement of synthetic vaginal mesh kits (70).

Imaging of Vaginal Mesh Kits
Vaginal mesh may be depicted at US (Fig 12b) (17,18,20,21); however, we have generally found that primary evaluation with US is inadequate because of nondepiction of the distant extent of the arms of the mesh. There is a paucity of radiology literature describing MR imaging of vaginal mesh; and in most prior MR imaging–based studies, investigators have focused on the evaluation of dynamic end points to document improvement in prolapse, rather than actual depiction of the mesh (8,10,13,27,28). We believe that MR imaging has more potential in this regard, with use of high-resolution MR images with a small field of view, as detailed earlier. Similar to urethral slings, vaginal mesh components appear hypointense on T2-weighted MR images, although the signal intensity may in part be related to surrounding scar tissue. The arms of the mesh may be easiest to identify in the ischiorectal fossae (ischioanal fossae) on axial MR images; on these images, the arms are depicted as cordlike structures on end, surrounded by the high signal intensity of fat (Fig 15b). Sagittal and coronal MR images depict the arms as linear structures
as they traverse the levator muscles or sacrospinous ligaments (Fig 15e). Vessels in the ischiorectal fossae can mimic the mesh arms and should be differentiated by identification of proximal branching from or confluence into larger vessels. In addition, the mesh arms generally end abruptly, in contrast to vessels, which taper distally. The arms can also be tracked superiorly and centrally on axial MR images as they traverse the levator muscles or sacrospinous ligaments (Figs 15a, 20c, 20d, Fig E4). The intrapelvic course of the arms can then be followed from the levator muscles or sacrospinous ligaments back toward the vagina to identify the body of the mesh. On axial and sagittal T2-weighted MR images, the body of the mesh may be depicted as a slightly thicker condensation of linear hypointense signal intensity along the anterior or posterior vaginal walls (Figs 15a, 15d, 16a, 16c). Focal or excesive thickening along the arms or body of the vaginal mesh should be reported. Although this finding may be related to exuberant granulation tissue, it may indicate inflammation or extrusion (Fig 20c–20e). In general, we have not found MR imaging to be sensitive or specific for detection of extrusion; however, areas of focal thickening that may direct the surgeons to potential areas of abnormality should be reported.

The radiologist plays an important role in the care of patients after pelvic floor repair by helping in the detection of potential normal or abnormal mesh material and by offering a road map for surgical exploration when indicated on the basis of the clinical data. Adequate description should include the location and extent of the suspected mesh body and arms and their relationship to native anatomic structures, because these details may provide important preoperative planning information. For example, anterior vaginal mesh arms seen coursing close to the ureter (Fig E4) may require counseling the patient about potential need for ureteral repair or reimplantation or may require placement of ureteral stents before mesh removal. Anterior vaginal mesh can also scar to the posterior bladder wall and may cause a focal retraction deformity of the bladder, and posterior vaginal mesh arms may be adjacent or adherent to the rectal wall (Fig 15a). The surgeon should be alerted to these findings to avoid bladder or rectal injury during mesh removal.

As in the case of urethral slings, vaginal mesh cannot always be readily differentiated from scar tissue at imaging, and this caveat is particularly important when patients have had multiple prior attempts at placement and removal of synthetic material.

Although fat-suppressed MR images may be particularly unsuitable for identifying normal mesh components because of the lack of tissue contrast against the hypointense signal intensity of suppressed fat, such images may highlight areas of potential inflammation or fluid collections. Artifactual loss of fat suppression (ie, frequently selective fat suppression) may occur along certain mesh components and suture material because of the susceptibility effect and must be differentiated from true inflammation. Optimized fat saturation strategies such as use of Dixon-based methods and inversion-recovery sequences may be beneficial in these instances.

### Sacrocolpopexy Mesh

Sacrocolpopexy mesh placement is considered the reference standard surgical option for correction of vaginal apex or uterine prolapse. The procedure involves suspension of the vaginal apex onto the sacral promontory by using permanent mesh material and is associated with higher success rates and lower reoperation rates as compared to repair with a vaginal approach or mesh (65). The mesh typically has an upside-down Y configuration. Its proximal fixation may be just anterior to the L5-S1 intervertebral disk or, preferably, at the sacral promontory. The mesh remains extraperitoneal, just anterolateral to the mesorectal fascia, as it courses inferiorly with a rightward curve along the right pelvic side wall, attaching on the vaginal apex (Fig 23, Movie 8). Mesh components are splayed distally, extending along the anterior and posterior vaginal wall for variable distances.

Lower rates of recurrent vaginal vault prolapse and dyspareunia have been reported with abdominal sacrocolpopexy than with vaginal apex sacrospinous colpopexy, albeit with longer surgical times, longer recovery times, and higher cost (6,65). Long-term success rates for abdominal sacrocolpopexy range from 78% to 100%, with
a 3%-4% incidence of mesh erosion (71). This lower rate of mesh erosion, compared with vaginal mesh kits, has further broadened use of sacrocolpopexy for repair of prolapse of the vaginal apex (apical prolapse). Total abdominal hysterectomy may increase the risk for postoperative mesh erosion into the vagina when performed concomitantly at the time of sacrocolpopexy, particularly in patients who are receiving estrogen therapy (72,73). In certain patients, the uterus or cervix may be left in place to decrease the risk of erosion, and an abdominal sacrohysteropexy may be performed with mesh suspending the cervix or uterus from the sacrum. Other factors that increase the risk of mesh erosion include use of a combined abdominal-vaginal approach and accidental opening of the vagina during an abdominal approach (68). Sacrocolpopexy can be performed with open, laparoscopic, or, more recently, robotic techniques that have been shown to be equally effective (74,75), with the laparoscopic technique having a slightly longer surgical time, but with lower blood loss and a shorter hospital stay (65,76). Other less-common complications of abdominal sacrocolpopexy include bowel injury or obstruction, sacral osteomyelitis, and severe bleeding (68,71). Extraperitoneal placement of the mesh with closure of the peritoneum over the mesh may diminish the risk for bowel obstruction (26,71).

**Imaging of Sacrocolpopexy Mesh**

Common indications for postoperative imaging include the evaluation of chronic pain or dyspareunia, dynamic pelvic floor imaging to evaluate suspected recurrence of prolapse, evaluation of mesh integrity or attachment sites in the setting of known recurrent prolapse, evaluation for mesh infection in the setting of vaginal discharge or back pain, or evaluation of less-common complications such as bleeding or a bowel obstruction. US is unable to adequately depict the superior extent of the sacrocolpopexy mesh as it traverses the pelvis to the sacral promontory, and the larger field of view offered with MR imaging makes it an ideal modality for this indication.

Normal sacrocolpopexy mesh most often demonstrates a thin ribbonlike or cordlike appearance of hypointense signal intensity on T2-weighted MR images (Fig 24), extending from either the vaginal apex or cervix (in the case of supracervical hysterectomy) or the posterior surface of the uterus (in the case of uterus preservation and sacrohysteropexy) to the sacrum. Other configurations of normal mesh can be seen on occasion, such as a flat or “seagull” shape because of curling of the edges on axial MR images (26). Foci of susceptibility artifact or signal void may be seen along the course of the mesh and have been postulated to be related to hemosiderin deposition (26) or suture material.

The sacrocolpopexy mesh may be depicted centrally within the pelvis because of placement under tension (26); however, in our experience, the mesh is often depicted with a slight rightward curvature along the pelvic side wall, a finding that is best demonstrated on the coronal T2-weighted MR images (Fig 24a). Others have postulated that this more-curved route seen at supine MR imaging may translate into inadequate support of the vaginal apex in the upright position (26). In our experience, this slight rightward curvature of the sacrocolpopexy mesh may be an expected finding, depending on the surgical technique used. Not infrequently, the sacrocolpopexy mesh passes close to the pelvic bowel loops. When encountered, this observation should be described in the radiology report, to allow adequate presurgical planning if removal of the mesh is being considered.

Although apical exposure of the mesh as a cause of pain or dyspareunia is difficult to depict at imaging, mesh infection should be considered when the mesh appears thickened with areas of high signal intensity on T2-weighted MR images (Fig 25). Associated fluid collections may be present with the sacrocolpopexy mesh and would be readily depicted at MR imaging. Using a T2-weighted fat-suppressed MR pulse sequence in the sagittal plane allows us to not only evaluate for inflammation in the pelvis, but also assess for bone edema in the sacrum to rule out discitis or osteomyelitis, complications that are unique to sacrocolpopexy mesh because of its attachment site at either the sacral promontory or at the level of the L5-S1 disk. In cases of recurrent prolapse after sacrocolpopexy mesh placement, MR imaging can be used to detect detachment...
or tearing of the mesh. Extrusion or erosion of the sacrocolpopexy mesh components along the anterior and posterior vaginal wall can also occur. Other complications that may be apparent at MR imaging include pelvic hematoma or recurrent apical enterocoeles or rectoceles. In rare cases in which a patient is suspected of having a bowel obstruction, CT may be more beneficial because it allows adequate evaluation of the bowel.

**Conclusion**

Numerous surgical and nonsurgical options exist for treatment of urinary incontinence and pelvic organ prolapse. Synthetic products such as slings and mesh play a key role in this setting; however, patients may present with complications after intervention. Knowledge of the specific synthetic materials or interventions used, as well as the patient’s presenting complaints, is imperative not only to facilitate image interpretation, but also to decide which modality to use in the postoperative period. US and MR imaging can both be used for evaluation of injected urethral bulking agents and midurethral slings, depending on the location of the suspected complication. US is ideal for depicting slings in the periurethral or suburethral space, and MR imaging has the advantage of improved depiction in the retropubic space. Vaginal
mesh kits and sacrocolpopexy mesh may be better depicted at MR imaging because the large field of view allows detection of the distant extent of the mesh components. MR imaging may also be more useful for detection of intrapelvic complications such as infection or abscesses. Voiding cystourethrography may have a small role in the imaging of patients who present with urinary symptoms or recurrent cystoceles after sling placement. CT may be used when there is a concern for rare complications such as bowel obstruction after surgery. Given the complementary nature of these imaging examinations, the complexity of the surgical interventions, the frequency of vague or generalized symptoms (eg, pain), and the potential involvement of multiple pelvic compartments, many of these patients often require evaluation with more than one imaging modality.

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References


