Ultrasound Imaging of the Pelvic Floor

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KEYWORDS

• Ultrasound • Vaginal ultrasound • Endoluminal ultrasound • Endoanal ultrasound

KEY POINTS

• Ultrasound is a detailed anatomic assessment of the muscles and surrounding organs of the pelvic floor.
• Anatomic variability and pathology, such as prolapse, fecal incontinence, urinary incontinence, vaginal wall cysts, synthetic implanted material, and pelvic pain, can be easily assessed with endoluminal vaginal ultrasound.
• Knowledge of pelvic floor anatomy is essential for effective ultrasound imaging techniques.

INTRODUCTION

The pelvic floor is a complex system, and adequate assessment of pelvic floor disorders is greatly supplemented by pelvic floor imaging. Rather than focusing on the clinical examination of pelvic floor surface structures, imaging modalities, such as sonography, allow for immediate, real-time confirmation of anatomic findings. Pelvic floor ultrasound offers a low cost, minimally invasive method of assessing pelvic floor anatomy and function. For example, clinical assessment of the anatomy of the levator ani by palpation requires significant skill and teaching. Clinical diagnosis by imaging has been shown to be more reproducible than palpation and provides a more objective method of teaching.

PELVIC FLOOR ANATOMY

The female pelvic floor and the levator ani complex are composed of muscle fibers and a fascial network, which spans the area underneath the pelvis. An intact, well-innervated pelvic floor is necessary to maintain pelvic organ support, facilitate...
urination and defecation, and allow childbirth. The pelvic floor muscle hammock, or levator ani complex, is comprised of five distinguishable subdivisions, based on MRI studies (Fig. 1).4,5 The pubovaginalis muscle arises from the posterior aspect of the pubic rami and inserts in the anterior vaginal wall at the level of the midurethra. The puborectalis muscle arises from the posterior aspect of the pubic ramus and runs posteriorly to form a sling around the rectum. During childbirth the puborectalis sustains the most stretch in vaginal delivery.6 The puboperinealis muscle arises from the posterior aspect of the pubic rami and bilaterally inserts in the contralateral side of the perineal body. The puboanalis muscle arises from the posterior aspect of the pubic rami and inserts into the intersphincteric groove between the internal anal sphincter (IAS) and external anal sphincter (EAS). The iliococcygeus muscle arises from the arcus tendineous levator ani and runs medially to fuse at the midline in the iliococcygeal raphe. An intact pelvic floor muscle hammock functions to keep the urogenital hiatus closed by compressing the vagina, urethra, and rectum against the pubic bone during contraction.

The pelvic organs and levator ani muscle complex are encased by a dense network of endopelvic fascia. This network aids in pelvic organ support and keeps the pelvic organs in proper orientation during daily activities. Innervation of the pelvic floor is provided through the pudendal nerve and sacral nerve plexus arising from L4-S5. The pudendal nerve primarily innervates the anal and urethral sphincter, thus controlling the continence mechanisms. The levator ani nerve innervates the major musculature that supports the pelvic floor. The sacral nerve plexus is a distal component of the lumbo-sacral plexus and innervates the levator ani complex.

Knowledge of pelvic floor anatomy is essential for effective ultrasound imaging techniques. Advancing ultrasound technologies have improved the ability to detect pelvic floor defects and gain insight into the pathophysiology of pelvic floor disorders.

Fig. 1. Musculoskeletal anatomy of the female pelvic floor. ATLA, arcus tendineus levator ani; EAS, external anal sphincter; ICM, iliococcygeus muscle; PAM, puboanalis muscle; PB, perineal body; PPM, puboperinealis muscle; PRM, puborectalis muscle. (From Kearney R, Sawhney R, DeLancey JO. Levator ani muscle anatomy evaluated by origin-insertion pairs. Obstet Gynecol 2004;104:172; with permission.)
ULTRASOUND TECHNIQUE

Transperineal Ultrasound

Requirements for two-dimensional (2D) perineal ultrasound include a B-mode-capable 2D ultrasound system, and a 3.5- to 6-MHz transducer. To perform the examination, the patient is placed in dorsal lithotomy position after the patient voids. The probe may be covered with a nonpowdered glove or probe cover. Ultrasound gel is applied to the probe and the probe is placed firmly on the perineum. Once a midsagittal view is obtained, the following structures should be identified from ventral to dorsal: symphysis pubis, urethra and bladder neck, vaginal canal, uterus and cervix, anorectal canal, and the central portion of the puborectalis muscle. Parting the labia may improve image quality. By rotating the probe 90°, one can obtain a coronal view and by placing a dorsal inclination on the probe, the anal canal and sphincter complex are seen and assessed. Once adequate images are obtained, the probe is removed from the perineum and cleaned.

2D images can be integrated into three-dimensional (3D) volume data either by a free-hand acquisition of images or using a probe equipped with a motor to allow for motorized automatic acquisition of images. To perform the examination the patient is in the same position as described for 2D ultrasound. Ultrasound gel is applied to the 3D-capable probe and placed firmly on the perineum in a midsagittal orientation. The probe is then held in place while the images are obtained. Postprocessing of the images then occurs and is evaluated with the appropriate software. Four-dimensional imaging refers to the real-time acquisition of data to produce and save cineloops of the images obtained. To perform four-dimensional imaging, one must record images during a prompted maneuver, such as a squeeze or a Valsalva.

Endoluminal Ultrasound

Although a fair amount of information is obtained with an abdominal 2D probe when placed on the perineum (in the technique detailed previously), additional information is obtained by endoluminal ultrasound (endovaginal and endoanal ultrasound) with such equipment as the BK Medical Pro Focus Ultra View and Flex Focus (Peabody, MA). These systems provide high performance with efficiency and speed, high resolution, and a sensitive color Doppler with great spatial resolution and sensitivity.

Endovaginal ultrasound is performed with the patient in the dorsal lithotomy position, with the patient having a comfortable amount of urine in the bladder. Multiple types of probes are used including an electronic biplane 5- to 12-MHz probe, a high multifrequency 9- to 16-MHz probe, a 360° rotational mechanical probe, or with a radial electronic probe, such as the one by BK Medical. To perform the examination, the transducer is inserted into the vagina in a neutral position, avoiding excessive pressure on the surrounding structures. The biplane electronic probe provides 2D imaging of the anterior and posterior compartments. Typically it is performed at rest, on Valsalva, and during pelvic floor muscle contraction. 3D images are obtained by connecting this transducer to an external 180° rotational mover. Other methods of obtaining 3D images are using a radial electronic probe or a rotational mechanical probe to obtain a 3D 360° view image of the pelvic floor. The 3D volume can be used on the scanner, but the better functionality is to use the free software, which can be installed in any personal computer. This allows for the volume to be exported to a CD, DVD, USB, or external drive and be viewed and analyzed at any time. The available functions of the software allow for manipulation of the 3D cube in the x, y, or z planes, and obtaining linear, angle, area, and volume measurements.
**Endoanal Ultrasound**

Endoanal ultrasound is the gold standard for evaluating anal sphincter pathology.\(^{11}\) It is performed with the patient either in dorsal lithotomy, left lateral, or prone position. It can be performed either with a high multifrequency 360° rotational probe or a radial electronic probe. Irrespective of patient positioning, the transducer should be positioned so that the anterior aspect of the anal canal is superior on the screen at the 12-o’clock position. The distal end of the probe should be at the level of the puborectalis muscle or 6 cm into the anal canal. The mechanical rotational probe, once activated, automatically obtains 3D images.\(^9\) 3D image acquisition with the radial electronic probe involves manual withdrawal.\(^{12}\)

**CLINICAL UTILITY**

This discussion is focused on the clinical use of ultrasound imaging of the pelvic floor mostly to endoluminal ultrasound. Although pelvic floor imaging can be initiated with a transperineal ultrasound, having the advantage of dynamic imaging with minimal tissue distortion, the resulting images have a lower resolution.

**Anterior Compartment**

The anterior compartment of the pelvis is often assessed with transperineal and endovaginal ultrasound. Because there is an inherent displacement of tissue with endovaginal ultrasound, transperineal ultrasound is preferred for visualization of bladder neck descent, urethral hypermobility, cystocele, and cystourethrocele.\(^{13}\) 3D endovaginal ultrasound is used to provide a detailed anatomic depiction of anterior compartment structures including the trigone, compressor urethra, and the urogenital sphincter.\(^{14}\) 3D endovaginal ultrasound also allows the examiner to accurately measure the components of the urethral complex including urethral width, length, and volume.\(^9,^{14}\) **Fig. 2** Shows an example of normal urethral anatomy, including the striated urogenital sphincter and compressor urethra as seen in this 3D endovaginal ultrasound.

![3D endovaginal ultrasound showing normal urethral anatomy](image)

**Fig. 2.** Example of normal urethral anatomy, including the striated urogenital sphincter and compressor urethra as seen in this 3D endovaginal ultrasound.
sphincter and compressor urethra. It is an excellent tool for visualizing anterior vaginal cysts and masses including Skene gland cysts, urethral diverticula, and Gartner duct cysts.15

The female urethra is a complex organ that plays a central role in urinary incontinence. Normal anatomy, innervation, position, and proper relation to the surrounding pelvic floor structures ensure normal function of the urethra.16–18 The signs and symptoms of pelvic floor dysfunction often overlap with signs and symptoms of urethral diverticula, ectopic ureters, urethral tumors, and periurethral cystic lesions. Ectopic ureters and ureteroceles are usually diagnosed in childhood and rarely present in adults. Nevertheless, these conditions should be considered in patients with urinary tract infections or urinary incontinence because surgery can correct these disorders.19 Endovaginal ultrasound is a useful tool in the diagnosis of ectopic and dystopic ureters.20 Urethral diverticula are also occasionally found in women complaining of urinary incontinence and/or pain and dyspareunia. Ultrasound can help differentiate a diverticulum from other periurethral cystic lesions, such as ectopic ureters, calcifications, and injected material, and is useful in surgical planning because it can offer invaluable information, such as shape, size, and location in relation to the urethra and bladder.21 Endovaginal ultrasound is very useful in the diagnosis and monitoring of urethral tumors.22 An example is a urethral leiomyoma, which is a rare benign smooth muscle tumor that may grow in pregnancy and cause dysuria. On ultrasound these tumors appear well defined, homogenous, with increased vascularity.23 Urethral carcinoma is a rare cancer that accounts for less than 0.02% of all malignancies in women and typically appears as an anterior urethral tumor.23 Endovaginal ultrasound of the bladder can provide important information regarding the bladder neck, and the diagnosis of foreign bodies and bladder diverticula. Bladder wall thickness can also be measured by endovaginal ultrasound and has been found to positively correlate with detrusor instability.24

**Central Compartment**

Assessment of the central compartment is usually performed with transperineal ultrasound. Endovaginal techniques have a limited role in assessing the central compartment because the probe impedes descent of the uterus or vault. Additionally uterine or vaginal vault prolapse is typically diagnosed on clinical examination.

**Posterior Compartment**

For the posterior compartment, endovaginal ultrasound with a biplane transducer provides important information including ensuring integrity of the rectovaginal septum, and measuring the anorectal angle. During Valsalva, several other important aspects are appreciated including descent of an enterocele, rectocele, and movement of the puborectalis and anorectal angle to evaluate for pelvic floor dyssynergy, and visualization of intussusception.9 Transvaginal 3D ultrasound also is a useful tool in visualizing rectovaginal fistulae.25 Assessment of the anal canal is typically performed with endoanal ultrasound (discussed later).11,26

The anatomic causes associated with defecatory dysfunction are best visualized on dynamic transperineal or translabial and endovaginal scans.27 Many clinicians use the term “rectocele” to refer to any prolapse of the posterior vaginal wall; a true rectocele is defined as herniation of the anterior rectal wall into the vagina.28 Although examination is usually adequate to diagnose prolapse of the posterior vaginal wall, ultrasound is a useful tool in diagnosing a true rectocele. Typically this is done with a transperineal ultrasound because the endoluminal ultrasound probe may prevent the prolapse from occurring.
An enterocele is a hernia of the most inferior point of the abdominal cavity into the vagina or pouch of Douglas. On ultrasound, it is visualized as the downward movement of abdominal contents into the vagina, ventral to the rectal ampulla and anal canal. A sigmoidocele can usually be seen by differentiating hyperechoic stool movement from the surrounding tissue. Being able to differentiate a sigmoidocele from an enterocele is important in planning a surgical procedure. By definition, an intussusception occurs when the rectal wall telescopes into the rectal lumen and may involve the rectal mucosa or full thickness of the rectal wall. It is defined as intra-rectal, intra-anal, or external if it forms a complete rectal prolapse. Pelvic floor dyssynergy is typically described as a lack of normal relaxation of the puborectalis muscle during defecation. This is a difficult condition to verify through clinical examination. However, during Valsalva, it is documented by ultrasound because the anorectal angle becomes narrower, the levator hiatus is shortened, and the puborectalis muscle thickens.27

**Lateral Compartments**

Until recently, the concept of pelvic floor trauma focused mainly on perineal, vaginal, and anal sphincter injuries. But over the past several years, with advancements of 3D ultrasound technology, the concept of levator ani injury has become an important component of pelvic floor trauma. The pelvic floor is composed of symmetrically paired levator ani muscles, which together form a sheet of muscles attached to the internal surface of the true pelvis. The levator ani is divided into three muscle groups, named for their attachments: (1) pubovisceralis, (2) puborectalis, and (3) iliococcygeus. The pubovisceralis is further divided into the puboperinealis, pubovaginalis, and puboanalis muscles.29 Together, these muscles support the urogenital organs and the anorectum.

Studies have shown that levator ani injury is common. Levator avulsion is the disconnection of the levator ani from its insertion on the pubic ramus or pelvic sidewall. Levator tears can occur at any part of the muscle between the two insertion points. Avulsion and tears are a common complication of overstretching of the muscles during childbirth and occur in 10% to 36% of women in their first vaginal delivery.28,30–32 Not only can childbirth injure the muscles of the pelvic floor, but it can also disrupt the innervation of the muscles.33 Electromyography abnormalities in the pelvic floor associated with defecation disorders, stress urinary incontinence, and prolapse are more frequently seen in women who are multiparous, who have had prolonged second stages of labor, forceps delivery, and high birth weight.34–37

Levator ani injury has been shown to be negatively correlated with pelvic floor strength, and positively correlated with fecal incontinence and stage of pelvic organ prolapse. Steensma and colleagues36 found that weak pelvic floor muscles occurred more often in women who had levator ani avulsion, with injuries being present in 53.8% of women with weak pelvic floor strength compared with being present in 16.1% of women with normal strength. Women with levator ani injury have been found to have a greater incidence of fecal incontinence.39 Particularly the puborectalis muscle plays an important role in maintaining continence, as shown in a case-control study that found that fecal incontinence was more common in women with puborectalis abnormalities compared with control subjects.40 It is well established that women with levator ani injury have a higher risk of developing pelvic organ prolapse.41 Levator avulsion seems to play a significant role particularly in the central and anterior compartments because the risk of having prolapse in these compartments doubles with levator ani avulsion.42 The relationship with stress incontinence and levator ani injury is unclear because some studies shown no correlation,43 whereas others have shown
a negative correlation. However, women with previous stress incontinence are twice as likely to have a levator ani injury during childbirth.

Levator avulsion can be accurately seen through 3D endovaginal ultrasound imaging, especially during a pelvic floor muscle contraction. Because levator damage from childbirth is not always an “all or none” phenomenon, a scoring system was developed to quantify levator ani injury with 3D endovaginal ultrasound. This scoring system has been shown to have high interrater reliability.

**Implanted Vaginal Material**

Over the last two decades, pelvic floor surgeries involving permanent vagina implants used to aid in pelvic organ prolapse and stress incontinence have risen in popularity. Polypropylene mesh is one of the most commonly used meshes in vaginal surgery and is highly echogenic on endovaginal ultrasound. Imaging can determine the size, shape, position, distortion, and mobility of the implants. Position of the mesh is typically either along the posterior vaginal wall sometimes extending to the perineal body, along the anterior wall, or near the midurethra in the case of midurethral slings. Often the implanted mesh is found to be shrunken, contracted, or folded. Fig. 3 shows an example of anterior and posterior vaginal wall mesh materials. In the case of midurethral slings, ultrasound can help distinguish transobturator versus retropubic slings, and help locate and map the location of the synthetic material on axial imaging of the anterior compartment relative to the bladder neck. Fig. 4 shows an example of a transobturator sling visualized on ultrasound. This is helpful in planning a procedure to remove permanent synthetic materials in the absence of an operative report, or as adjunctive imaging in cases where the synthetic materials appear displaced. Periurethral bulking agents can also easily be seen on endovaginal ultrasound.

**Endoanal Imaging**

Endoanal ultrasound is the gold standard for morphologic assessment of the anal canal. When performing endoanal ultrasound, the anal canal is divided into three levels in the axial plan: (1) upper, (2) middle, and (3) lower. The uppermost level is marked proximally by the puborectalis muscle and distally by the ring of the IAS. The middle level is marked by the complete ring of the IAS and EAS, and the visualization of the...
transverse perinei muscles. The lower level is marked by the subcutaneous part of the EAS. Fig. 5 shows an example of normal IAS and EAS anatomy.

Endoanal ultrasound is often the diagnostic test of choice in patients presenting with fecal incontinence and a history of a traumatic childbirth. Fig. 6 shows an example of a combined IAS and EAS defect. Fecal incontinence is defined as the involuntary loss of feces, whereas anal incontinence is the involuntary loss of flatus or feces. It is an embarrassing problem that has a devastating impact on a woman’s life. Because of the embarrassing nature of the problem, women often do not complain to their physician, making the true incidence of anal incontinence likely underestimated. Reported prevalence varies widely, ranging from 1% to 24% of the US adult population, and is projected to increase 59% by 2050.51–57 An intact, innervated, and well-functioning
IAS, EAS, and puborectalis muscle is a prerequisite for fecal control. Anal sphincter defects most often occur following instrumented vaginal deliveries, and are a common cause of fecal incontinence. Sultan and colleagues\textsuperscript{58} found in a study of 79 primiparous women that 35% of them had defects of either the IAS or the EAS or both 6 weeks after delivery. Forceps-assisted vaginal deliveries are associated with 80% chance of having sphincter defects found after delivery\textsuperscript{58} and a 32% chance of having anal incontinence.\textsuperscript{59} Endoanal ultrasound has been found to be superior to other diagnostic tools for the evaluation of sphincter defects with a sensitivity of 100%, compared with a sensitivity of 89% for electromyography, 67% for manometry, and 57% for clinical assessment.\textsuperscript{60} When performing anal ultrasonography the EAS appears hyperechoic and has a heterogeneous appearance, whereas the IAS appears homogeneously hypoechoic. By defining the margins of disruption, it provides invaluable information for the surgeon if surgical repair is considered.

Surgical repair of hemorrhoids, anal fissures, and anal fistulas can also be a cause of anal sphincter disruption leading to fecal and anal incontinence. Hemorrhoids cause soiling and endoanal ultrasound can be particularly useful in diagnosing internal hemorrhoids. However, surgical excision of internal hemorrhoids can lead to damage of the IAS and anal incontinence.\textsuperscript{61} Hemorrhoid stapling has been shown to prevent IAS damage as opposed to hemorrhoid excision.\textsuperscript{62} An anal stretch procedure, done for anal fissures, is associated with a 27% chance of anal incontinence after the procedure with 90% of those patients having evidence of IAS disruption on endoanal ultrasound.\textsuperscript{63} Although endoanal ultrasound is helpful in diagnosing fistula tracts involving the anus and rectum, it can also be useful in diagnosing anal sphincter injury after surgical correction of the fistula.\textsuperscript{64}

**SUMMARY**

This article provides a background and appraisal of endoluminal ultrasound of the pelvic floor. It offers a detailed anatomic assessment of the muscles and surrounding organs of the pelvic floor. Different anatomic variability and pathology, such as prolapse,
fecal incontinence, urinary incontinence, vaginal wall cysts, synthetic implanted material, and pelvic pain, are easily assessed with endoluminal vaginal ultrasound. With pelvic organ prolapse in particular, not only is the prolapse itself seen but the underlying cause related to the anatomic and functional abnormalities of the pelvic floor muscle structures are also visualized.

REFERENCES


