MR Imaging and US of Female Urethral and Periurethral Disease

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The spectrum of female urethral and periurethral disorders includes both benign and malignant entities. Establishing an accurate clinical diagnosis may be challenging because symptoms and physical findings frequently overlap among the various entities. Recent technologic advances in magnetic resonance (MR) imaging and ultrasonography (US) allow more detailed evaluation of urethral and periurethral abnormalities. Advances in MR imaging hardware and pulse sequences allow high-resolution, high-contrast static and dynamic imaging of the female urethral and periurethral region in the context of the entire pelvic floor. Similarly, the introduction of high-resolution surface and intracavitary transducers in conjunction with three-dimensional acquisition have enhanced the role of US in this clinical setting. High-resolution MR imaging and real-time US have exciting potential as tools for more comprehensive analysis of the pathophysiologic features of the complex disorders that affect the female urethra and periurethral tissues.

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TEACHING POINTS
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Abbreviations: HMO = H line, M line, organ prolapse, PCL = pubococcygeal line, RARE = rapid acquisition with relaxation enhancement, SE = spin-echo

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Introduction

Imaging of the female urethra with magnetic resonance (MR) imaging has improved significantly with the capacity to provide high-resolution multiplanar images, allowing evaluation of various benign and malignant urethral and periurethral processes (1). The diagnosis of female disease in this anatomic region is challenging for clinicians because patients present with nonspecific signs and symptoms, including pelvic pain, dysuria, urinary frequency, urinary urgency, incontinence, urethral bleeding, and urinary tract infections (2). Furthermore, physical examination can be unreliable in distinguishing among the many types of urethral or vaginal wall masses. Although conventional imaging studies such as voiding cystourethrography and retrograde double-balloon positive-pressure urethrography are helpful, they are invasive and cannot help evaluate periurethral tissues. Misdiagnosis and delayed management often occurred before the advent of high-resolution MR imaging (3).

In this article, we describe MR imaging and ultrasonographic (US) techniques for imaging the female urethra, as well as the anatomy and imaging features of the normal female urethra. In addition, we discuss and illustrate benign urethral and periurethral disease (urethral diverticulum, caruncle, leiomyoma, and fistula), malignant disease (primary and secondary urethral carcinomas), and periurethral cystic lesions (Gartner duct cyst, Bartholin gland cyst, Skene duct cyst, müllerian cyst, epidermal inclusion cyst, endometrioma, and others). We also discuss the role of MR imaging and dynamic US in the diagnosis and classification of pelvic floor dysfunction and pelvic organ prolapse.

Techniques for Imaging the Female Urethra

MR Imaging Techniques

MR imaging may be performed on either a 1.5-T or a 3.0-T magnet with a pelvic phased-array coil and a relatively rapid protocol. If necessary for presurgical planning, endocavitary coils (endovaginal or endorectal coils) may be used; they provide the highest-resolution images of the female urethra and periurethral anatomy, since the receiving antenna is within a centimeter of the urethra (4). A study by Aronson et al (5) demonstrated that use of an endovaginal coil coupled with a pelvic phased-array coil allows greater soft-tissue differentiation of the periurethral region than does use of a body coil, a phased-array coil, an endorectal coil coupled with a pelvic phased-array coil, or an endocervical coil coupled with a pelvic phased-array coil. MR imaging has been consistently reported to have higher sensitivity and higher positive and negative predictive values than either voiding cystourethrography or retrograde double-balloon positive-pressure urethrography in the detection of female urethral and periurethral disorders (4,6–8). Because of its superb resolution, increased signal-to-noise ratio, and multiplanar capability, MR imaging has become the imaging modality of choice for diagnosis and preoperative planning in female patients with urethral and periurethral disease. Important additional advantages of MR imaging include its capacity to (a) help detect noncommunicating urethral diverticula and (b) demonstrate the radial and circumferential extent of periurethral disease without the need for catheterization or urethral contrast material injection. On the other hand, despite its excellent characterization of female urethral disease, MR imaging is limited in certain areas due to lack of accessibility, high cost, and the need for experienced radiologists to obtain and accurately interpret the images.

At our institution, the following MR imaging sequences are performed through the pelvis on a 1.5-T imager for evaluation of the female urethra: sagittal fast spin-echo (SE) T2-weighted sequences with and without fat saturation, axial fat-saturated fast SE T2-weighted sequences, axial gradient-echo T1-weighted sequences with and without fat saturation, axial single-shot fast SE half-Fourier rapid acquisition with relaxation enhancement (RARE) T2-weighted sequences, and axial in-phase and out-of-phase T1-weighted sequences. In addition, small-field-of-view images are obtained through the urethra with axial, sagittal, and coronal true FISP (fast imaging with steady-state precession) sequences (Table 1).

US Techniques

Transvaginal US, transperineal US, and transurethral US are emerging modalities that are being used to evaluate female urethral and periurethral disease in a more cost-effective manner. The development of small, high-frequency catheter-based endoluminal US transducers has allowed more comprehensive evaluation of the urethral and periurethral tissues. For transvaginal US, a 5–9-MHz curved-array transducer is inserted approximately 1–2 cm into the vagina. For transperineal US, a 5–10-MHz linear-array transducer is placed on the perineum between the labia.
For transurethral US, a 12.5-MHz endoluminal transducer is placed directly into the urethra. Sagittal and transverse images with and without color Doppler are obtained at transvaginal and transperineal US, whereas only transverse images are obtained at transurethral US (9). Patients are typically placed in a lithotomy position with the bladder partly full. The urethra is evaluated from the bladder neck to the distal urethral opening, with subsequent attention given to the periurethral area. In addition to lower costs, the advantages of US include absence of radiation exposure and the ability to perform real-time imaging during straining and imaging in different orientations, differentiation between solid and cystic lesions, and evaluation of periurethral processes (10). Disadvantages include operator dependence, difficulty in differentiating Gartner duct cysts from small urethral diverticula, and the possibility that the ostia of small diverticula may not be visualized (8). Furthermore, transurethral US currently has limited utilization and availability due to the high cost of dedicated equipment and a limited field of view (9).

### Table 1
Protocol for Abdominopelvic MR Imaging Assessment of Urethral Disease

<table>
<thead>
<tr>
<th>Sequence</th>
<th>TR/TE (msec)</th>
<th>Field of View (mm)</th>
<th>Matrix</th>
<th>Purpose</th>
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<td>Pelvis</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sagittal fast SE T2-weighted</td>
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<td>Evaluation of the pelvic and urethral anatomy and fluid collections</td>
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<td>Sagittal fat-saturated fast SE T2-weighted</td>
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<td>300</td>
<td>384 × 269</td>
<td>Evaluation of the pelvic and urethral anatomy</td>
</tr>
<tr>
<td>Axial fat-saturated fast SE T2-weighted</td>
<td>6340/110</td>
<td>300</td>
<td>384 × 269</td>
<td>Evaluation of the pelvic and urethral anatomy</td>
</tr>
<tr>
<td>Axial GRE T1-weighted</td>
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<td>256 × 256</td>
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</tr>
<tr>
<td>Axial fat-saturated GRE T1-weighted</td>
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<tr>
<td>Axial single-shot fast SE half-Fourier RARE T2-weighted</td>
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<tr>
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<td>256 × 128</td>
<td>Assessment of intracytoplasmic fat for incidental pelvic masses</td>
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<td>Urethra</td>
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<td></td>
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<td></td>
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<tr>
<td>Coronal true FISP*</td>
<td>493/1.4</td>
<td>250</td>
<td>256 × 230</td>
<td>Detailed depiction of urethral anatomy and disease</td>
</tr>
<tr>
<td>Axial true FISP*</td>
<td>384/1.4</td>
<td>250</td>
<td>256 × 230</td>
<td>Detailed depiction of urethral anatomy and disease</td>
</tr>
<tr>
<td>Sagittal true FISP*</td>
<td>384/1.4</td>
<td>250</td>
<td>256 × 230</td>
<td>Detailed depiction of urethral anatomy and disease</td>
</tr>
</tbody>
</table>

Note.—GRE = gradient-echo, TE = echo time, TR = repetition time.
*Fast imaging with steady-state precession with a small field of view.

### Anatomy and Imaging Features of the Normal Female Urethra

#### Anatomy
The normal female urethra is a tubular structure that measures approximately 3–4 cm in length. It extends from the internal urethral meatus at the bladder neck to the external urethral meatus at the vestibule, coursing in an oblique anteroinferior direction through the urogenital diaphragm. The zonal anatomy of the urethra consists of mucosal, submucosal, and muscular layers, which are distinguished at MR imaging, particularly on T2-weighted images. There are numerous small submucosal paraurethral and periurethral glands that secrete material into the lumen of the urethra. The paraurethral glands of Skene are a conglomeration of small glands that secrete mucous material into either side of the distal urethra at the external meatus. Transitional cell epithelium lines
the proximal third of the urethra, and stratified squamous epithelium lines the distal two-thirds. The urethropelvic and pubourethral ligaments are important structures in maintaining urinary continence and urethral stability (Fig 1) (11–13).

**Imaging Features**

**MR Imaging.**—The classic appearance of the normal female urethra on axial T2-weighted and gadolinium-enhanced T1-weighted MR images has been described as targetlike due to the alternating signal intensity characteristics of the different zones. The four concentric rings are as follows: an outermost layer of longitudinal smooth and circular striated muscle cells (hypointense), a middle submucosal layer of vascularized connective tissue and smooth muscle cells (hyperintense), an inner mucosal layer of epithelial cells (hypointense), and an innermost layer of hyperintense urine or secretions that may or may not be seen (Fig 2a) (13,14). Sagittal T2-weighted and gadolinium-enhanced T1-weighted MR images of the urethra demonstrate a similar zonal anatomy (Fig 2b).

**Ultrasonography.**—At US, the female urethra appears as a tubular structure extending from the bladder to the vestibule (Fig 3) inferior to the pubic symphysis and anterior to the vagina. Anechoic urine may be seen centrally in the urethra in patients with incontinence or pelvic organ prolapse.

The utility of computed tomography (CT) in the assessment of the female urethra is limited. Although urethral and periurethral processes may be detected at CT performed for other indications, detailed evaluation of these processes will usually be suboptimal compared with MR imaging evaluation. However, CT is useful in the detection of urethral calculi.

**Benign Urethral Disease**

**Urethral Diverticulum**

Urethral diverticula are protrusions of the urethra into the periurethral fascia. The epithelial lining of a diverticulum is identical to the urethral mucosa, and communication with the urethral lumen is maintained (2,15). Although studies indicate that approximately 0.6%–6% of women have urethral diverticula, the true prevalence of this disorder is likely underestimated secondary to misdiagnosis and lack of symptoms (15). Urethral diverticula have no racial predilection and can occur at any age, although they are most common in the 3rd to 5th decades. A pediatric urethral diverticulum is rare and is likely congenital. Proposed theories of congenital etiologies include an origin from cloacogenic rests, müllerian cell rests, Gartner duct remnants, or incor-
rect union of primordial urogenital sinus folds (15). The vast majority of urethral diverticula are from acquired causes, with the most widely accepted theory involving rupture of a chronically obstructed and infected periurethral gland into the urethral lumen. The outpouching epithelializes over time and becomes a true diverticulum lined with urothelium (1). *Escherichia coli* and, less often, gonococci and *Chlamydia* species are the most common infectious causes. Intraurethral wall diverticula, also known as noncommunicating urethral diverticula, are potentially symptomatic lesions that represent the initial stage of a true urethral diverticulum, during which the cystic cavity is localized to the wall of the urethra (16). Other acquired causes such as birth trauma and urethral instrumentation are less common.

The classic clinical manifestation of urethral diverticula has been described as the “triad of Ds”: dysuria, dyspareunia, and postvoid dribbling. However, most patients present with nonspecific signs and symptoms, including urinary frequency, urinary urgency, pelvic pain, urinary tract infections, incontinence, and urine retention. The differential diagnosis for this nonspecific clinical presentation is vast and includes cystitis, several types of periurethral cysts, periurethral fibrosis, urethrocele, and urethral carcinoma. Physical examination does not help narrow the diagnosis, since urethral diverticula may not be palpable or tender, may manifest as a discrete lesion or diffuse fullness along the length of the urethra, and may mimic vaginal wall lesions (15). Studies have demonstrated a delay of approximately 9.5 months from the time of presentation to the diagnosis of urethral diverticula as a result of the various challenges described earlier (3).
Figure 4. Variable anatomic appearances of urethral diverticula. Axial T2-weighted MR images demonstrate a simple diverticulum (a), a U-shaped anterior diverticulum (b), and a near-circumferential diverticulum (c).

Figure 5. Simple urethral diverticulum in a 50-year-old woman with a 6-month history of urinary urgency. Axial short inversion time inversion-recovery (a) and sagittal T2-weighted (b) MR images demonstrate a single unilocular T2-hyperintense lesion (arrowhead) surrounding the right aspect of the midurethra at the level of the pubic symphysis, a finding that is consistent with a simple urethral diverticulum. The lesion was hypointense at T1-weighted imaging. A large uterine leiomyoma (arrows) is incidentally noted.

The MR imaging appearance of urethral diverticula varies. Classically, urethral diverticula arise from the posterolateral wall of the midurethra at the level of the pubic symphysis. Urethral diverticula may (a) be single or multiple, unilocular or multiseptated; (b) have a narrow or wide neck; and (c) demonstrate various degrees of extension around the circumference of the urethra. A simple urethral diverticulum is round or oval and usually located lateral or posterior to the urethra, a U-shaped diverticulum extends partially around the urethra, and a circumferential diverticulum extends completely around the urethra, often having a “saddlebag” appearance (Fig 4) (7). Urethral diverticula are classically most conspicuous on T2-weighted images, since the fluid-containing cystic cavity is hyperintense relative to the surrounding soft tissues (Fig 5). However, diverticula with hemorrhagic or proteinaceous contents will appear hyperintense on T1-weighted images and hypointense on
T2-weighted images (Fig 6). Inflamed urethral diverticula may also demonstrate heterogeneous signal intensity on T1-weighted images and marked hyperintensity on T2-weighted images with a possible fluid-fluid level (13). For preoperative planning, it is vital to evaluate the diverticula in terms of location, size, number, configuration, possible sac contents, mass effect, and position of the neck, resection of which is critical in preventing recurrence (12). Radiologists may use a “clock face” template with axial MR images to more easily convey to the surgeon the exact location of the urethral diverticulum and neck, with the 12 o’clock position representing the anterior aspect of the urethra, the 3 o’clock position representing the left parasagittal aspect, the 6 o’clock position representing the posterior aspect, and the 9 o’clock position representing the right parasagittal aspect (Fig 7).
Complications of urethral diverticula include infection, calculus formation, and neoplasm development. An infected urethral diverticulum is suggested at MR imaging by the presence of (a) heterogeneous signal intensity on T1-weighted images, with the signal being hyperintense relative to that of urine; and (b) markedly increased signal intensity on T2-weighted images, with the signal being hyperintense relative to that of urine in the appropriate clinical setting (17). Calculus formation occurs in up to 10% of patients and is easily demonstrated at US as a focus of echogenic shadowing within the urethral diverticulum. At MR imaging, calculi appear as hypointense foci on both T1- and T2-weighted images. To date, there have been fewer than 100 cases of malignancy developing in a urethral diverticulum. Although squamous cell carcinoma is the most common malignancy of the female urethra, the majority (60%) of tumors arising from urethral diverticula are adenocarcinomas (Fig 8), followed by transitional cell carcinoma (30%) and then squamous cell carcinoma (10%) (12). An irregular enhancing heterogeneous solid mass in a urethral diverticulum with possible extension to the surrounding tissues is highly suspicious for a urethral diverticulum complicated by malignancy.

There are various treatment options for symptomatic urethral diverticula, including transvaginal and transurethral partial or complete diverticulectomies. According to a study by Porpiglia et al (18), a circumferential diverticulum, a size greater than 4 cm, and delayed diagnosis are the most significant risk factors for postoperative complications. Postsurgical recurrence is seen in 1%–29% of cases, stress incontinence in 1.7%–12.5%, and urethrovaginal fistula in 0.9%–5% (15).

**Urethral Caruncle**

Urethral caruncles are small benign lesions of the posterior margin of the external urethral meatus that are caused by distal urethral prolapse in hypoestrogenic postmenopausal women (1). Histologic examination of a caruncle reveals hyperplastic squamous epithelium with submucosal vascularity, fibrosis, and inflammation (19). Although most women are asymptomatic, pain and hematuria can result from urethral caruncles. At MR imaging, caruncles may manifest as T2-hyperintense tissue surrounding the external urethral meatus, a finding that correlates with the presence of a soft exophytic lesion at the meatus at physical examination (Fig 9) (19). Conservative treatment in symptomatic patients includes sitz baths and the application of topical estrogen.
Figure 9. Urethral caruncle in a 65-year-old woman with an external urethral meatus mass. Axial (a) and sagittal (b) T2-weighted MR images obtained with a pelvic coil demonstrate a high-signal-intensity cuff (arrows) surrounding the external urethral meatus. At pathologic analysis, the lesion proved to be a urethral caruncle. (Reprinted, with permission, from reference 1.)

Figure 10. Urethral leiomyoma in a 54-year-old woman with a suspected vaginal mass. Axial (a) and sagittal (b) fast SET2-weighted MR images obtained with an endorectal coil demonstrate a homogeneous low-signal-intensity mass (M) anterior to the vagina. The mass is located between the muscle bundles of the urethra (arrows in a), and the urethral lumen (*) is displaced to the left. Results of pathologic analysis confirmed a benign urethral leiomyoma. (Reprinted, with permission, from reference 1.)

vaginal creams. In cases that do not improve after 4–6 weeks, surgical excision is recommended to exclude neoplasm.

Urethral Leiomyoma
Urethral leiomyomas are extremely rare, benign smooth muscle tumors that may grow during pregnancy and result in dysuria. At MR imaging, a nondegenerating leiomyoma demonstrates intermediate signal intensity on T1-weighted images, low signal intensity on T2-weighted images, and contrast enhancement (Fig 10). Leiomyomas with degeneration have variable appearances (20,21). A well-defined homogeneous tumor with increased vascularity is the typical US manifestation (12).
Urethral Fistula

Urethral fistulas are divided into urethrovaginal, rectourethral, and urethroprierineal subtypes. The causes of urethrovaginal fistulas include Crohn disease, Behçet disease, and postsurgical complications of urethral diverticulectomy or vaginal surgery (22,23). Rectourethral fistulas are commonly congenital with associated complex anorectal developmental abnormalities (24). Urethroprierineal fistulas are acquired fistulas in patients with chronic decubitus ulcers or abscesses in the perineal region. At T2-weighted and gadolinium-enhanced T1-weighted MR imaging, urethral fistulas manifest as hyperintense tracts extending from the urethra to the vagina, rectum, or perineum (Fig 11).

Malignant Urethral Disease

Primary Urethral Carcinoma

Urethral carcinoma is a rare neoplasm that accounts for less than 0.02% of all malignancies in women. Postmenopausal Caucasian women are most commonly affected. Significant risk factors include chronic urinary tract infections and irritation, urethral diverticula, human papilloma virus infection, and proliferative lesions of the urethra such as caruncles, adenomas, polyps, and leukoplakia. Patients may present with urinary frequency, hematuria, urine retention, and a palpable urethral mass. Squamous cell carcinoma is the most common subtype (70% of cases) and classically involves the distal urethra and the external urethral meatus. Transitional cell carcinoma (20% of cases) and adenocarcinoma (10%) typically involve the proximal urethra (25). Urethral malignancies exclusively involving the distal third of the urethra are known as anterior urethral tumors, with the remainder of malignancies being referred to as entire urethral tumors. This distinction is important because anterior urethral tumors have a better prognosis, drain primarily to the superficial and deep inguinal lymph nodes, and are treated with local surgical excision. In contrast, entire urethral tumors drain primarily to the external iliac, hypogastric, obturator, and paraaortic lymph nodes and manifest as high-grade locally advanced tumors, often requiring a combination of surgery, radiation therapy, and chemotherapy (11).
The use of MR imaging has enabled radiologists to detect primary urethral carcinoma more frequently; however, distinguishing between subtypes remains a challenge. Urethral tumors classically manifest with low signal intensity on T1-weighted images and high signal intensity on T2-weighted images, with heterogeneous contrast enhancement (Fig 12) (11,12).

Secondary Urethral Carcinoma
Secondary urethral carcinomas are rare tumors that extend contiguous from the urinary bladder, cervix, vagina, uterus, and anus. Approximately 2%–13% of women with primary transitional cell carcinoma of the urinary bladder will have extension to the proximal urethra at diagnosis (1). In addition, seeding of the anterior urethra may occur during urethral instrumentation (11). Hematogenous tumor spread to the urethra is very rare, with melanoma being the most common metastatic lesion.

Gartner Duct Cyst
Gartner duct cysts are embryologic secretory retention cysts that arise from the residual wolffian (mesonephric) duct remnant and are lined by nonmucinous low columnar cells. The classic location of this vaginal cyst is along the anterolateral vagina above the level of the most inferior aspect of the pubic symphysis. The cyst is usually solitary and less than 2 cm, and may contain septa (26). Similar to urethral diverticula, Gartner duct cysts manifest as T2-hyperintense lesions at MR imaging if the contents are primarily simple fluid (Fig 13a, 13b), as T1-hyperintense and T2-hypointense lesions if the contents are hemorrhagic or proteinaceous, and can be mistaken for a urethral diverticulum if its relation to the vaginal wall is not appreciated. In addition, there is classically a lack of urethral displacement or deformity in the presence of a Gartner duct cyst. US demonstrates a cystic lesion in the anterolateral vaginal wall (Fig 13c). It has been
shown that these embryologic cysts are associated with other wolffian abnormalities, such as unilateral renal agenesis, renal hypoplasia, and ectopic ureteral insertion (12). Although these cysts are usually asymptomatic, cyst aspiration, tetracycline sclerotherapy, or surgical excision may be used to treat larger lesions.

**Bartholin Gland Cyst**

Bartholin glands are small glands located on either side of the posterolateral vagina that are derived from the urogenital sinus and are lined with transitional or columnar epithelium (27). Bartholin gland cyst formation is caused by chronic inflammation or infection of the underlying glands, resulting in ductal obstruction from purulent material or mucus. Bartholin gland cysts are located in the posterolateral inferior third of the vagina medial to the labia minora and at or below the level of the pubic symphysis. The cysts are usually unilocular, 1–4 cm in size, and hyperintense on T2-weighted images with variable appearances on T1-weighted images depending on their proteinaceous or mucinuous content (Fig 14) (1). Treatment options for symptomatic cysts include administration of silver nitrate, surgical excision, and marsupialization.

**Skene Duct Cyst**

Skene duct cysts are retention cysts lined with stratified squamous epithelium and caused by inflammatory obstruction of the paraurethral ducts. They are located lateral to the external urethral meatus and inferior to the pubic symphysis. At MR imaging, Skene duct cysts manifest as round or oval hyperintense lesions just lateral to the external urethral meatus on T2-weighted images (Fig 15) (28). It may be difficult to distinguish between Skene duct cysts and Bartholin gland cysts due to their similar location. Symptomatic cysts are treated with surgical excision or marsupialization.

**Müllerian Cyst**

Müllerian cysts are embryologic remnants of the müllerian (paramesonephric) duct that are lined with mucinous, pseudostratified columnar epithelium. They are located in the anterolateral vaginal wall (29). Symptomatic cysts may require surgical excision.

**Epidermal Inclusion Cyst**

Epidermal inclusion cysts, also known as vaginal inclusion cysts, are located at sites of prior trauma or surgery and are lined with stratified squamous epithelium (12). The posterior or lateral vaginal walls are common sites of cyst formation. Marsupialization is used to treat symptomatic cysts.

**Endometrioma**

Endometriosis is the presence of endometrial tissue in extrauterine sites, typically in the ovaries and peritoneal cavity. Implantation of endome-
trial tissue in the periurethral tissues may occur during surgical procedures (30). Lesions are treated with complete surgical resection or removal by laser surgery and electrocautery (29).

**Other Periurethral Lesions**

Periurethral collagen injections are used to treat stress incontinence in female patients. The collagen appears as hyperintense nodules in the wall of the urethra on T2-weighted images and may mimic periurethral cystic lesions or urethral diverticula (Fig 16) (31).

Additional periurethral lesions include neurofibromas (Fig 17), angiomas, and cysts of the canal of Nuck, which correspond to hydroceles in male patients (27).

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**Figure 15.** Skene duct cyst in a 32-year-old woman with urinary urgency. Axial (a) and sagittal (b) T2-weighted MR images demonstrate a cystic lesion (arrow) lateral to the expected location of the external urethral meatus inferior to the pubic symphysis. Results of pathologic analysis confirmed a Skene duct cyst.

**Figures 16, 17.** (16) Injected periurethral collagen in a 65-year-old woman with a history of stress incontinence. Axial fast SE T2-weighted MR image demonstrates a periurethral mass (arrow) at the right aspect of the bladder base. The location and signal intensity of the mass are atypical for a urethral diverticulum, and the mass proved to represent injected periurethral collagen. (Reprinted, with permission, from reference 28.) (17) Labial neurofibroma in a 35-year-old woman with neurofibromatosis. Axial fat-saturated fast SE T2-weighted MR image demonstrates an ovoid hyperintense lesion (arrow) along the right labium minorum, a finding that proved to be a neurofibroma at pathologic analysis.
Pelvic Floor Dysfunction

The term **pelvic floor dysfunction** encompasses a diverse group of disorders affecting up to 50% of middle-aged and elderly women. Approximately 10% of women in the United States have severe symptoms requiring surgical intervention (32). There are numerous risk factors for the development of pelvic floor dysfunction, including age, multiparity, history of vaginal delivery, menopausal status, obesity, and history of hysterectomy. Patients present with signs and symptoms that often overlap with those of urethral diverticula and periurethral cystic lesions, including pelvic pain, incontinence, dyspareunia, incomplete emptying, and, at times, visible organ protrusion.

Pelvic floor dysfunction is subdivided into pelvic floor relaxation and pelvic organ prolapse.

**Pelvic Floor Relaxation**

Pelvic floor relaxation is weakening of the pelvic floor resulting in pelvic floor descent and widening. Pelvic organ prolapse is the external protrusion of a pelvic organ due to weakening of its supporting structures. Organ prolapse may involve one or more organs and is named accordingly: urethrocele (urethra), cystocele (bladder), cystourethrocele (bladder and urethra), vaginal vault prolapse (vaginal vault), uterine prolapse (uterus), enterocele (small bowel), sigmoidocele (sigmoid colon), and rectocele (rectum). In this article, we focus solely on disease associated with urethral prolapse.

**MR Imaging in the Assessment of Pelvic Organ Prolapse**

At our institution, patients are imaged in a 1.5-T or 3.0-T magnet with a pelvic or torso phased-array coil. An experienced technologist is crucial for proper coaching of patients to achieve maximal straining. The patient is instructed simply and clearly on how to progressively and maximally strain the pelvic floor inferiorly (Valsalva maneuver) before imaging is begun. The bladder should be at least one-half to three-quarters full to maximize the detection of cystourethroceles.

Axial, sagittal, and coronal static rapid half-Fourier T2-weighted images of the entire pelvis such as single-shot fast SE or half-Fourier RARE images are obtained. Once the midline between the pubic symphysis and the coccyx is identified, the patient is instructed to perform the Valsalva maneuver for at least 10 seconds. Six to eight dynamic rapid single-shot fast SE or half-Fourier RARE images are acquired in the midsagittal plane as the patient begins the maneuver. Subsequently, dynamic images are obtained in the sagittal plane.

### Table 2

**HMO Grading of Pelvic Floor Relaxation**

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<th>Grade</th>
<th>Hiatal Enlargement (cm)</th>
<th>Pelvic Floor Descent (cm)</th>
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<td>0 (Normal)</td>
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<td>0–2</td>
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<tr>
<td>1 (Mild)</td>
<td>6–8</td>
<td>2–4</td>
</tr>
<tr>
<td>2 (Moderate)</td>
<td>8–10</td>
<td>4–6</td>
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<tr>
<td>3 (Severe)</td>
<td>≥10</td>
<td>≥6</td>
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### Table 3

**HMO Grading of Pelvic Organ Prolapse**

<table>
<thead>
<tr>
<th>Grade</th>
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</thead>
<tbody>
<tr>
<td>0 (No prolapse)</td>
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<tr>
<td>1 (Mild)</td>
<td>0–2 cm below</td>
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<tr>
<td>2 (Moderate)</td>
<td>2–4 cm below</td>
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<td>3 (Severe)</td>
<td>≥4 cm below</td>
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ittal plane with single-shot fast SE or half-Fourier RARE sequences. It should be noted that the exact protocols vary by institution.

**HMO Grading**

The HMO (H line, M line, organ prolapse) system is an objective classification scheme for assessing the degree of pelvic floor relaxation and pelvic organ prolapse that makes use of midsagittal single-shot fast SE or half-Fourier RARE MR images obtained during maximal straining (33). There are four steps to determining the severity of pelvic floor relaxation and pelvic organ prolapse using the HMO system.

1. Three points of reference are defined on the midsagittal image obtained during maximal straining: the inferior margin of the pubic symphysis (point A), the convex posterior margin of the puborectalis muscle sling (point B), and the junction between the first and second coccygeal segments (point C) (Fig 18).

2. A line known as the PCL is drawn between points A and C. Point B and the PCL are two anatomic fixed references in the HMO system.

3. A line known as the puborectal hiatus line (H line) is drawn between points A and B. This line is used to measure hiatal widening in the anteroposterior direction.

4. An M line is drawn, which is defined as the shortest line between the PCL and point B. The M line demonstrates the extent of descent of the muscular pelvic floor. The grading of pelvic floor relaxation has two components: hiatal enlargement as demonstrated by the H line, and pelvic floor descent as demonstrated by the M line. Abnormal pelvic floor relaxation is defined as an H line longer than 6 cm and an M line longer than 2 cm and can vary in degree of severity (Table 2). The determination of pelvic organ prolapse is an additional step in the HMO system that is taken if an organ protrudes inferior to the H line. The shortest distance between the most inferior aspect of a pelvic organ and the H line is used to determine the grade of prolapse (Table 3). If no organ protrudes inferior to the H line, there is no evidence of pelvic organ prolapse. Although in this article we discuss pelvic floor dysfunction only in terms of the urethra (Fig 19), the HMO system pertains to all pelvic organs.

Urethral hypermobility is demonstrated at dynamic MR imaging when the urethra rotates from its normal vertical oblique course into an abnormal horizontal orientation (Fig 19). It is important to assess urethral and bladder prolapse separately, since high-grade cystoceles can mask symptoms of stress incontinence and hide evidence of urethral hypermobility, which is then discovered only after cystocele repair. Symptoms of stress incontinence are masked due to kinking of the bladder neck caused by the abnormal horizontal orientation of the urethra (33). The treatment of urethral hypermobility includes a suburethral sling procedure to provide urethral support.
and reduce stress incontinence (34). Cystourethroceles are treated nonsurgically with pessary placement in mild cases; in more severe cases, transabdominal or transvaginal mesh placement is performed, as well as a sling procedure is some instances (35).

**Dynamic US in the Assessment of Pelvic Floor Dysfunction**

Dynamic US with endoluminal transducers is an emerging technique in the evaluation of pelvic floor dysfunction. It allows real-time evaluation of the displacement of pelvic floor muscles and pelvic organs during provocative maneuvers such as coughing and the Valsalva maneuver. The patient is typically placed in a semireclining position to allow maximal straining. The ideal bladder volume prior to imaging is 300 mL, since greater bladder distention results in underestimation of pelvic floor prolapse (36). After placement of the endovaginal transducer, low pressure is maintained to avoid displacement of the bladder neck. Initially, midsagittal images of the bladder and urethra are obtained, with subsequent evaluation of the periurethral tissues (Fig 3). In the absence of endoluminal US, translabial and transvaginal US can be useful in the assessment of pelvic floor prolapse.

In women with symptoms of stress incontinence, hypermobility of the urethra or a “funnel” appearance of the proximal urethra may be noted during coughing due to laxity of the connective tissues. However, the severity of stress incontinence cannot be inferred from the degree of urethral hypermobility or funneling (37). US detection of cystourethroceles is based on descent of the bladder and urethra caudal to the inferoposterior aspect of the pubic symphysis (Fig 20a, 20b) (38). After surgical correction of pelvic organ prolapse, endoluminal US is valuable in assessing for achievement of normal genitourinary anatomy and the absence of urethral funneling and recurrent cystourethroceles (Figs 20c, 21). Postsurgical US also aids in detecting retropubic hematomas, abnormal intravesical suture material, and possible overcorrection.

**Conclusions**

There is a wide spectrum of benign and malignant urethral and periurethral diseases with nonspecific clinical symptoms and variable physical examination findings, highlighting the importance of MR imaging and US evaluation in affected patients. Recent advances in these modalities allow more detailed evaluation of urethral and periurethral abnormalities. The distinctive imaging features and locations of the various diseases aid in narrowing the differential diagnosis.
In addition, dynamic studies can be performed to allow objective assessment of the degree of pelvic floor relaxation and pelvic organ prolapse. High-resolution MR imaging and real-time US have exciting potential as tools for more comprehensive analysis of the pathophysiologic features of the complex disorders that affect the female urethra and periurethral tissues.

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References


Because of its superb resolution, increased signal-to-noise ratio, and multiplanar capability, MR imaging has become the imaging modality of choice for diagnosis and preoperative planning in female patients with urethral and periurethral disease.

The classic appearance of the normal female urethra on axial T2-weighted and gadolinium-enhanced T1-weighted MR images has been described as targetlike due to the alternating signal intensity characteristics of the different zones.

Urethral diverticula are protrusions of the urethra into the periurethral fascia. The epithelial lining of a diverticulum is identical to the urethral mucosa, and communication with the urethral lumen is maintained (2,15).

Periurethral cystic lesions include Gartner duct cyst, Bartholin gland cyst, Skene duct cyst, mullerian cyst, epidermal inclusion cyst, perineal-vulvovaginal endometriomas, and injected collagen. It is important for radiologists to be aware of the imaging characteristics of these entities, in particular their location, to differentiate them from urethral diverticula.

The HMO (H line, M line, organ prolapse) system is an objective classification scheme for assessing the degree of pelvic floor relaxation and pelvic organ prolapse that makes use of midsagittal single-shot fast SE or half-Fourier RARE MR images obtained during maximal straining (33).