Perineal Pelvic Floor Ultrasound: Applications and Literature Review

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Learning Objectives

1. To review the literature on perineal ultrasound of the pelvic floor
2. To provide an overview of strengths and shortcomings of perineal ultrasound technique
3. To appreciate the role of perineal pelvic floor ultrasound in pelvic floor disorders

Introduction

Pelvic floor ultrasonography has revolutionized the clinician's approach to investigating pelvic floor disorders and also provided a useful tool for enhancing research methodology in identifying the pathophysiology behind such disorders. The reported prevalence of urinary incontinence varies significantly and ranges between 10 and 60% depending on the population studied, whereas for anal incontinence the percentage mounts to 39% [1, 2]. Pelvic organ prolapse too is highly prevalent and despite the development of standardized quantification methods, clinical assessment alone is inadequate and occasionally misleading. As pelvic floor disorders often co-exist, multi-planar imaging like pelvic floor ultrasound is key in helping apply a multi-compartmental approach to assessing the functional anatomy of the pelvic floor.

Although the initial focus of pelvic floor ultrasound studies was the anterior vaginal compartment, including the contributory role of bladder and urethra into the continence mechanism [3, 4], more light has recently been shed on the application of this modality in the mid and posterior vaginal compartments; depicting pathology like posterior vaginal wall prolapse, levator muscle injuries, and anal sphincter tears is now possible with a non-invasive technique [5–7]. Because of the technological advances in the field of multi-planar pelvic floor ultrasonography, the learner may become confused regarding the optimal approach, i.e. endovaginal, perineal, or endoanal, for depicting various aspects of pelvic floor pathology. However, in the hands of a skilled sonographer, each probe has distinct properties that can be taken advantage of. For example in the field of gynecology, imaging of the uterus may require both an abdominal and vaginal approach and these probes are complementary not exclusive. That is why in this book a multi-compartmental approach is advocated. A perineal approach is most widely available to the novice learners and with increasing skills the learner can advance to endovaginal and endoanal imaging as necessary. The lack of standardized criteria for

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reporting pelvic floor ultrasound studies has somewhat hindered the universal application of the modality in urogynecology and reconstructive surgery so far. The need for developing evidence-based guidance on the clinical applicability of this method is now perhaps more relevant than ever.

In the following sections of this chapter, we will demonstrate the equipment and technique for conducting two-dimensional (2D) and three-dimensional (3D) transperineal scan of the pelvic floor and refer to its various clinical applications as evident by the most recent literature.

Perineal Ultrasonography

Perineal pelvic floor ultrasound (pPFUS) is gaining ground fast in urogynecology as it has proved a valid, reproducible, readily available, and well tolerated by patients diagnostic tool. Standard 2D imaging of the pelvic floor can provide valuable information on the anatomy in all vaginal compartments, whereas with the more sophisticated 3D–4D equipment and relative software high-resolution static and dynamic imaging of the functional anatomy is achieved in three planes (sagittal, coronal, and axial).

Introital pelvic floor ultrasound (iPFUS) refers to acquisition of images with an endovaginal probe on the perineum (or posterior fourchette). It is often used interchangeably with the term perineal or translabial ultrasound (pPFUS), which is performed with a curvilinear probe placed between the labia majora.

Although pPFUS was employed as an imaging technique in assessing lower urinary tract symptoms as early as 1986 [8], there is still no standardized terminology or reporting system available, hence its use remains largely within the research setting. In contrast, endovaginal imaging has found widespread clinical utility for visualization of vaginal cysts, mesh, slings, etc. Recent technological advances in 3D–4D probes make pPFUS an attractive diagnostic tool for it comprises a valid, cheap, and readily available imaging modality. Recent data has proved the value of pPFUS in assessing the lower urinary tract, anal sphincter muscle complex, and levator ani muscle biometry and we will demonstrate these applications in the following sections of this chapter.

2D Perineal Ultrasonography

Irrespective of a 2D or 3D configuration of the ultrasound system in use and the intended imaging, the technique always starts with acquisition a dynamic 2D view of the pelvic floor structures in mid-sagittal view. Optimal views are achieved with gel applied on the transducer, which is then covered with a glove or condom, depending on whether a curvilinear or endovaginal probe is used. More gel is applied on the outside of the cover to eliminate reverberations. Screen orientation varies according to the use of probe (endovaginal or curved array) and the operator's preference (Fig. 4.1). In a commonly used orientation, the hyperechoic pubic symphysis is pictured on the far right of the screen, followed posteriorly by the echolucent vaginal canal and the anorectal angle (ARA) and levator plate (LP) lying on the far left of the image (Fig. 4.2). The pelvic floor anatomy can be appreciated at rest or with the patient contracting their pelvic floor muscles or executing a Valsalva maneuver. When the patient is asked to perform a pelvic muscle contraction (instructions will usually involve "squeeze as hard as you can" or "try and clench as if you are trying to hold urine in"), a cranioventral movement of the pelvic organs can be seen on the midsagittal plane, whereas narrowing of the levator hiatus is best depicted on the axial plane. Since an abdominal probe is designed to look down, when these probes are used for perineal imaging, the initial 2D midsagittal view appears upside down and in most publication this is how the pictures are depicted (see Fig. 4.1).

The opposite organ movement is seen when the patient is asked to perform a Valsalva maneuver, when instructed to "bear down" or "push as if you wished to have a bowel motion"; the urethra and vaginal walls are shifted in a dorsocaudal direction with the anorectal angle straightening (Fig. 4.3).

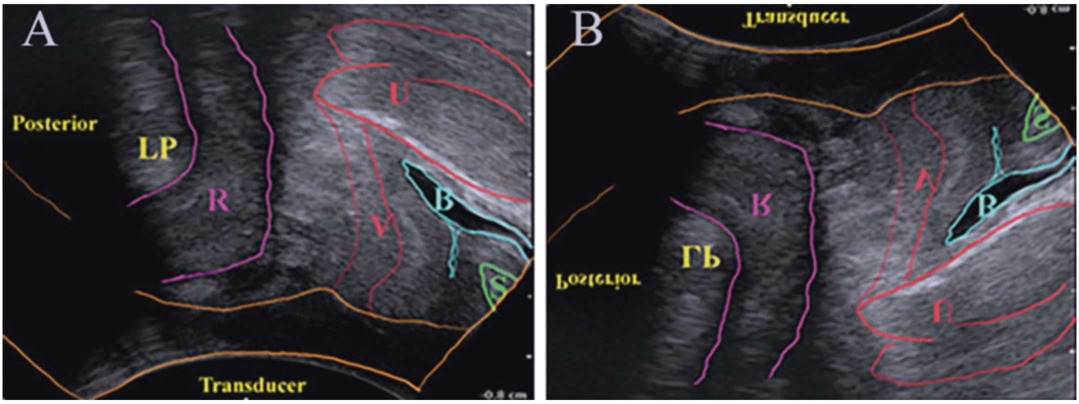


Fig. 4.1 (**a**) This view demonstrates correct positioning as the starting 2D field of view includes the pubic symphysis (S) anteriorly and the levator plate (LP) posteriorly. Also noted are the bladder (B), uterus (U), vagina (V), and anorectum (R); (**b**) demonstrates how the image will appear upside down on the screen as default unless the default is changed by the sonographer. © Shobeiri

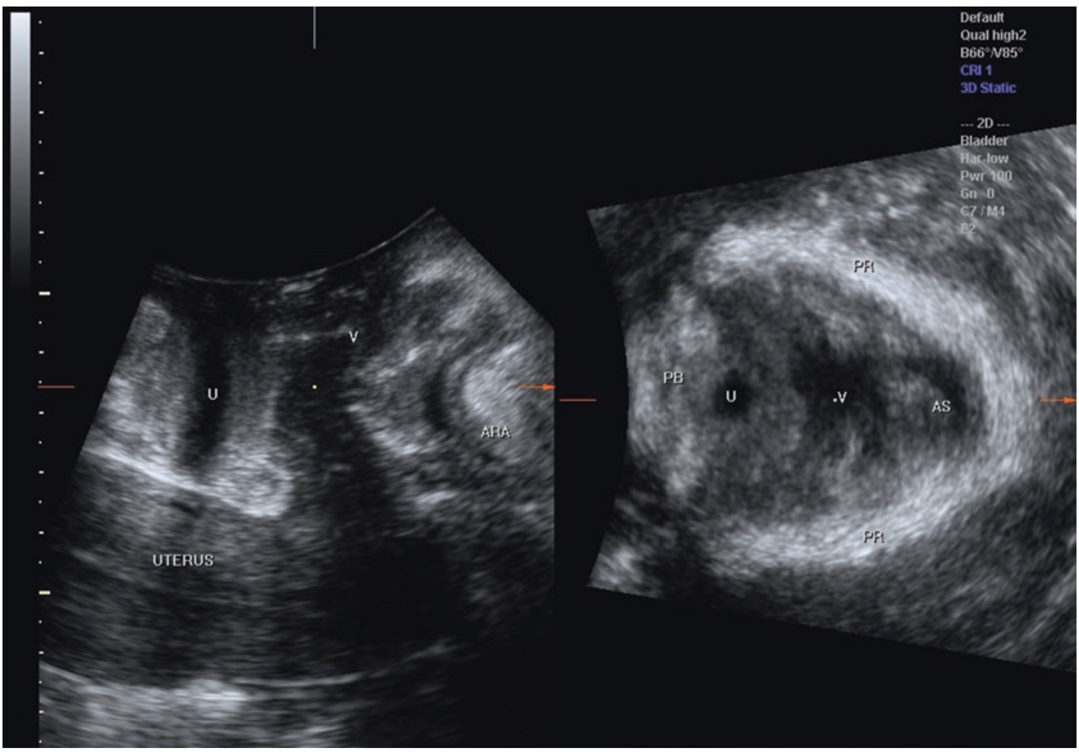


Fig. 4.2 Midsagittal (*left*) and axial (*right*) views of translabial ultrasound of pelvic floor–asymptomatic patient at rest. The different image orientation in comparison to Fig. 4.1 can be appreciated. The uterus, vagina (v), urethra (U), anorectal angle (ARA), pubic bone (PB), and puborectalis muscle (PR) are noted

While imaging the pelvic floor at maximum contraction is important for studying the biometry of the levator anal muscle and can be used by urogynecologists and physiotherapists to provide patients with feedback during pelvic floor muscle training program, 2D imaging at Valsalva can

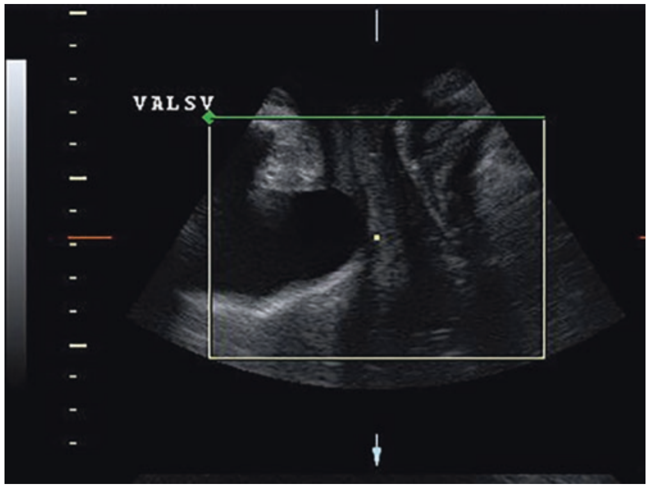


Fig. 4.3 Valsalva maneuver by asymptomatic patient. Notice the minimal dorso-caudal displacement of urethra and bladder and straightening of the anorectal angle

reveal various pathologies like urethra and bladder neck hypermobility, multi-compartmental prolapse, mesh/tape erosion or displacement or even bladder/urethra diverticula and bladder tumors [9]. The specific use of pPFUS in depicting pathology in different vaginal compartments will be studied further along in this chapter.

3D/4D Perineal Ultrasonography Equipment

The most commonly published data comes from GE machines (GE Healthcare, Chicago, IL, USA). Phillips, Hitachi, and others make similar or superior machines. However, GE's 4D View is available for offline analysis and use with 3D or 4D ultrasound volumes obtained using GE's Voluson series systems. The cheapest and most easily available GE system is Voluson *e* or *i* (Fig. 4.4). Despite its compact size the system is very capable when used with a GE RAB4-8-RS transducer (Fig. 4.5). The systems were developed and designed to visualize fetus' surface structures and adapted for pelvic floor imaging. GE Kretz 4D view allows manipulation of image characteristics and output of stills, cine loops and rotational volumes in bitmap and AVI format.

Fig. 4.4 GE Voluson *e* ultrasound machine (GE Healthcare, Chicago, IL, USA). © Shobeiri 2013

Fig. 4.5 GE RAB4-8-RS transducer (GE Healthcare, Chicago, IL, USA). © Shobeiri 2013

Slightly higher resolutions can be obtained if the endocavitary GE RIC5-9 W-RS is used on the perineum. The characteristics of these transducers are shown in Table 4.1.

The GE transducer is placed between labia majora and the 2D image as outlined above is displayed on the screen. Depending on the setting of your machine the image orientation may be different. We place the ultrasound machine to the patient's left and operate the probe with the left hand (Fig. 4.6), which leaves the right hand available for running the console (Fig. 4.7). Once you have the appropriate 2D view, maximize the angle of acquisition to 75–85° and proceed with 3D imaging (Fig. 4.8). During or after acquisition of volumes it is possible to process imaging information into slices of predetermined number and spacing, reminiscent of computer tomography. This technique has been termed *tomographic ultrasound imaging* (TUI) by manufacturers. The combination of true 4D (volume cine loop) capability and TUI allows simultaneous observation of the effect of maneuvers. Using this methodology, the minimal levator hiatus (MLH), defined in the midsagittal plane as the shortest line between the posterior surface of the symphysis pubis and the levator plate as the plane of reference, with 2.5 mm steps recorded from 5 mm below this plane to 12.5 mm above.

GE 4D View Software

The software is available on the GE machines and also through "Voluson club" for Voluson ultrasound machine purchaser. Separate licenses for the software are expensive and not available to those who do not have a machine.

2D/3D/4D Perineal Ultrasonography (pPFUS)

Basic Procedure and Equipment

For more details about this, refer to Chap. 3, "Instrumentation and Techniques for Perineal and Introital Pelvic Floor Ultrasound."

pPFUS Role in Evaluation of Pelvic Floor Trauma During Childbirth

The ability of 3D pPFUS to produce high-resolution images of the pelvic floor in 3 planes has rendered it a valuable tool in studying pelvic floor disorders stemming from childbirth injury. Although vaginal birth has long been linked with pelvic organ prolapse and urinary and fecal incontinence [10–12], recent advances in ultrasound and MRI have enabled researchers to identify the underlying pelvic floor injuries. Dietz et al. have reported levator ani muscle injury (avulsion) in 15–30% of parous women with one or more vaginal deliveries [13, 14]. Similar findings were reported by use of MRI [12]. Levator ani injuries can be depicted on 3D pPFUS/translabial ultrasound in the axial plane or the rendered volume, which is reproduced automatically by synthesis of the sagittal, coronal, and axial planes. For this, the plane of minimal hiatal dimensions is identified in the midsagittal view, as the shortest distance between the inferior most

Table 4.1 Characteristics of GE RAB4-8-RS used for perineal ultrasound, and GE RIC5-9 W-RS used for perineal ultrasound (GE Healthcare, Chicago, IL, USA)

Model	Description	Footprint	Bandwidth	FOV/Volume	Compatible with
 RAB4-8-RS	Real time 4D convex transducer	63.6 × 37.8 mm	2–8 MHz	70°/85° × 70°	Voluson *i*
	Real time 4D endocavity				
 RIC5-9 W-RS	Next generation real time 4D micro-convex endocavitary transducer, with wide FOV	22.4 × 22.6 mm	4–9 MHz	146°/146° × 120°	Voluson *i*

FOV field of view

Fig. 4.6 Left-handed application of the transducer during perineal ultrasonography ©. Shobeiri 2013

Fig. 4.7 The dominant hand generally operated the console. Unlike the BK console, (BK Ultrasound, Analogic, Peabody, MA, USA), the GE Voluson *e* buttons on the console (GE Healthcare, Chicago, IL, USA) are multifunctional; their function corresponds to the menu at the bottom of the screen. © Shobeiri 2013

aspects of the symphysis pubis to the anorectal angle, marked by the levator plate [15]. In order for best views to be achieved on this plane, a step-by-step standardized rotation technique is described below:

1. The transverse (axial) 3D volume is rotated approximately 90° clockwise in the plane of the puborectalis muscle (PRM) for an appropriate anterior-posterior (AP) orientation of the image. (The plane is defined as a line joining the inferior border of the pubic symphysis and the apex of the anorectal angle.)
2. The cursor dot is placed in the area of the pubic bone that allows the symphysis pubis to come into view on the coronal view.

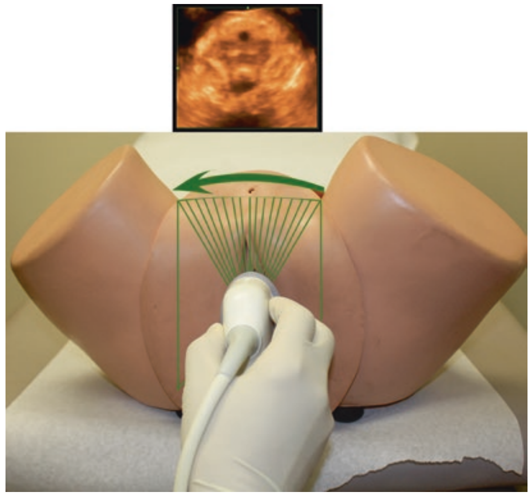


Fig. 4.8 3D pelvic floor volume acquisition with the GE RAB4-8-RS transducer. The internalized mechanism in the probe moves the crystals obviating the need for hand movement. The hand and the elbow should be rested in a steady position for good quality imaging. The volume obtained is displayed on the screen. © Shobeiri 2013

3. The coronal image is then analyzed millimeter by millimeter to identify and mark the location where the 2 pubic rami meet to form the inferior border of the symphysis pubis.
4. The sagittal plane is then rotated to align the inferior border of the symphysis pubis with the apex of the anorectal angle, noting that this allows the PRM to come into the full view on the transverse (axial) plane.

In this plane, measurement of the hiatal dimensions can be taken: anteroposterior and transverse diameter, as well as hiatal area, either at rest, muscle contraction or at Valsalva (Fig. 4.9). In addition avulsion injuries can be depicted by reference to this plane, however data suggest that these injuries are best demonstrated at pelvic floor contraction and particularly so on Tomographic Ultrasound Imaging (TUI) mode in order to appreciate the extent of injury (partial injury or complete avulsion) [16]. Fig. 4.10 shows a levator muscle injury (LAM) avulsion in a parous woman, while levator hiatal overdistension can be appreciated in Fig. 4.11.

Levator ani muscle injury has been proposed as one of the potential causes for pelvic organ prolapse and to a lesser degree stress urinary

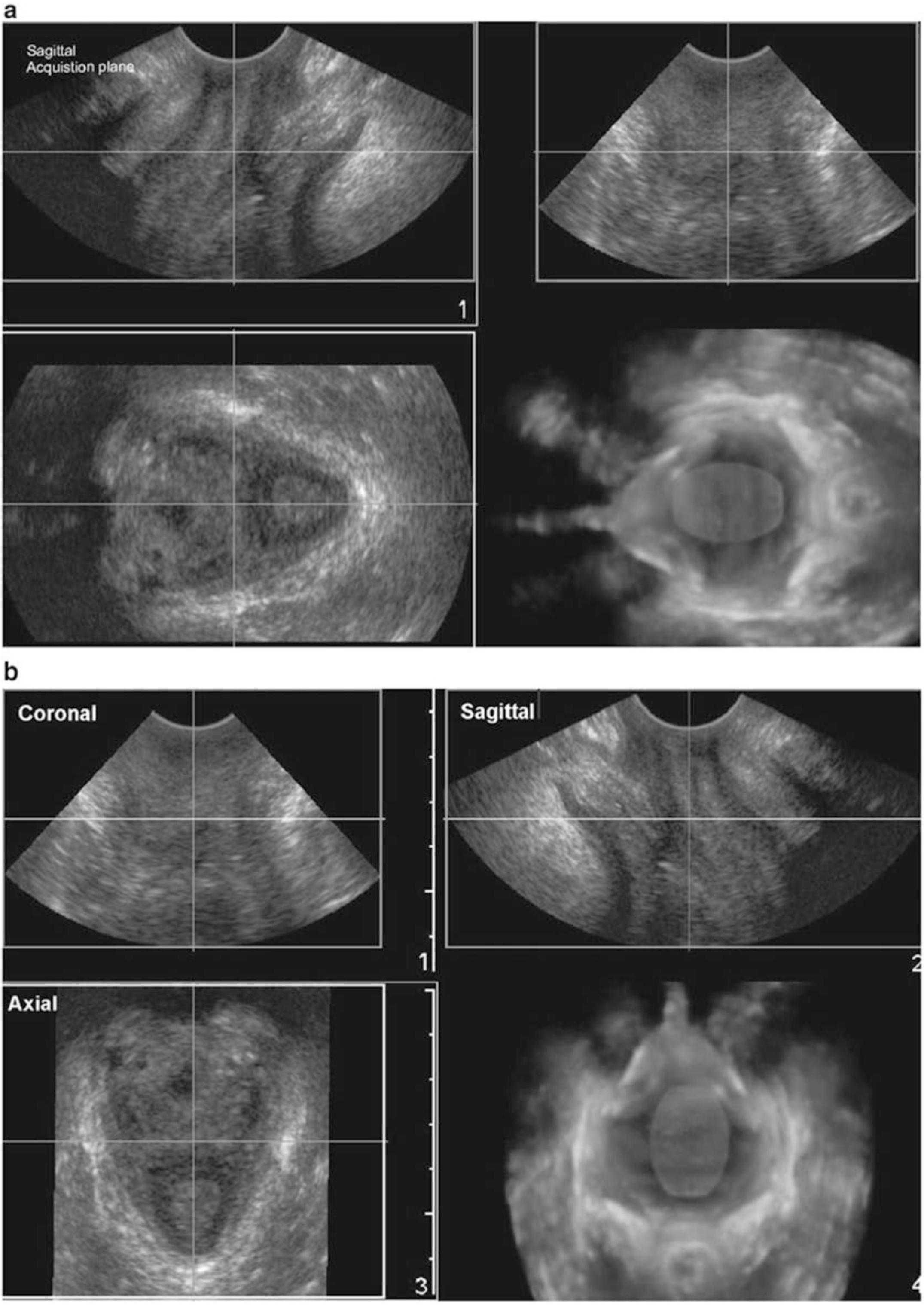
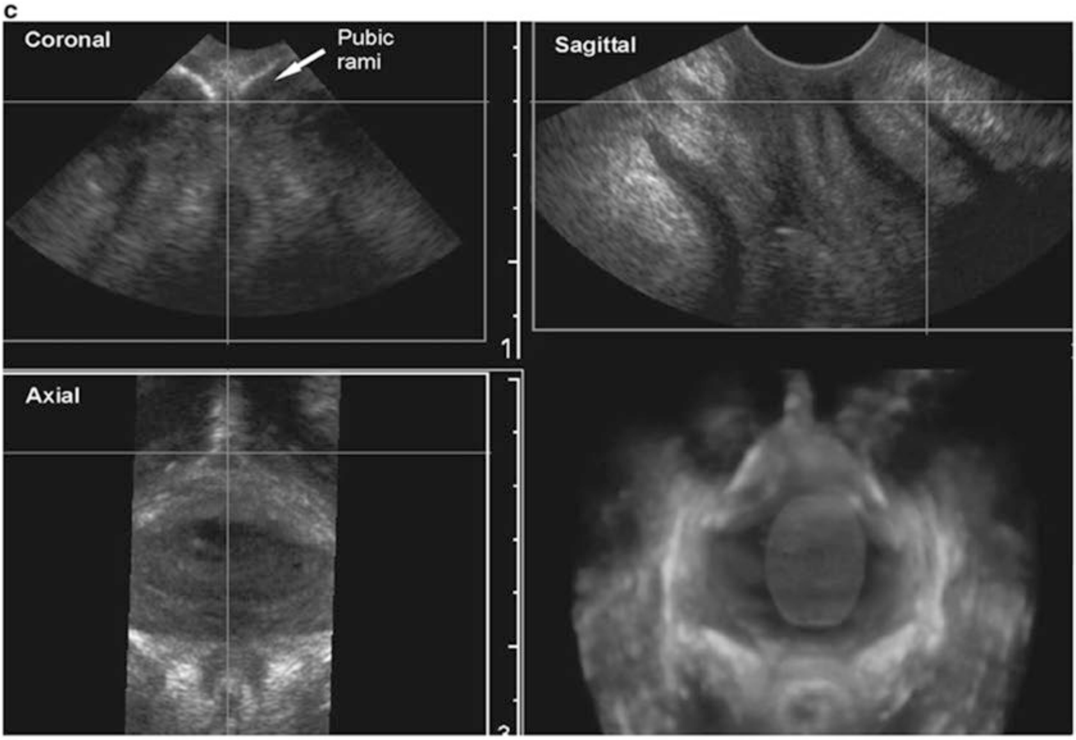


Fig. 4.9 3D perineal pelvic floor ultrasound volume post-processing step by step: (**a**) perineal ultrasound of the pelvic floor hiatus with the sagittal acquisition plane—sagittal plane optimized by visualizing the pubic symphysis and the anorectal angle; (**b**) volume is rotated to orient the axial plane upright. The multiplanar of the 3D perineal volume shown with coronal, sagittal, and axial (transverse) planes identified; (**c**) the cursor dot is moved in the axial (transverse) plane in the area of the pubic symphysis. The pubic rami and pubic symphysis are visible in the coronal plane.

c



d

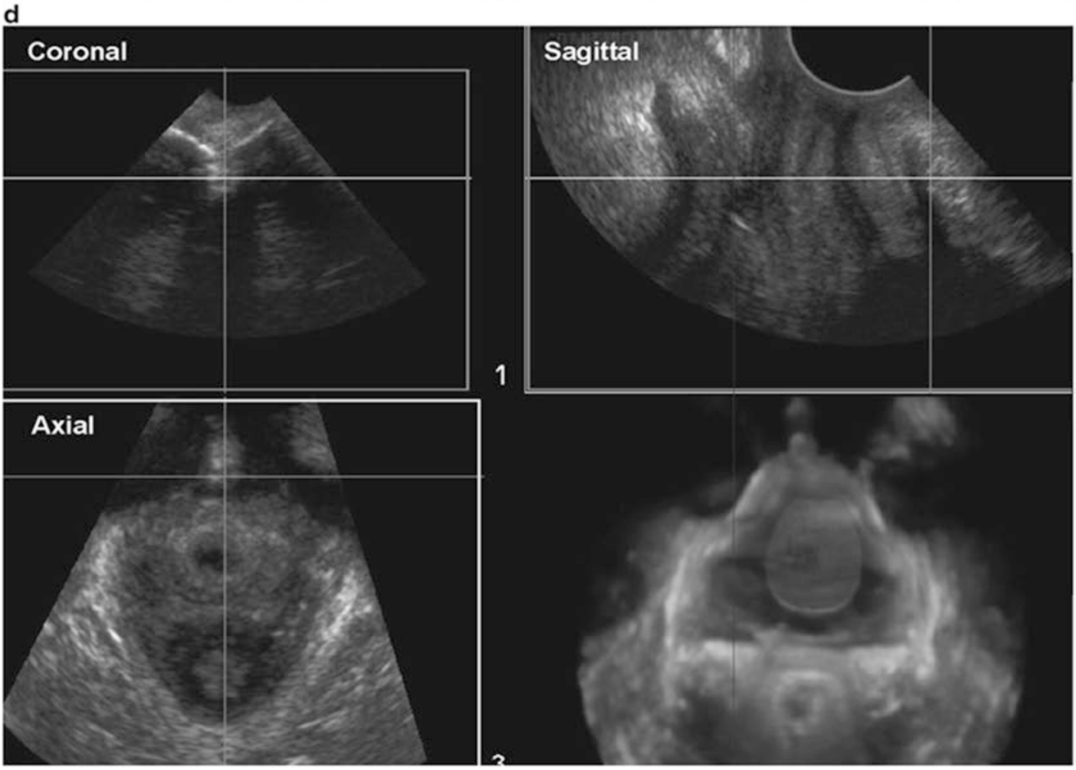


Fig. 4.9 (continued) The dot-marker is positioned on the pubic symphysis; (**d**) in the sagittal plane the volume is rotated to align the pubic symphysis with the anorectal angle which—represents the puborectalis muscle (PRM) plane. The PRM is seen encircling the pelvic floor hiatus in the transverse image; (**e**) the perineal view of the pelvic floor hiatus after completion of the volume rotation. The rendered thick slice (10 mm) allows for more detailed assessment of the hiatal structures. The pelvic floor hiatus anatomy includes cross-section of the urethra, vagina, and the anorectum. The hiatus is encircled by the PRM

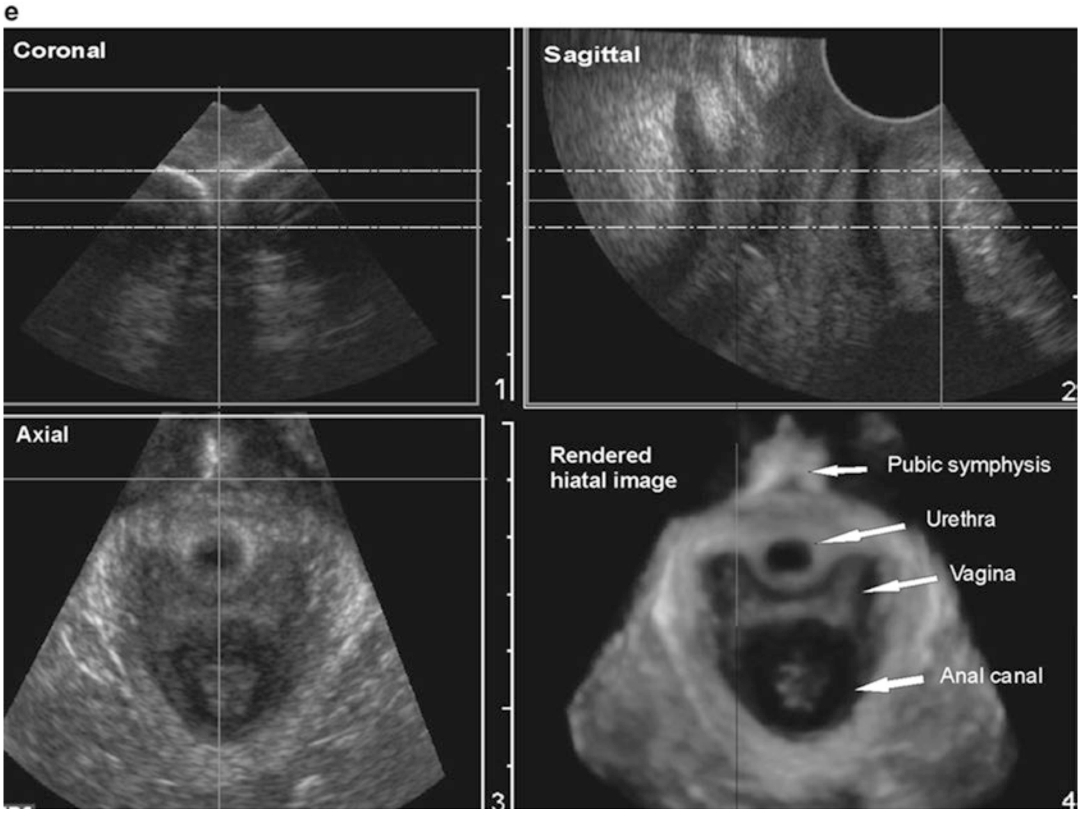


Fig. 4.9 (continued)

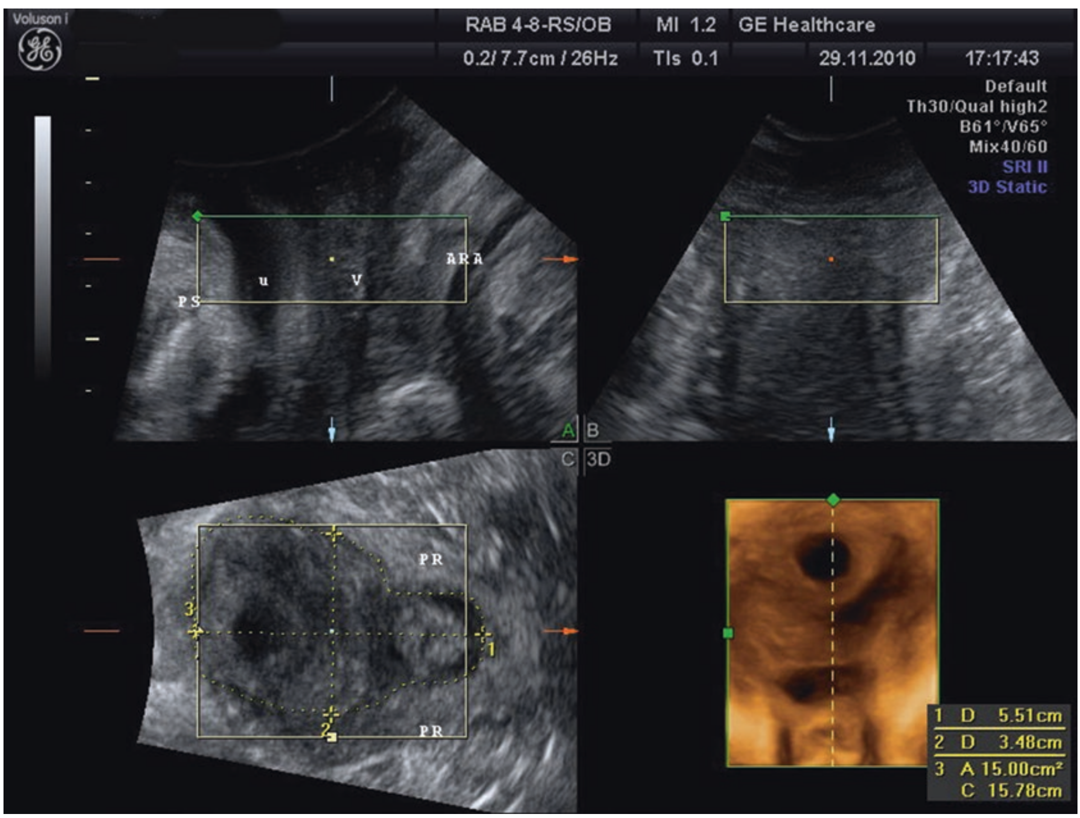


Fig. 4.10 Levator hiatus biometry on an asymptomatic patient where measurements of the antero-posterior and transverse diameters, as well as area are taken. Symphysis pubis (PS), urethra (u), vagina (V), anorectal angle (ARA), puborectalis muscle (PR)

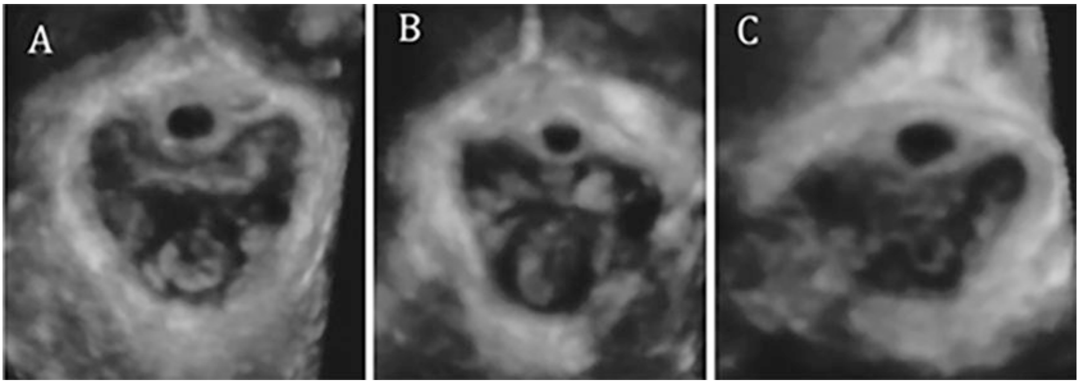


Fig. 4.11 3D perineal pelvic floor ultrasound of the axial 10 mm thick slice rendered hiatal image showing normal hiatal structures (**a**) and example of the puborectalis muscle injury (**b**, **c**). Note how urethra and vagina shift away from the midline to the side where the puborectalis muscle (injury is greater)

incontinence [13, 14]. Studies on MRI of the pelvic floor have looked into grading LAM injuries and suggested an association with prolapse [16], however no universal agreement exists so far on a classification system for such defects [17]. This becomes highly relevant when considering data that suggest that the origin of the LAM from the pubic bone may not be visible bilaterally in up to 10% nulliparous women, alluding to inherent limitations in 3D ultrasonography or/and anatomical variations in the LAM morphology [18].

Several risk factors, associated with childbirth, have been identified for LAM injury; forceps delivery incurs an odds ratio (OR) of up to 14.7, protracted second stage of labor an OR of 2.27, while vacuum delivery does not seem to constitute a risk factor [19, 20]. In turn, LAM injury, as a result of vaginal delivery, has been shown to correlate with prolapse in the anterior and midvaginal compartments, but not with rectocoele or stress urinary incontinence [14]. LAM defects are also a strong predisposing factor for recurrent prolapse in women with previous surgical repair [21].

pPFUS Role in Evaluation of Urinary Incontinence

One of the very first applications of 2D perineal/introital ultrasound of the pelvic floor was the assessment of bladder neck position in women with stress urinary incontinence. In 1995 Schaer et al. [3]. described a coordinate system for bladder neck and urethral mobility ultrasound appearance; *x*-axis is determined by a straight line through the central portion of the pubic symphysis, while a line perpendicular to that at the lower level of the pubic symphysis represents the *y*-axis. The urethrovesical angle or the UVJ is measured by creating a perpendicular line from the *x*-axis on the image, and following this line to the margin of the bladder base when the patient is at rest. The most common index in assessment of bladder neck position and urethral mobility are the urethral height (H), which is defined as the distance between the lower edge of the pubic symphysis and the bladder neck [22] (Fig. 4.12). In continent women normal values measured for urethrovesical angle is 96.8° at rest and 108.1° with Valsalva maneuver, and for height are 20.6 and 14.0 mm, respectively [22].

Another index that can be studied with pPFUS in regard to the bladder neck is the posterior urethrovesical angle. This is the angle between the urethral axis and the bladder floor and can be measured at rest, at maximum contraction or maximum Valsalva (Fig. 4.13).

Previous studies have shown high reproducibility of the ultrasound measurement of bladder neck descent [23]. Although there is no definition of normality regarding bladder neck descent, cutoffs between 15–40 mm have been proposed to define hypermobility. Various confounders such

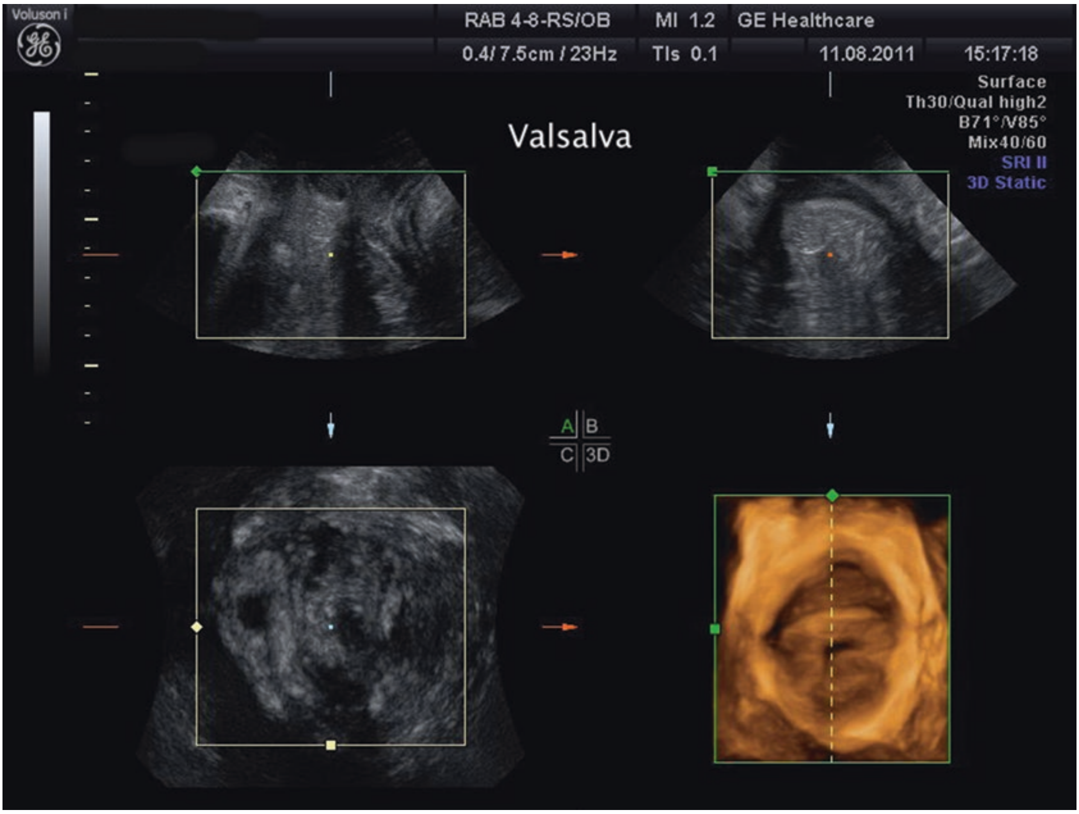


Fig. 4.12 3D translabial ultrasound on a woman with stage 2 posterior wall prolapse showing levator hiatal overdistension (ballooning) at Valsalva effort in axial and rendered image. Note the rectocoele protruding in the coronal and rendered image

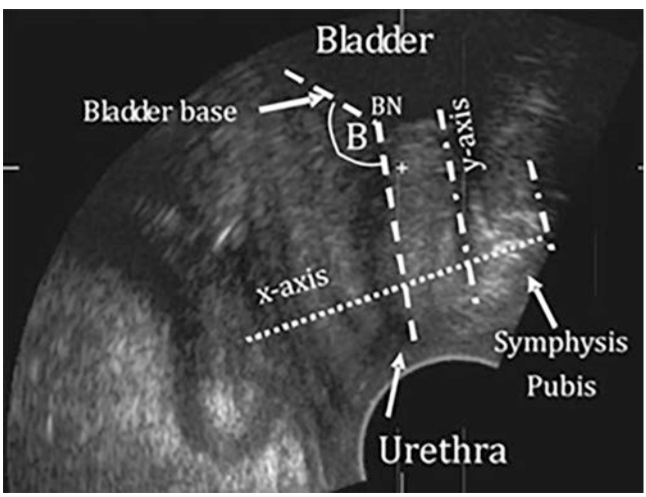


Fig. 4.13 The posterior urethrovesical angle measurement method with perineal ultrasound described by Schaer et al. [3]. The rectangular coordinate system was constructed with the *y*-axis at the inferior symphysis pubis and the *x*-axis perpendicular through the mid-symphysis pubis. The posterior urethrovesical angle (B) was measured with a line through the urethral axis and the other line through the at least one-third of the bladder base

as bladder volume, patient's position, and catheterization have been shown to influence measurements. Interestingly, mobility appears to be greater when the bladder is empty, whereas better imaging of BN funneling is observed when the bladder is full [24]. It is also worth noting that executing, and more so standardizing, an effective Valsalva maneuver can often be difficult, especially in nulliparous women who frequently co-activate the levator muscle [25].

Bladder neck descent has both a congenital and an environmental etiology, the latter being mainly linked with direct birth trauma and prolonged second stage of labor [26, 27]. Perineal ultrasound imaging of the bladder neck with a standard Valsalva pressure of 40 cm H_2O has been used as a method of predicting the development of stress urinary incontinence postnatally; a woman in the third trimester with a bladder neck movement of greater than 1 cm or 40° has a 50% chance of persisting postnatal stress incontinence. If the bladder neck movement is less than this, then the risk of postnatal stress incontinence is 5% [28]. Antenatal pelvic floor exercises can halve the incidence of postnatal stress incontinence in the high risk group [29]. Correlation between ultrasound findings of bladder neck descent measurements and urodynamic testing has been inconsistent [30, 31] and largely does not help distinguish continent and incontinent women [32].

Another easily visualized feature of the urethrovesical junction is urethral funneling [33]; widening of urethral meatus may be observed on Valsalva, and sometimes even at rest, and is often, but not always, associated with urine leakage.

3D ultrasound scanning of the pelvic floor can also clearly depict the urethral sphincter, offering a useful tool for investigating both urethral anatomy and function [34, 35]. This technique had been previously validated by correlating urethral images from cadavers with histological findings [36]. Athanasiou et al. have demonstrated that women with stress urinary incontinence have smaller urethral sphincter volumes, as well as shorter and thinner urethras than their continent counterparts [37]. A recent study showed that 3D pPFUS is reliable in measuring urethral sphincter volume in nulliparous asymptomatic women [38]. The technique, which involves volume calculation on 1-mm cross-sectional areas at set distances across the urethra rather than the use of standardized mathematical equations, is demonstrated in Fig. 4.14.

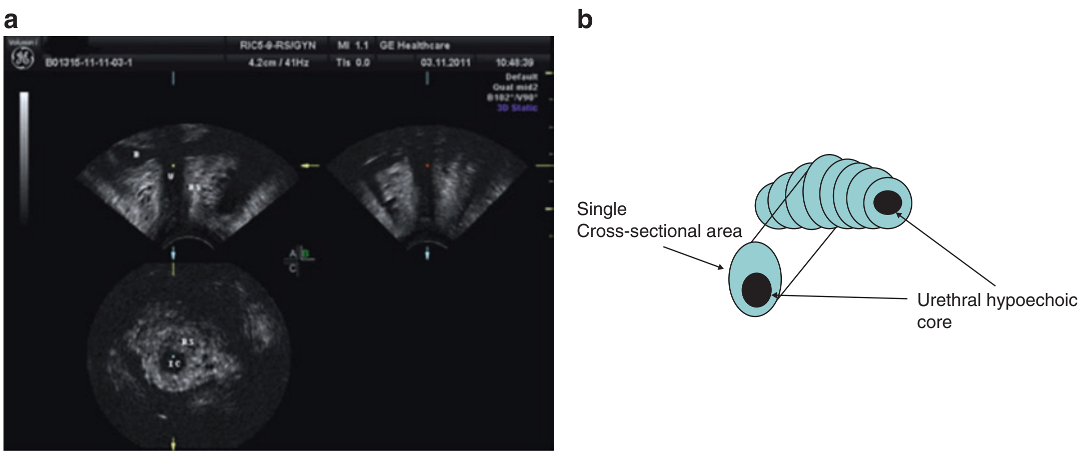


Fig. 4.14 (*Left*) 3D perineal pelvic floor ultrasound image of the female urethra. The volume measurements of the core sphincter and total sphincter were taken in the axial plane (*bottom left*). Bladder (B), inner core (IC), urethra lumen (U), rhabdosphincter (RS). (*Right*) Schematic presentation; multiple shaded cross-sectional areas of the urethral sphincter measured by tracing the outline of the urethral sphincter at 1-mm intervals. The volume is computed from the cross-sectional areas multiplied by the slice gap of 1 mm

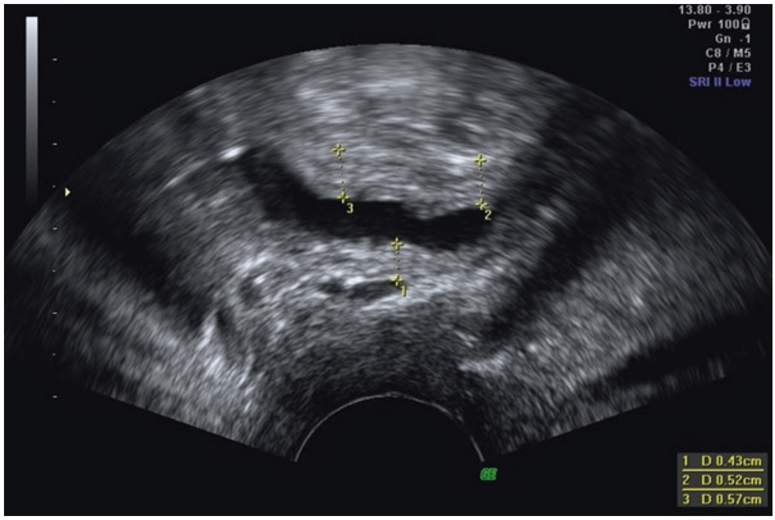


Fig. 4.15 2D ultrasound image of BWT measurement. Measurements are taken at the trigone (*1*), anterior wall (*2*), and dome (*3*) of the bladder and the average thickness is calculated. The image shows the transvaginal approach, however the exact same views can be obtained via the introital or perineal technique

By use of this technique researchers have demonstrated that black nulliparous premenopausal asymptomatic women have a larger urethral rhabdosphincter than their Caucasian counterparts, perhaps partially explaining the racial differences in the prevalence of stress urinary incontinence [39, 40]. Although the clinical benefit of measuring urethral sphincter volume in patients with urinary incontinence is so far unsubstantiated, the value of perineal ultrasound as an adjunct in guiding women with stress urinary incontinence through pelvic floor muscle training has been demonstrated [41, 42].

2D perineal ultrasound has been utilized as a diagnostic adjunct for overactive bladder and detrusor overactivity. Increased bladder wall thickness (BWT) (proposed cut-off is 5 mm) has been described in patients with overactive bladder (OAB) or detrusor overactivity and is hypothesized to be associated with detrusor hypertrophy secondary to isometric contractions [43, 44]. Recent systematic reviews have looked at different techniques of BWT measurement and suggested that discrepancies between the described techniques do not allow for safe conclusions about its diagnostic accuracy to be drawn (Fig. 4.15) [45].

pPFUS Role in Evaluation of Pelvic Organ Prolapse

The advent of 3D/4D technology in perineal/translabial ultrasound has popularized the modality as an aid to the clinical evaluation of uterovaginal prolapse. One of the first papers by Dietz et al. described a quantification method for POP by use of pPFUS and reported good correlation with clinical staging of prolapse by pelvic organ prolapse quantification system (POPQ), more so in the anterior and midvaginal compartment [46]. Lone et al. explored the relationship between 2D perineal ultrasound and POPQ system in staging prolapse and concluded that the accuracy of pelvic floor ultrasound in quantifying prolapse is limited [47]. Occasionally, a clinical finding of anterior wall prolapse may form a false impression of cystocele, while the bulging the tissue is in fact a urethral diverticulum or an anterior enterocele. pPFUS of the pelvic floor can be helpful in enhancing the diagnosis and thus dictate the appropriate management (Fig. 4.16).

Ultrasound imaging of the posterior compartment is characterized by good agreement between the degree of rectocele on examination and the rate of rectal ampulla descent on pPFUS at

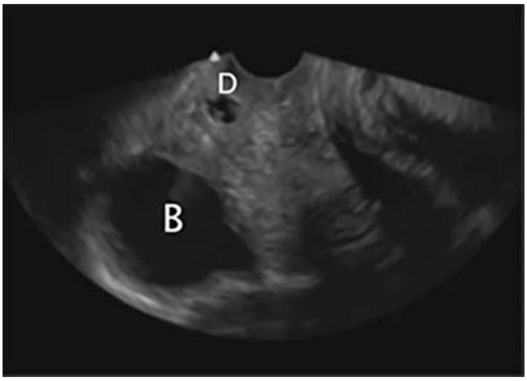


Fig. 4.16 2D ultrasound sagittal view of a urethral diverticulum (D). The bladder (B) is shown cephalad to the diverticulum

Valsalva; intra-class correlation with clinical examination was 0.75 for ampullary descent, 0.93 for rectocele depth, and 0.91 for rectocele width [48]. Further data suggest that rectovaginal septal defects can be easily identified on pPFUS and help differentiate between a rectocoele with a defective septum, a distensible septum accompanied by prolapse symptoms, a recto-enterocele or indeed an intussusception [48]. Some studies on the use of pelvic floor imaging on patients with defecatory symptoms showed a good degree of agreement between ultrasound and defecography [49], while others reported a lower degree of agreement between the two modalities for the diagnosis of rectocele, but confirmed the high concordance for intussusception [50]. Despite dynamic perineal ultrasound showing good agreement with defecography in the diagnosis of cul-de-sac hernia in patients with evacuatory difficulty, the two techniques did not agree on the contents of the hernia, suggesting a complementary role for pPFUS in optimizing the plan for surgical treatment [51].

pPFUS Role in Evaluation of Fecal Incontinence

Evolution of pelvic floor imaging has led to optimization of the diagnostic workup for women with anal incontinence. The anal sphincter complex (ASC) and, to a lesser extent, the levator plate/PRM are responsible for maintaining the continence mechanism; direct or indirect injury to either muscle during childbirth comprises one of the main causes of fecal incontinence.

Perineal/introital ultrasonography offers a credible alternative to endoanal ultrasound for studying the anal sphincter muscle complex, and the puborectalis muscle, where indicated. pPFUS utilizes cheaper and more readily available equipment than endoanal ultrasound and depiction of the relevant anatomy correlates well with the endoanal approach, which is considered as the gold standard [49, 52].

The technique involves using an endovaginal (iPFUS)/perineal transducer (pPFUS) positioned on the perineum and oriented caudally; the acquired sagittal image should visualize the anal canal and the anorectal angle, as mentioned before (see Fig. 4.10). The dynamic changes in the displacement of the anorectal angle (ARA) can provide visual biofeedback for levator ani activity and are easily appreciated and readily accepted by women [42]. For 3D pPFUS the image is taken as always in 2D mode at sagittal orientation of the probe (axial orientation could be an alternative), so as for the anorectal angle to be pictured on the far right of the image (see Fig. 4.10). Images are captured either at rest or maximum contraction and offline analysis can be performed by free manipulation of the images in sagittal, coronal, and axial plane. Additionally, the sphincter structures can be further characterized using single thick slice or multi-slice assessments tools. The inner portion of the axial sphincter image has been called "mucosal star" (Fig. 4.17) [53]. The visualization of the mucosal folds of the anal canal differentiates pPFUS from endoanal technique, where the inserted transducer flattens the folds of the anal mucosa. The appearance of the sphincter is different depending on the level of capturing. In the middle of the anal canal, the classical "target" sphincter appears. The echolucent IAS encircles the anal mucosal layer. IAS, in turn, is encircled by the echogenic external anal sphincter (EAS). As with other structures use of tomographic sonography with 3D volume processing can enhance depiction of the relevant anatomy (Fig. 4.18).

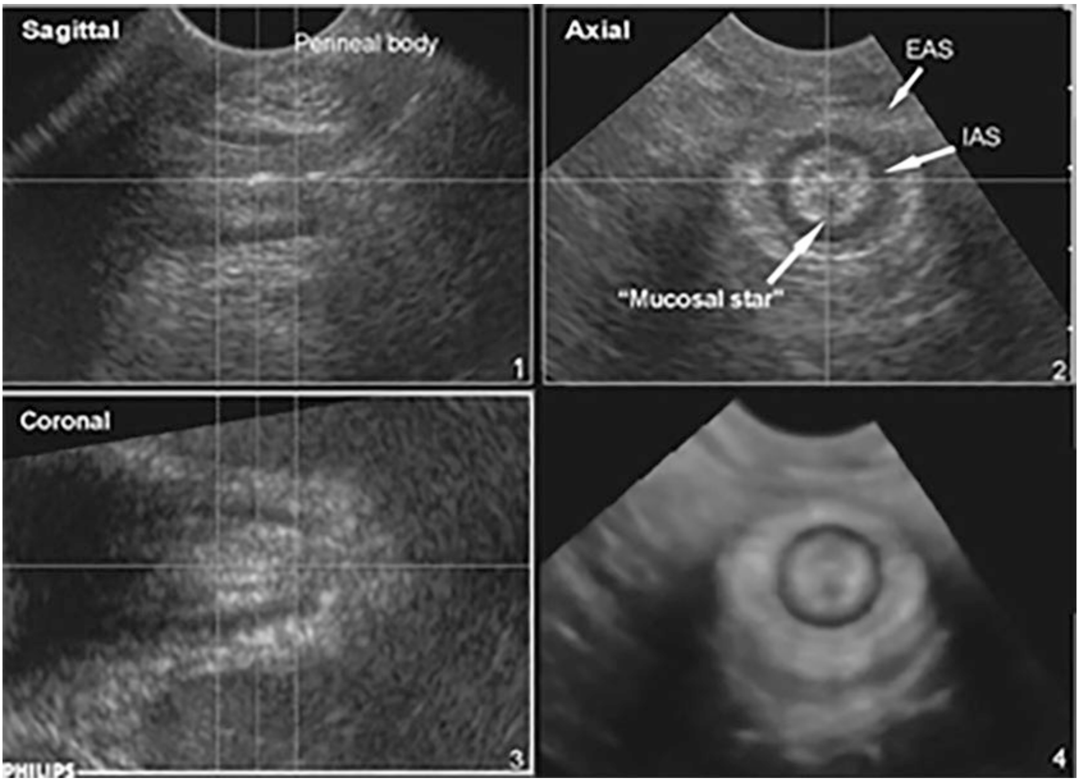


Fig. 4.17 3D perineal pelvic floor ultrasound of the normal anal canal: the multiplanar image with three orthogonal planes shown: sagittal, coronal, and axial identified. The rendered thick slice (10 mm) allows for integrated evaluation of the mid-anal sphincter portion. In the sagittal plane the perineal body is seen as an oval-shape structure. On the axial plane the mucosal fold—"mucosal star" and the classic representation of the mid-anal canal with hypoechoic internal anal sphincter (IAS) and hyperechoic external anal sphincter (EAS)

pPFUS of the pelvic floor allows characterization of anal sphincter defects. Studies have compared its accuracy in depicting obstetric anal sphincter injuries (OASIS) with endoanal ultrasound and MRI. Roos et al. showed that while pPFUS was useful in identifying normal anatomy, the sensitivity for assessing anal sphincter defects was inferior to the endoanal approach [54]. Other researchers however suggested that pPFUS accurately depicts the anatomy of the ASC at all levels and its diagnostic ability for defects correlates highly with intraoperative findings at the time of surgical repair [55, 56].

Valsky and co-authors used 3D pPFUS to study primiparous women who delivered vaginally and had an overlap repair of sphincter tear; they described the "half moon sign" (IAS thinning in the area of damage and opposite thickening), as well as an abnormal appearance of mucosal folds as signs indicative of sphincter damage [57]. Further comparison studies on the diagnostic accuracy between endoanal and perineal ultrasonography in women with fecal incontinence have emerged; Oom et al. revealed good agreement between 2D-endoanal ultrasound and 3D pPFUS in detecting both external and internal anal sphincter defects. Excellent interobserver agreement for diagnosing anal sphincter defects on 3D pPFUS was also demonstrated [58].

Despite some obvious advantages of the 3D pPFUS or iPFUS over endoanal ultrasonography in assessing women with fecal incontinence (non-invasive procedure, ability to depict global anatomy at the dynamic state of pelvic floor contraction), lack of standardization of technique and reporting has not allowed pPFUS to become the modality of choice for anal incontinence thus far.

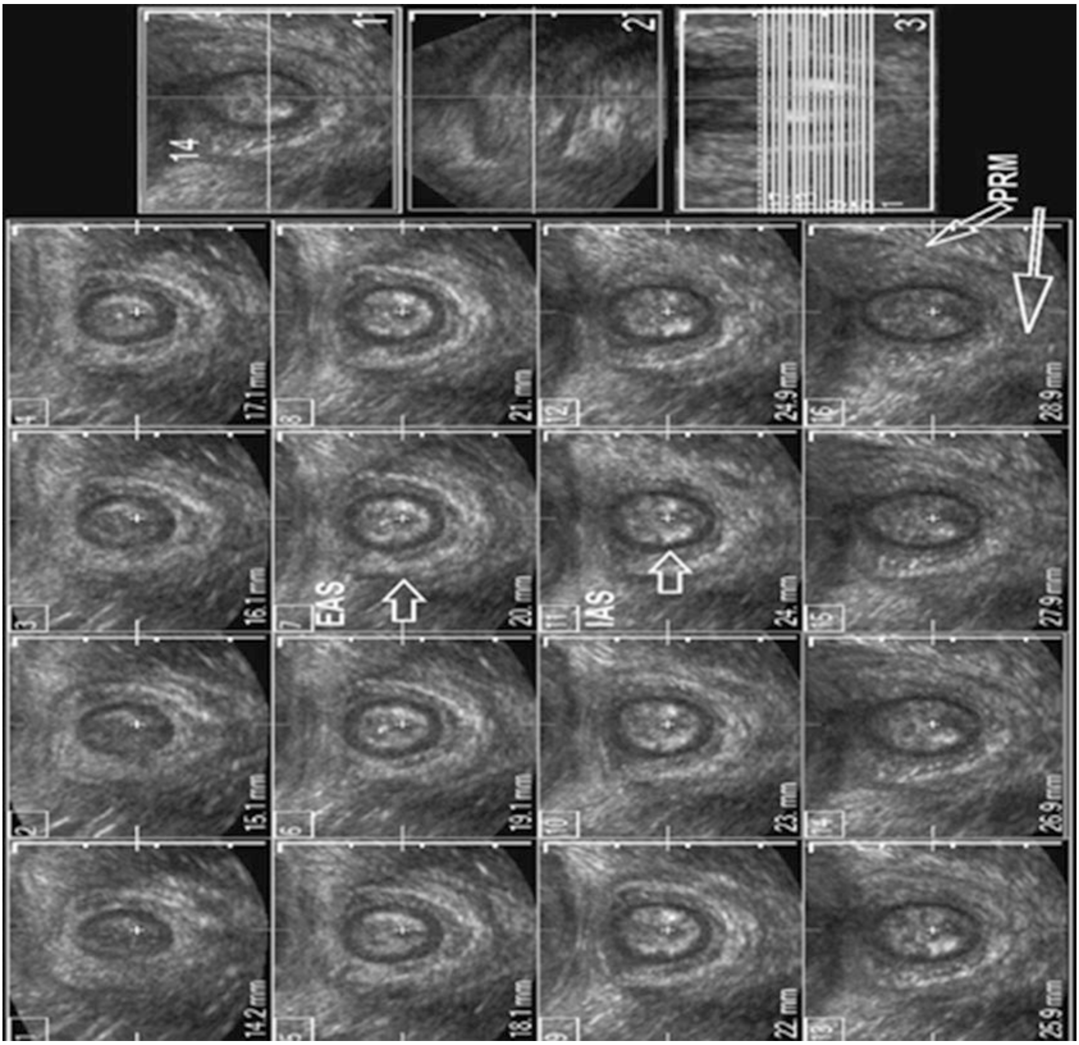


Fig. 4.18 3D perineal ultrasound of the anal canal with 1 mm slices from the anal verge to the anorectal angle. Internal anal sphincter (IAS), external anal sphincter (EAS), and posterior portion of the puborectalis muscle shown

pPFUS Role in Evaluation of Vaginal Implants Such As Mesh and Bulking Agents

The role of pelvic floor ultrasound in urinary incontinence and uterovaginal prolapse has strengthened since the advent of real time 3D technology. More and more urogynecologists are nowadays utilizing multicompartmental pelvic floor ultrasonography not only as an adjunct in the diagnostic workup for patients with pelvic floor disorders, but also as a tool to assess surgical treatment outcomes.

Bladder neck mobility following insertion of tension-free vaginal tape type mid-urethral slings (MUS) was one of the first targets for researchers; Yalcin et al. suggested a significant difference between successful surgery and failure based on bladder neck mobility postoperatively; however, the wide range of measured values pointed at a significant overlap between success and failure groups [59]. Subsequent work on positioning of mid-urethral mesh sling as seen by pelvic floor ultrasound failed to show a relationship, however more promising results in the depiction rate of slings emerged [60–62]. Schuettoff et al.

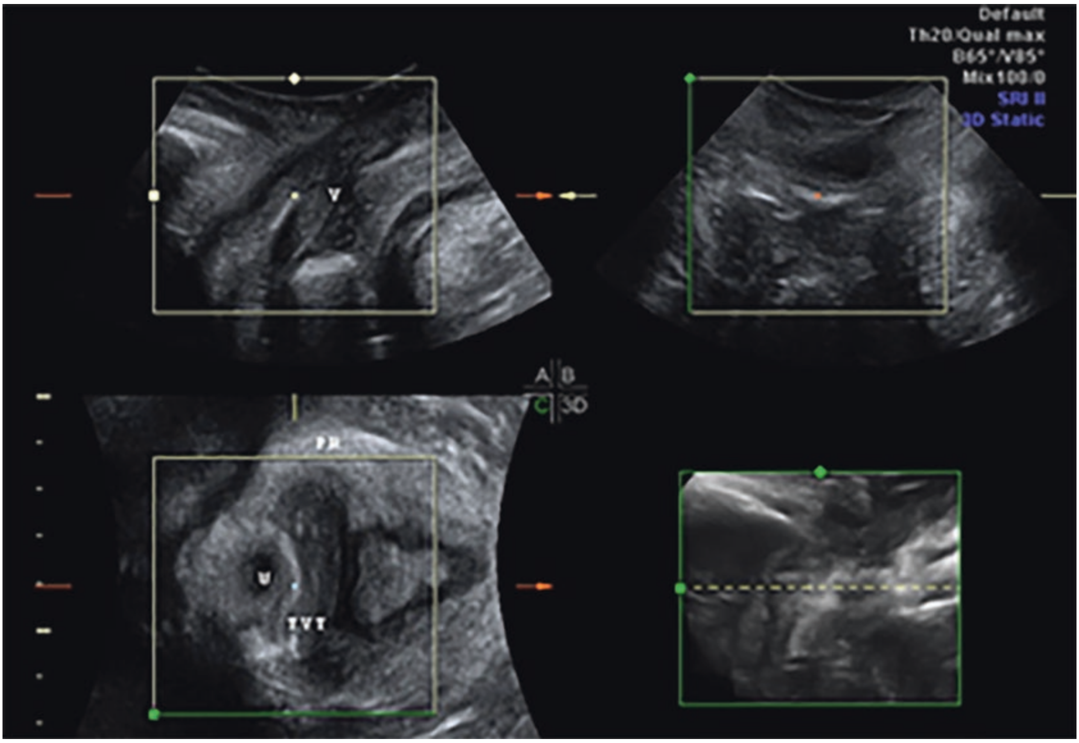


Fig. 4.19 3D perineal ultrasound of the pelvic floor demonstrating tension-free vaginal tape sling in the three orthogonal planes and the rendered volume

compared the use of MRI and pPFUS and suggested that ultrasound is most suited for assessing the suburethral and periurethral mesh portion, whereas MRI is more suitable for mesh evaluation in the retropubic space [63]. Ultrasound can also show the spatial relationship between a suburethral sling, the urethra, and the symphysis pubis. Mid-urethral slings are made, by and large, of polypropylene mesh, which transmits a hyperechoic signal on ultrasound (Figs. 4.19 and 4.20). During Valsalva effort the bladder neck will move like an arc around the posterior symphysis pubis closing the gap between the symphysis and the sling thereby compressing the urethra and avoiding urine leakage. Analysis of this movement before and after implantation of a sling suggested reduced mobility of the mid part of the urethra following surgery, although no difference was found between successful procedures and failures [64]. Contradictory data from the same group demonstrated that a wider gap between a transobturator sling and the symphysis pubis is associated with failure of SUI surgery [65]. The ability to review the variability in the location movement of slings allows clinicians to comprehend the reasons for the variation in the actual efficacy of this surgical technique and to help determine if a sling needs to be adjusted [66]. On the whole, data from various research groups have indicated that a mid-urethral position of the sling is not imperative for successful treatment of SUI [60, 61]. Recently, the work by Jiang and co-authors added to the controversy as they reported their findings from 153 women with SUI, suggesting that positioning of the MUS at the bladder neck appears to be associated with a higher stress urinary incontinence recurrence rate, whereas positioning at the proximal and middle urethra had the best outcomes [67]. Shobeiri described the use of 3D pelvic floor ultrasonography intraoperatively for releasing the mid-urethral part of a sling to overcome voiding dysfunction [68].

Fig. 4.20 3D perineal ultrasound of the hiatus showing a Monarc tape in the axial image

pPFUS has been shown to be valuable in depicting mesh implanted for prolapse surgery. Mesh "shrinkage" of "folding" can be diagnosed on scan by measuring the difference in size between the mesh at implantation and at scanning postoperatively [69]. A more recent paper by Staack et al. compared pPFUS images of mesh and slings with clinical and intraoperative findings and reported 100% sensitivity in determining the sling type and its location, as well as 100% sensitivity in correctly diagnosing urethral and bladder erosion [70].

Urethral bulking agents are used to improve continence by enhancing urethral coaptation. Periurethral collagen has been imaged by perineal ultrasound. Using an endovaginal probe Elia and Bergman found that optimal location of collagen implant was less than 7 mm from the bladder neck [71]. With the use of 3D ultrasound, Defreitas et al. suggested that optimal periurethral collagen location is a circumferential distribution around the urethra, while an asymmetric distribution is associated with a significantly smaller improvement in incontinence symptoms [72]. Poon and Zimmern described the use of 3D ultrasound as part of their standard algorithm in managing incontinence in patients who undergo periurethral collagen injection; if a patient has no or minimal improvement after collagen injection therapy and ultrasound shows low volume retention of collagen or an asymmetric distribution, the patient is offered a repeat injection in the area of deficiency. In case of no symptom improvement with a circumferential pattern seen on ultrasound, the injection is considered optimal and the patient is offered an alternative treatment [73].

pPFUS Role in Planning Surgery and Summary/Future Directions

The considerably high failure rates of surgical repair of prolapse, mainly in the anterior compartment, necessitate a tighter diagnostic workup and better selection process for choosing the optimal procedure for women undergoing surgery. Dietz et al. have reported higher support failure in the anterior compartment in women with levator ani muscle avulsion or overdistension ("ballooning") [74], which may help clinicians opt for a mesh-augmented procedure. Lone and co-authors compared 2D perineal ultrasound—assisted ad hoc by additional 3D endovaginal ultrasound—with clinical examination for pelvic floor disorders and found that pPFUS enhanced the differential diagnosis in the anterior compartment by distinguishing vaginal cysts and urethral diverticula from pelvic organ prolapse [75]. Bladder wall thickness (BWT) is another scan index of the anterior compartment that could help plan for the appropriate surgical technique; increased BWT has been linked to de novo urgency incontinence following anti-incontinence procedures, thus allowing the surgeons to better counsel their patients regarding potential risks of surgery [76].

Perhaps the pre-operative value of pPFUS is even greater when it comes to defects in the posterior compartment. Lone et al. reported on improvement in diagnosis of enterocele with multi-compartmental pelvic floor scan, which were not picked by clinical examination; diagnosis of enterocele and intussusception was further enhanced after primary surgical correction of the prominent prolapse in the posterior or the other two compartments [75]. Dynamic pPFUS showed good agreement with defecation proctogram in diagnosing enterocele in patients with evacuatory difficulty, but the two techniques did not agree as to the contents of the hernia or the degree of transvaginal descent, highlighting the potential role of pPFUS in planning surgery appropriately [51]. More recently, Weemhoff et al. reported that pPFUS findings of intussusception was predictive of abnormal evacuation proctography, however prediction of enterocele was poorly compared with proctogram findings [77].

Irrespective of the vaginal compartment studied, pPFUS seems to correlate moderately to well with clinical examination by POPQ in assessing uterovaginal prolapse [47]. Other researchers have stressed the non-superiority of pPFUS in staging symptomatic prolapse in comparison to clinical examination [78]. Nonetheless, it appears that pPFUS of the pelvic floor can indeed be a useful tool for urogynecologists and pelvic reconstructive surgeons in their efforts to optimize surgical planning due to its qualitative characteristics and, less so, its ability to up- or down-stage pelvic organ prolapse.

In summary, ultrasound is a valuable tool in the hands of the urogynecologists who know the ultrasound machines and probes' properties and how to interpret the resulting 2D images or 3D/4D volumes. Ultrasound competency correlates with diagnostic accuracy. Ultrasound should be advocated as a core competency for urogynecology fellows. It is reasonable to start with 2D perineal imaging and graduate to 3/4D introital and perineal PFUS and subsequently master multicompartmental pelvic floor ultrasonography.

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