3 Instrumentation and Techniques for Translabial and Transperineal Pelvic Floor Ultrasound

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Learning Objectives

1. To describe 2D and 3D sonographic anatomy of the pelvic floor structures
2. To understand the transperineal and translabial ultrasound technique with transducer position and image orientation and optimization
3. To provide overview of angles and measurements in transperineal and translabial pelvic floor US
4. To appreciate role of transperineal and translabial pelvic floor US in pelvic floor disorders

3.1 Introduction

Pelvic floor disorders include pelvic organ prolapse (POP) urinary and anal incontinence (UI and AI). Pelvic floor disorders have high prevalence in women of all ages [1]. Pelvic floor disorders may also manifest with myriad of urinary, defecatory, and pain symptoms. At times the symptoms of pelvic floor disorders and clinically observed findings do not correlate [2]. Imaging techniques have increased our understanding of pelvic floor disorders by providing more insight into pathophysiology of these conditions and enhancing clinical assessment. Imaging studies that are used to further understand pelvic floor disorders are defecography or dynamic fast-field magnetic resonance imaging (MRI) [3].

Defecography can demonstrate interaction of rectal evacuation with the other pelvic viscera and presumed relationship of pelvic musculature, but it requires multi-organ opacification and exposure to radiation [4]. Dynamic MRI imaging obtains high-resolution pelvic structures images; however MRI is an expensive and not widely available technique requiring radiology expertise. Furthermore provocative maneuvers for dynamic MRI are usually performed in non-physiologic positioning [3].

For the purposes of this chapter the ultrasound performed by placing an abdominal 2D/3D/4D probe between the labia to obtain pelvic floor volumes is referred to as Trans Labial Ultrasound (TLUS). The ultrasound performed by placing a 2D/3D/4D endovaginal ultrasound probe on the perineal area will be called Transperineal Ultrasound (TPUS). There is quite an overlap in terminology where TPUS and TLUS are used interchangeably. Transperineal ultrasound (TPUS) has been used for the past 25 years to assess the

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anatomy and physiology of the genitourinary tract [5–7]. TPUS provides noninvasive static and dynamic visualization of pelvic anatomy with use of easily accessible ultrasound platforms [8]. Despite the ease of use and long history pelvic floor ultrasound still remains mostly experimental technique with many possible applications in clinical practice. Large body of TPUS literature has emerged in the last decade making progress in developing the TPUS technique in investigation of pelvic floor disorders; however still much work is needed to standardize imaging terminology and outcome measures [9]. TPUS can investigate pelvic floor anatomy and function in variety of pelvic floor disorders, including UI, POP, and AI and can be used as an adjunct to pelvic muscle training. This chapter will focus on practical aspects of transperineal ultrasound techniques, pelvic floor biometry, and application of ultrasound in investigating different pelvic floor conditions.

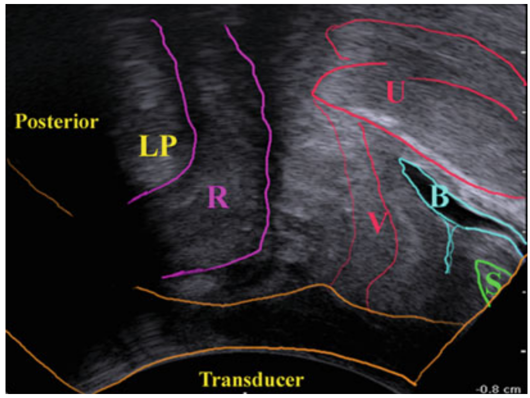


Fig. 3.1 This view demonstrates CORRECT positioning as the starting 2D field of view includes the pubic symphysis (S) anteriorly and the levator plate (LP) posteriorly. Also noted are the bladder (B), uterus (U), vagina (V), anorectum (R) © SHOBEIRI 2013

3.2 Translabial Ultrasonography

3.2.1 2D Translabial Ultrasonography

Regardless of the intention to perform 3D Translabial Ultrasound (TLUS), Transperineal Ultrasound (TPUS) vs. a 3D Endovaginal Ultrasound (3D EVUS) or a 3D Endoanal Ultrasound (3D EAUS), the imaging should always start with a 2D overview of the pelvic floor in midsagittal view. In the case of a TLUS or TPUS, regardless of the machine used, the probe will be capable of obtaining a 2D view of the pelvic floor. The orientation on the screen will vary depending on the machine and the setting. In case of multicompartmental imaging with BK Ultraview or Flexfocus, an 8802 probe is used (Fig. 3.1). The transducer is placed between the labia majora with the on screen view that includes the pubic symphysis to the right of the screen and the anorectal angle to the left. In resting position you can see location of mesh and synthetic slings, but if you cannot see them, you may investigate further with 3D or 4D imaging. You may also notice the patient's resting prolapse. Although the 2D imaging can be done with stage 3 or 4 POP-Q defects, it will necessitate pushing the prolapse back in and the utility of imaging for indication of advanced prolapse alone is questionable. Imaging of the pelvic floor structures may be easier with endovaginal imaging precisely because the prolapse can be pushed in to look at the muscles. The patient is asked to perform the following maneuvers: (1) the patient is asked to squeeze her muscles. Observing a pelvic floor muscle contraction on ultrasound provides visual biofeedback to the patient and can be used for pelvic floor muscle training and for quantification of pelvic floor muscle activity. In the midsagittal plane, a cranioventral shift of the pelvic organs is observed as well as a narrowing of the levator hiatus and changes in bladder neck position.

Many patients may not know what you mean or what to do. So, you have to be specific finding phrases that are familiar to the patient such as please do a kegal or pretend you are holding your urine. This maneuver shows if the patient is discoordinated. Generally, a normal patient has a strong resting tone and the levator lifts slightly vs. a patient who has weak pelvic floor can move the levator plate to a longer distance but cannot reach normal woman's resting position (Fig. 3.2). (2) The patient is asked to perform Valsalva. You can say "bear down as if you are trying to have a bowel movement." It is important that this is the

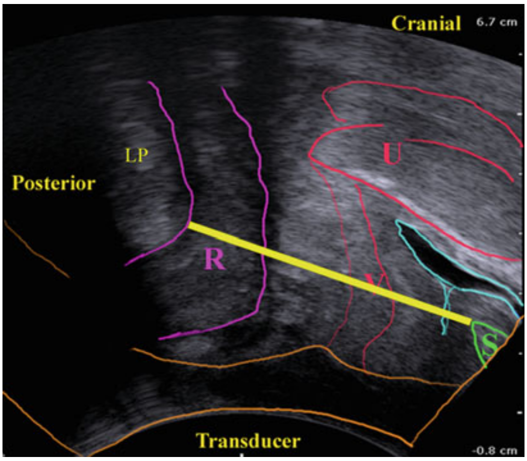


Fig. 3.2 The distance between the pubic symphysis and the levator plate (the *yellow line*) can be measured in resting, squeeze, and Valsalva position. In 2D images a pelvic floor muscle contraction can be quantified using displacement of the bladder neck, as well as a reduction of the midsagittal diameter (antero—posterior, AP) of the levator hiatus at the level of minimal hiatal dimensions © SHOBEIRI 2013

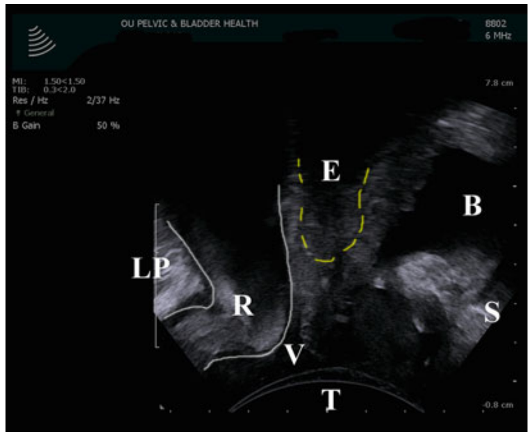


Fig. 3.3 Translabial imaging with Valsalva in this patient demonstrates a low rectocele (R). The bladder (B) does not demonstrate prolapse, however the shadow of an apical enterocele (E) is seen. Also noted are: the levator plate (LP), vagina (V), the transducer (T), and the pubic symphysis (S) © SHOBEIRI 2013

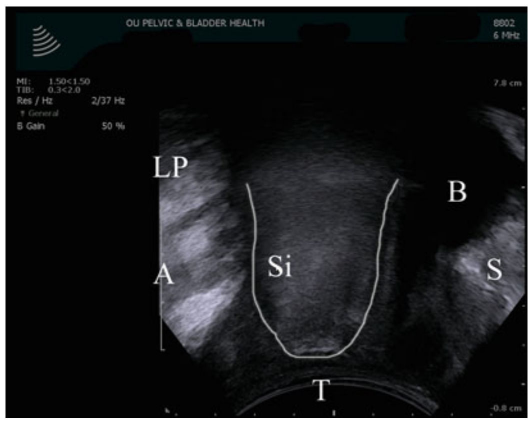


Fig. 3.4 Translabial imaging with Valsalva in this patient demonstrates a sigmoidocele (Si). Also noted are: the levator plate (LP), anus (A), bladder (B), vagina (V), the transducer (T), and the pubic symphysis (S) © SHOBEIRI 2013

last thing you would ask the patient to do since if she has gas in the upper rectum, it may move down and obscure the 3D images you mean to obtain. If this happens you can ask the patient to perform Valsalva again and the gas and prolapse may move up cephalic. Much important information may be obtained with Valsalva. Rectocele (Fig. 3.3), enterocele or most commonly sigmoidocele (Fig. 3.4), cystocele (Fig. 3.5) or multicompartmental defects may come to view with Valsalva maneuver. Dynamic imaging with Valsalva shows the movement of slings and meshes and may show the point of defects above, below or lateral to the mesh (Figs. 3.6 and 3.7). More about this is discussed in chapter about imaging of meshes.

3.2.2 3D/4D Translabial Ultrasonography (TLUS)

Three- and four-dimensional ultrasound has increased public interest in pelvic floor tremendously. The superficial axial plane faces the puborectalis portion of the levator ani, and all the levator subdivisions are better imaged by endocavitary transducers such as BK 2052 or BK 8838. However, endocavitary transducers impede Valsalva maneuver. Although the quality of translabial 3D/4D US are reasonable, the endocavitary transducers used transperineally have much higher resolution and may give better images.

If you have a BK ultrasound machine, the 8802 transducer is capable of free hand acquisition of 3D volumes (Figs. 3.8 and 3.9). However, freehand acquisition with 8802 is only advisable if you do not possess a 2052 or 8838. Performing freehand acquisition of a Translabial 3D volume (1) takes considerable skill to move the transducer at a constant speed as it sweeps radially from the patient's right to left. (2) The acquired 3D volume is not repeatable or reliable for measurement purposes and most importantly (3) if you have endocavitary 16 MHz transducers at your disposal which obtains automatic high-resolution views of the levator ani muscles, it obviates the need for freehand translabial acquisition.

The most commonly published data comes from GE machines. Phillips, Hitachi, and others make similar or superior machines. However, GE's 4D View is available for offline analysis

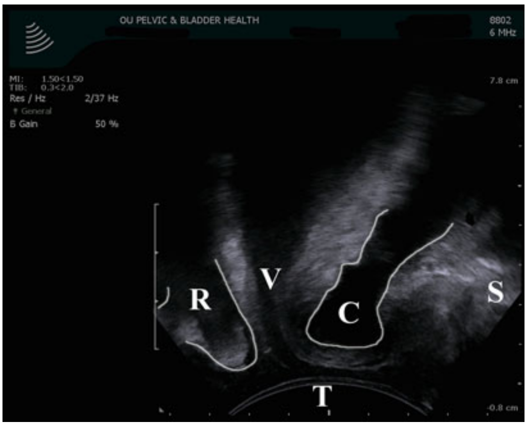


Fig. 3.5 Translabial imaging with Valsalva in this patient demonstrates a concomitant cystocele (C) and a rectocele (R). Also noted are: vagina (V), the transducer (T), and the pubic symphysis (S) © SHOBEIRI 2013

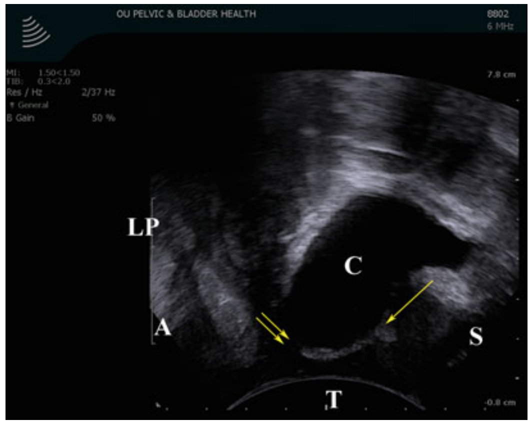


Fig. 3.7 Translabial imaging of a patient with anterior vaginal mesh. The image is with Valsalva. With Valsalva the patient demonstrates a cystocele (C) and detachment of the apical part of the mesh. The *double arrows* point to the cephalad end of the mesh, and the *single arrow* points to the caudad end of the mesh. Also noted are: the levator plate (LP), bladder (B), the transducer (T), and the pubic symphysis (S) © SHOBEIRI 2013

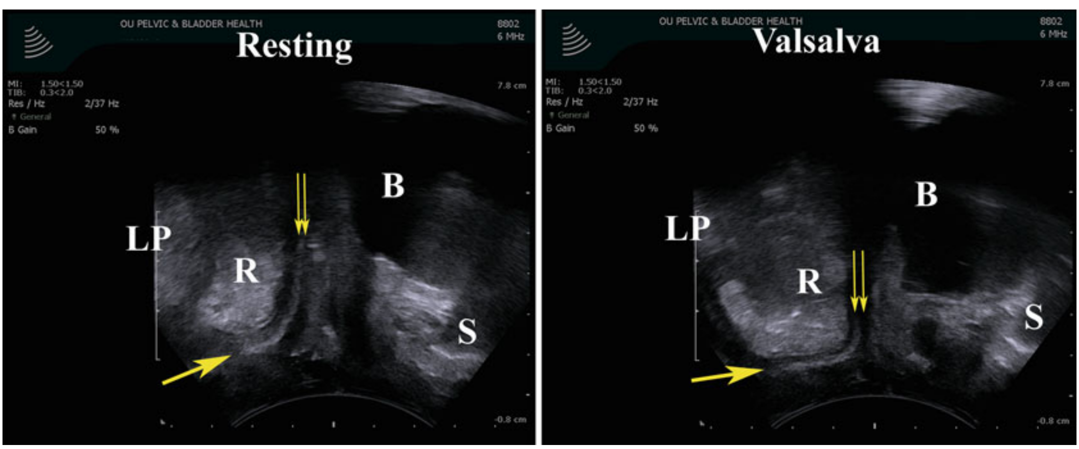


Fig. 3.6 Translabial imaging of a patient with anterior and posterior vaginal mesh. The anterior mesh cannot be seen as clearly. The image to the *left* is at rest. The *double arrows* point to the cephalad end of the mesh, and the *single arrow* points to the caudad end of the mesh. A resting rectocele (R) is seen behind the mesh. The image to the *right* is with Valsalva. With Valsalva the patient demonstrates worsening of the rectocele and detachment of the apical part of the mesh. Also noted are: the levator plate (LP), bladder (B), the transducer (T), and the pubic symphysis (S) © SHOBEIRI 2013

and use with 4D ultrasound volumes obtained using GE's Voluson series systems. The cheapest and most easily available system is Voluson e or i (Fig. 3.10). Despite its compact size the system is very capable when used with a RAB4-8-RS transducer (Fig. 3.11). The systems where developed and designed to visualize fetus' surface structures and adapted for pelvic floor imaging.

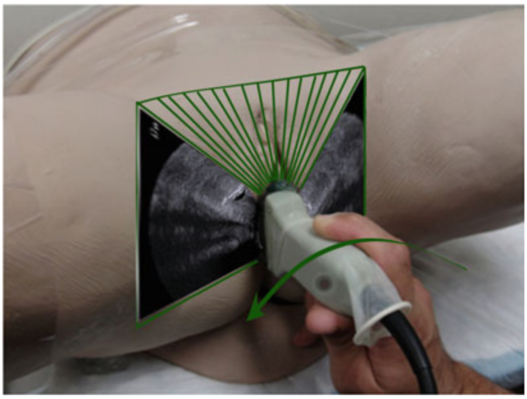


Fig. 3.8 The use of BK 8802 transducer for freehand acquisition of 3D volumes. The transducer is placed between the labia majora and swept at a constant rate from the patient's *left* to *right*. The time during which imaging is obtained can be set. However slower acquisition will result in higher quality 3d volumes © SHOBEIRI 2013

Fig. 3.10 A GE Voluson e ultrasound machine © SHOBEIRI 2013

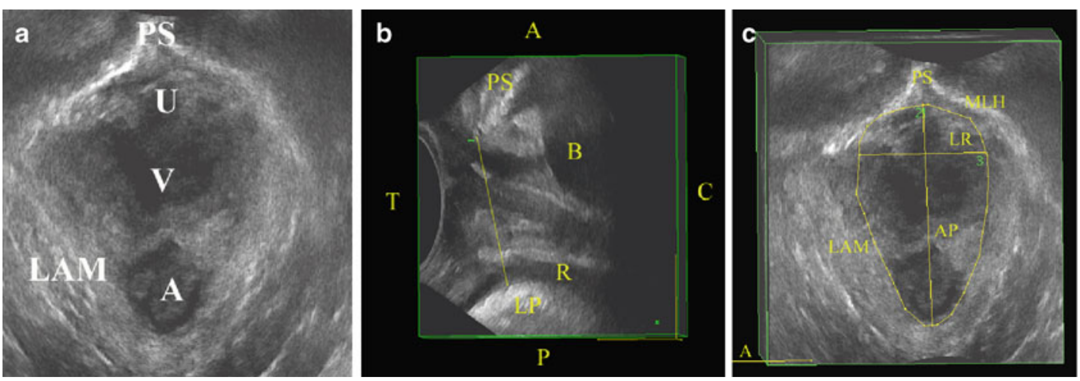


Fig. 3.9 (**a**) A 3D volume obtained using BK 8802 transducer. The 3D volume can be rotated to look at different areas. (**b**) Demonstrated is the right sagittal view of the pelvic floor. The anterior-posterior (AP) distance defined as the shortest distance between the pubic symphysis and the levator plate is drawn in a *yellow line*. The AP line forms the AP line of the minimal levator hiatus (MLH) in (**c**). Also noted are: the levator plate (LP), bladder (B), the transducer (T), anorectum (R), anterior (A), posterior (P), caudad (C), the left-right line (LR) of the MLH, the levator ani muscle (LAM), and the pubic symphysis (PS or S) © SHOBEIRI 2013

Fig. 3.11 A GE RAB4-8-RS transducer © SHOBEIRI 2013

Fig. 3.12 A GE RIC5-9W-RS transducer

GE Kretz 4D view allows manipulation of image characteristics and output of stills, cine loops and rotational volumes in bitmap and AVI format. Slightly higher resolutions can be obtained if the endocavitary RIC5-9W-RS is used on the perineum (Fig. 3.12). The characteristics of these transducers are shown in Table 3.1.

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. 3.13) which leaves the right hand available for running the console (Fig. 3.14). Once you have the appropriate 2D view, maximize the angle of acquisition to 75°–85° and proceed with 3D imaging (Fig. 3.15). 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.

3.3 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.

3.4 2D/3D/4D Transerineal Ultrasonography (TPUS)

3.4.1 Basic Procedure and Equipment

Ultrasonography has become a common place in Obstetrics, Gynecology, and Urology. Most ultrasound platforms are equipped with curved array and/or endovaginal transducers which are suitable for transperineal ultrasound imaging.

Positioning

As with gynecologic ultrasound most TPUS exams are performed with the woman in either lithotomy in a standard gynecologic examination

Table 3.1 Characteristics of GE RAB4-8-RS used for translabial ultrasound, and RIC5-9W-RS used for transperineal ultrasound

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

Fig. 3.13 Left-handed application of the transducer during Translabial ultrasonography © SHOBEIRI 2013

Fig. 3.14 The dominant hand generally operated the console. Unlike BK console, the GE Voluson e buttons on the console are multifunctional, and their function corresponds to the menu at the bottom of the screen © SHOBEIRI 2013

table or in a modified lithotomy position with cushion placed under buttocks and lower extremities in frog-legged position. For 3-dimensional imaging the examiner may also need to prop their arm or elbow as the imaging capture time can be as long as 15–20 s and the absolute stillness is critical for the optimal image quality. It is certainly possible to do the TPUS with a patient standing, which could be especially useful in patients who are not as successful with dynamic maneuver in supine position.

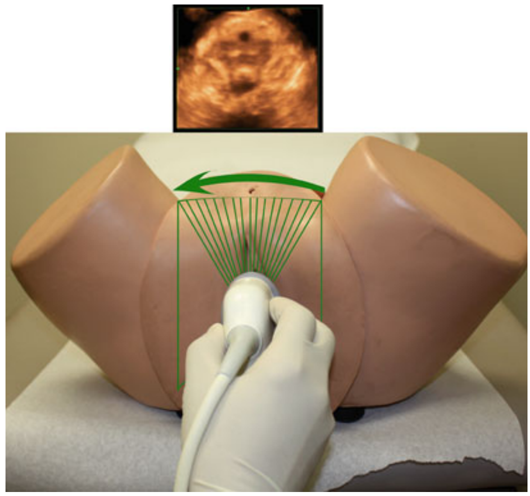


Fig. 3.15 3D pelvic floor volume acquisition with GE RAB4-8-RS transducer. The internalized mechanism in the probe moves the crystals obviating the need for hand movement. The hand and the elbow should be rested in a steady position for good quality imaging. The volume obtained is displayed on the screen © SHOBEIRI 2013

Transducers and Probes

Transperineal ultrasound refers to ultrasound performed with the transducer position on the perineum. There are techniques described in literature that use translabial ultrasound, i.e., transducer is placed on the labia majora. Term introital ultrasound [10] is also used where transducer is placed at the vaginal introitus or posterior fourchette. The common denominator for all those techniques is placement of transducers externally on the patient's vulva rather than introduction of the transducer into vagina or anal canal. For the

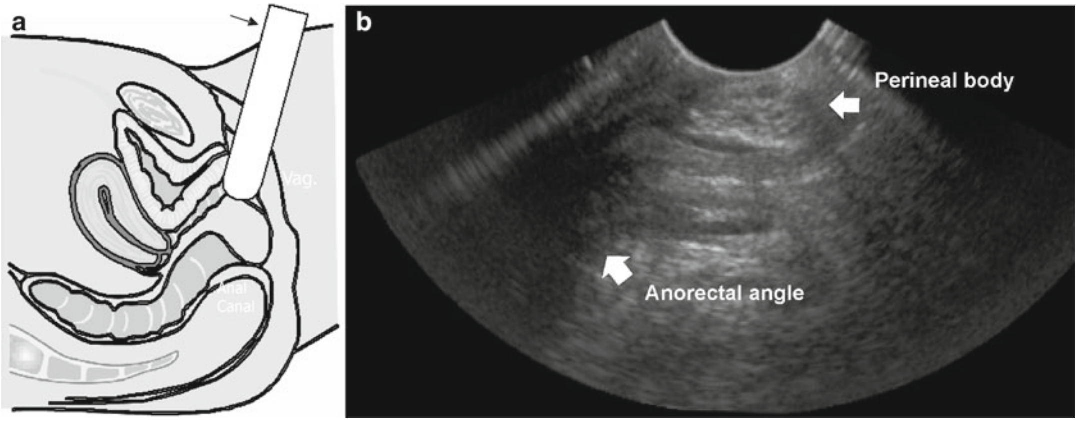


Fig. 3.16 Transperineal ultrasound of the anorectal structures: (**a**) schematic of endovaginal transducer positioned on the perineum and oriented caudally to visualize anorectum; (**b**) 2D transperineal sagittal image of the anorectum with perianal body easily visualized as an ovoid structure and anorectal angle marked

purposes of this chapter we will focus on transperineal ultrasound and mention other types of ultrasound where appropriate for specific studies. TPUS imaging can be performed with use of either trans-abdominal curvilinear transducers or with endovaginal transducer that is typically used for endovaginal gynecologic ultrasound. Curved array transducer is typically 4–8 MHz, whereas endovaginal transducers have frequencies up to 9.0 MHz. It is important to keep in mind that higher frequency transducers provide superior resolution, but have less tissue penetration. This trade-off is important for achieving images of diagnostic quality. For the purposes of this chapter, ultrasound performed with curved array transducers will be referred to as translabial ultrasound (TLUS) as the transducer is placed over the labia majora to visualize anatomic structures. With use of endovaginal transducer the transducer is mostly placed on the perineum or at the posterior fourchette and thus we will refer to it as transperineal ultrasound (TPUS). There is no agreement in nomenclature for these techniques.

Preparation

For transperineal ultrasound as with any ultrasound imaging use of coupling gel is a critical step as ultrasound waves do not pass through air. Whether trans-abdominal or endovaginal transducers are used the gel should be placed between the transducer and covering. For endovaginal transducers a disposable cover (e.g., male condom) and for curved trans-abdominal transducer glove or plastic wrap can be used. Additionally gel should be applied to the perineum to allow for better coupling. Warming the gel in a commercial warming device improves patient comfort. After each use, transducers should be cleaned and disinfected according to manufacturer recommendations.

3.4.2 Transperineal Ultrasound Orientation and Optimization

2D: Technique—Orientation

Different techniques have been described for transperineal and translabial pelvic floor imaging. Some investigators use a curved array transducer (4–8 MHz abdominal probe) [11–13]. The transducer oriented vertically with a mark (i. e., a groove or ridge on one side of the ultrasound transducer) facing up and placed firmly against symphysis pubis. The transducer can be placed on the labia or with labia parted. With the transperineal technique an endovaginal transducer is placed on the perineum with a mark facing up. In this chapter all the TPUS images are captured with endovaginal transducer. The image optimization depends on the goal of desired visualization. With imaging of the pelvic floor muscles and levator hiatus the transducer is directed cranially (Fig. 3.16a, b) with imaging of

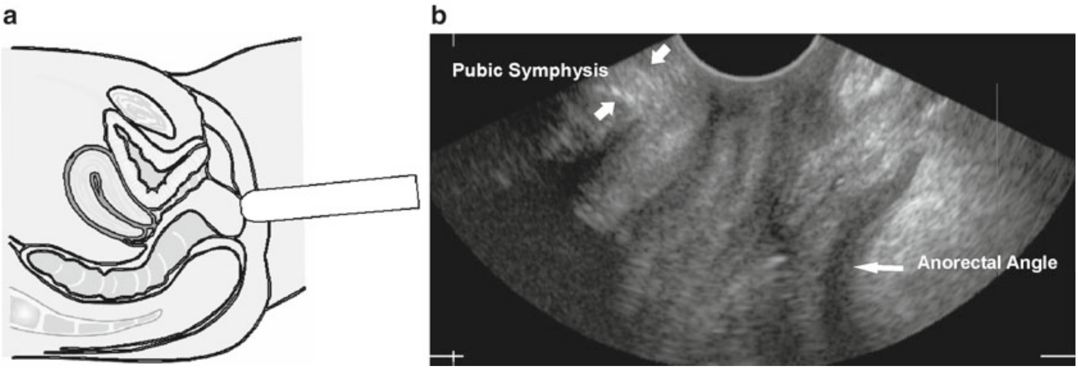


Fig. 3.17 Transperineal ultrasound of the pelvic floor hiatus: (**a**) schematic of endovaginal transducer positioned on the perineum and oriented cranially to visualize the pelvic floor hiatus; (**b**) 2D transperineal sagittal image of the pelvic floor hiatus with pubic symphysis and anorectal angle shown

the anorectum the transducer is usually oriented posteriorly towards the anal canal [14] (Fig. 3.17a, b). Care should be taken to avoid excessive pressure applied to the perineal structures. Most investigators advise to assure tissue contact enough to visualize anorectal structures avoiding any excessive pressure on the perineum. Compression of perineum may distort perineal anatomy and limit mobility of the pelvic floor during dynamic maneuvers.

In transperineal pelvic floor imaging the transducer is most commonly oriented with the mark facing up (12 o'clock position) with midsagittal orientation. The produced 2D image will represent anterior structures (pubic symphysis and urethra) at the left portion of the screen and the posterior structures (anorectum) at the right side of the screen (Fig. 3.17b). The 2D image produced by TPUS imaging allows for visualization of the urethrovesical junction (UVJ), anorectal angle, structures of the anal sphincter complex. This view can be used to observe pelvic floor mobility during pelvic floor maneuvers, like pelvic floor contraction (Kegel's exercise) and during straining.

In the midsagittal view the structures seen from left to right: pubic symphysis, urethra and bladder, vagina and anorectum. On the midsagittal view the pubic symphysis cross-section is usually oblong and bony structures of the pubic rami are not visible. Next, anterior and posterior urethral walls are delineated against periurethral tissues. Usually urethral mucosa and submucosa are imaged as a universally hypoechoic structure that appears as an open lumen. Vagina is usually seen as a collapsed structure, where vaginal walls are not clearly separated by ultrasound. Anorectum is seen as outline of hypoechoic internal anal sphincter (IAS) against the midline anal mucosa, which is usually echogenic with variable echogenicity due to fold of anal mucosa. Hyperechoic external sphincter surrounds the hypoechoic internal sphincter. The anorectal angle is normally easily visualized and changes with dynamic maneuvers of the pelvic floor muscles. Cross-section of the puborectalis muscle (PRM) is seen posterior to the anorectal angle.

3D TPUS: Technique

Three-dimensional (3D) ultrasound refers to two-dimensional static display of three-dimensional data. For acquiring and rendering 3D ultrasound dataspecial transducers and software are needed. The 3D ultrasound dataset is referred to as "volume." To obtain 3D ultrasound the transducer is held in the stationary position at the perineum during acquisition of the volume. The scanning angle is usually set to the widest available—depending on equipment this could be between 120° and 180°. The acquisition time depends on set image quality and varies between 2 and 15 s. The patients are usually instructed to hold her breath (or use shallow breathing) through the volume acquisition phase as any motion can introduce a motion artifact. For the static 3D volume acquisition the quality of acquisition (acquisition time) should be maximized for best quality images. The faster scanning modes usually compromise quality of image but can be useful during dynamic maneuvers. When 3D volumes of dynamic maneuvers are obtained the image quality could be sacrificed for faster acquisition since the subject has to sustain the dynamic state for the length of the acquisition. The dynamic conditions most commonly used for the imaging included pelvic floor contraction and the Valsalva maneuver. When acquiring volumes during the dynamic imaging the position of the transducer at rest may need to be adjusted to allow for the capturing of the dynamic state. The best imaging is achieved by assuring that patients maintain the dynamic state without movement. Any movement from operator or the subject can introduce motion artifact.

3D TPUS: Pelvic floor hiatus—Orientation, Optimization, and Rotation

To capture transperineal 3D US volume of the pelvic floor hiatus and the surround levator ani muscles the transducer placed on the perineum and the ultrasound beam is directed in the cranial direction (Fig. 3.17). The field of view is optimized by identifying the symphysis pubis on the left of the screen and the anal canal on the right side of the screen [15]. The operator should also maximize the midline alignment with assuring that the urethra is also visible in this view. After capturing the volume images can be stored on a compact disk or drive and assessed offline. The offline post possessing is done with equipment-specific software—this is usually proprietary software that allows rotation of the volume, thick and thin slicing of the volume, and multiple measurements. During the post-processing of volumes the 3D static images are rotated to be displayed in a symmetric orientation in the three orthogonal planes: coronal sagittal and transverse planes. A cursor dot is located in corresponding positions in all three orthogonal planes. A cursor dot allows for the exact position of an anatomical structure to be identified simultaneously in the three orthogonal planes (Fig. 3.18). One of the standardized rotation techniques described is demonstrated in the serial figures [15] (Fig. 3.19a–e).

1. The transverse (axial) 3D volume is rotated approximately 90° clockwise in the plane of the 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.
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.

After post-processing rotation the pelvic floor hiatus is visualized in the transverse (or axial) plane. The visualization of the hiatal structures can be further optimized by tomographic function where the volume is sliced with predetermined thickness to visualized structures at different levels. The rendering function can also further assist in visualization of the specific anatomy. This "thick slice" technique is usually set at the thinnest slice ~1 cm. The normal appearance includes pubic rami and symphysis and the midline positioned urethral cross-section. The cross-section of the vagina normally has "butterfly" or H-appearance, which is due to lateral vaginal attachments of the vagina to the endopelvic connective tissues—to the arcus tendentious anteriorly and the posterior arcus posteriorly. The cross-section of the anal canal is also seen. The PRM surrounds the pelvic floor forms the most distal portion of the levator hiatus (Fig. 3.19e).

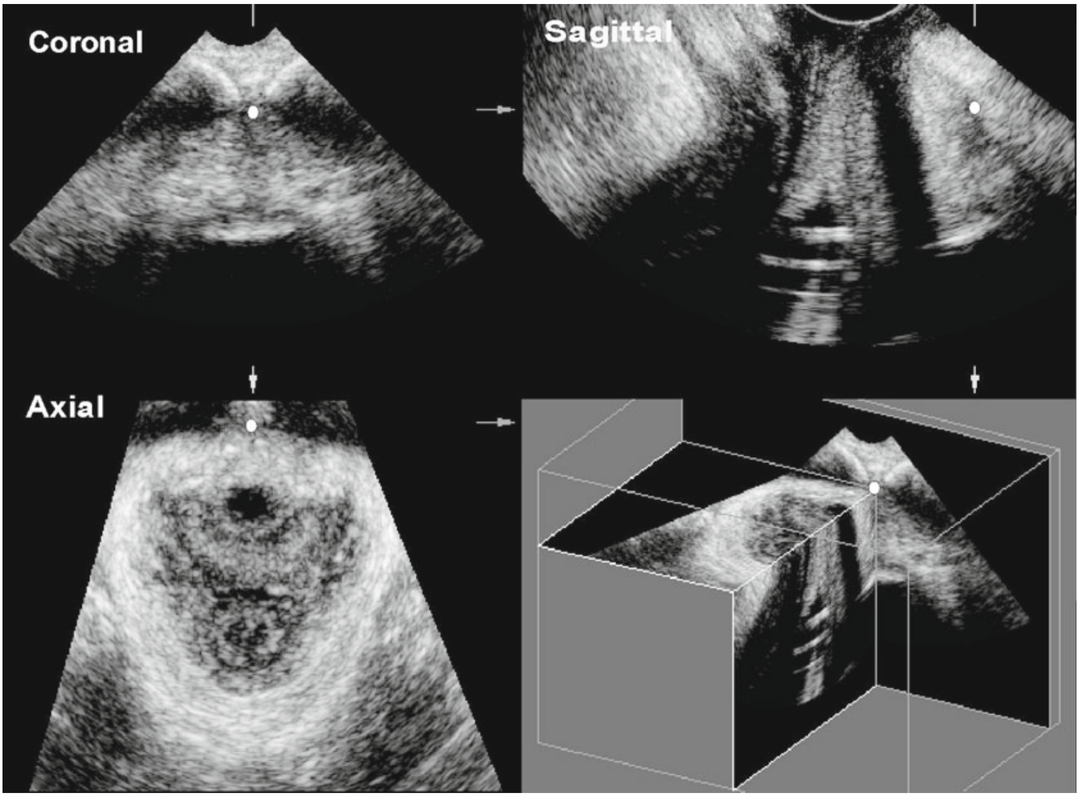


Fig. 3.18 Transperineal static 3D volume processed to demonstrate the relationship of the three orthogonal planes—coronal, sagittal, and axial. The cursor dot seen in each plane represents the exact same spot in each plane

3.5 Transperineal Ultrasound and Pelvic Floor Disorders

3.5.1 Pelvic Floor Biometry with TLUS/TPUS

Multiple TLUS/TPUS pelvic floor biometry measurements are described in the literature. The lower edge of the pubic symphysis, UVJ, and the anorectal angle are the most common used reference points in transperineal imaging. The biometry can be performed at rest and during dynamic maneuvers.

For assessment of bladder neck position and mobility in the sagittal plane variety of measurements have been described with use of 2D TPUS. In 1995 Schaer et al. [7] described a coordinate system for bladder neck and urethral mobility ultrasound appearance. *X*-axis determined by a straight line through the central portion of the pubic symphysis. The *Y*-axis is perpendicular to the *x*-axis at the lower border of the symphysis. 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 [7]. 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 [10] (Fig. 3.20). The location of the symphysis is defined as an imaginary line drawn through the lower edge of the pubic symphysis. In addition, posterior urethrovesical angle can be measured. This is the angle between the urethral axis and the bladder floor. These indices can be measured at rest

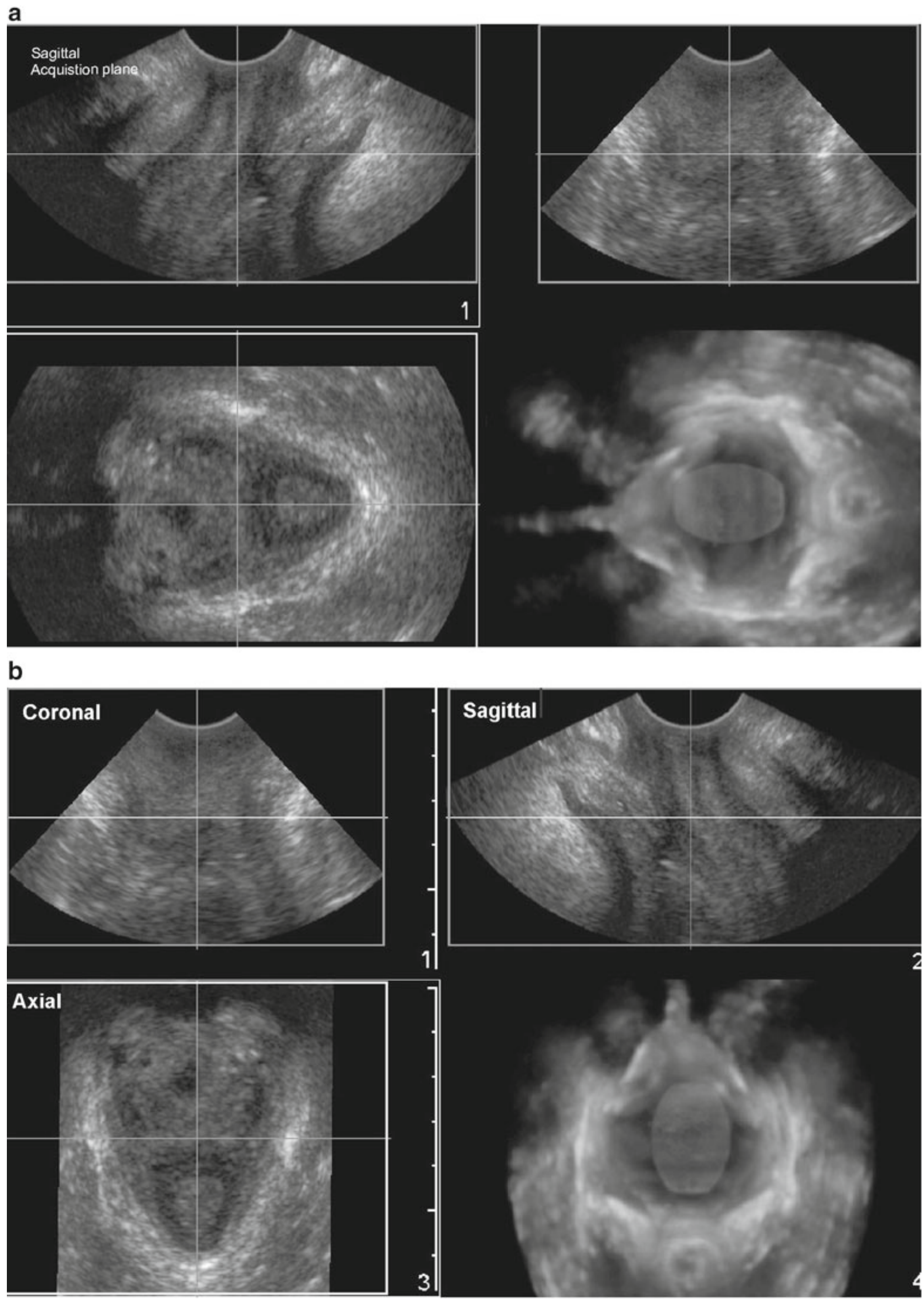
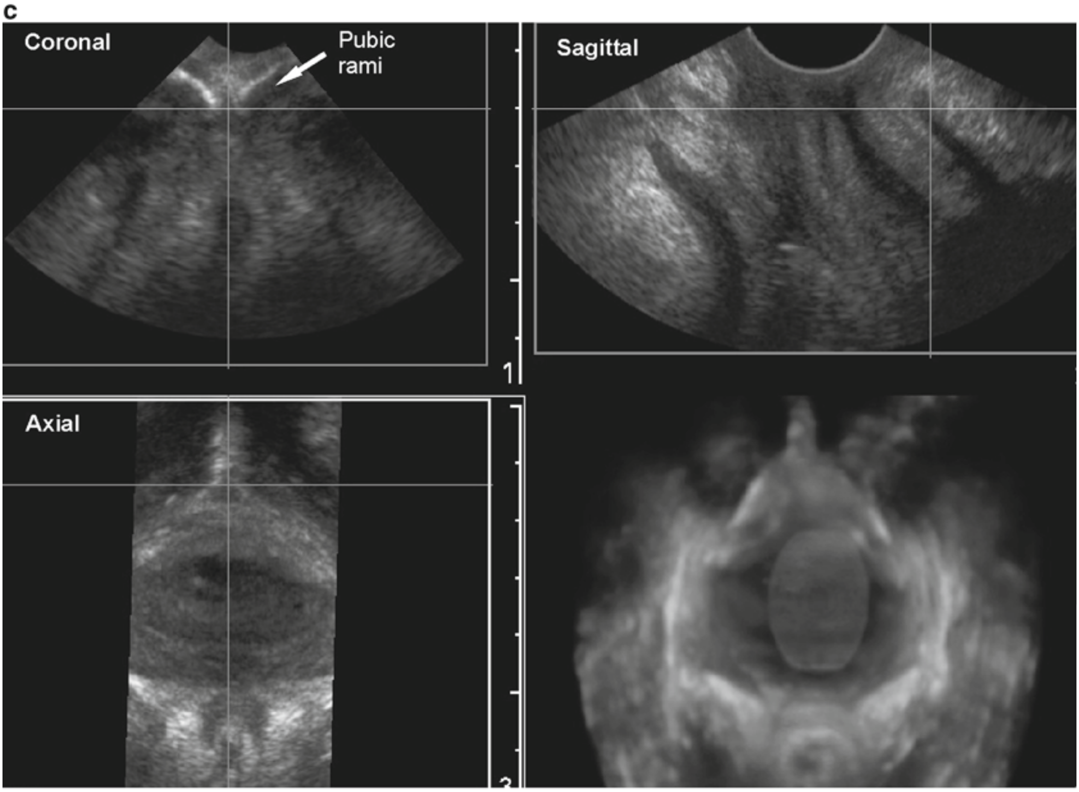


Fig. 3.19 3D TPUS—volume post-processing step-by-step: (**a**) transperineal ultrasound of the pelvic floor hiatus with the sagittal acquisition plane—sagittal plane optimized by visualizing the pubic symphysis and the anorectal angle; (**b**) volume is rotated to orient the axial plane upright. The multiplanar of the 3D transperineal 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. 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—the represents the puborectalis muscle (PRM) plane. The PRM is seen encircling the pelvic floor hiatus in the transverse image; (**e**) the transperineal 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

c



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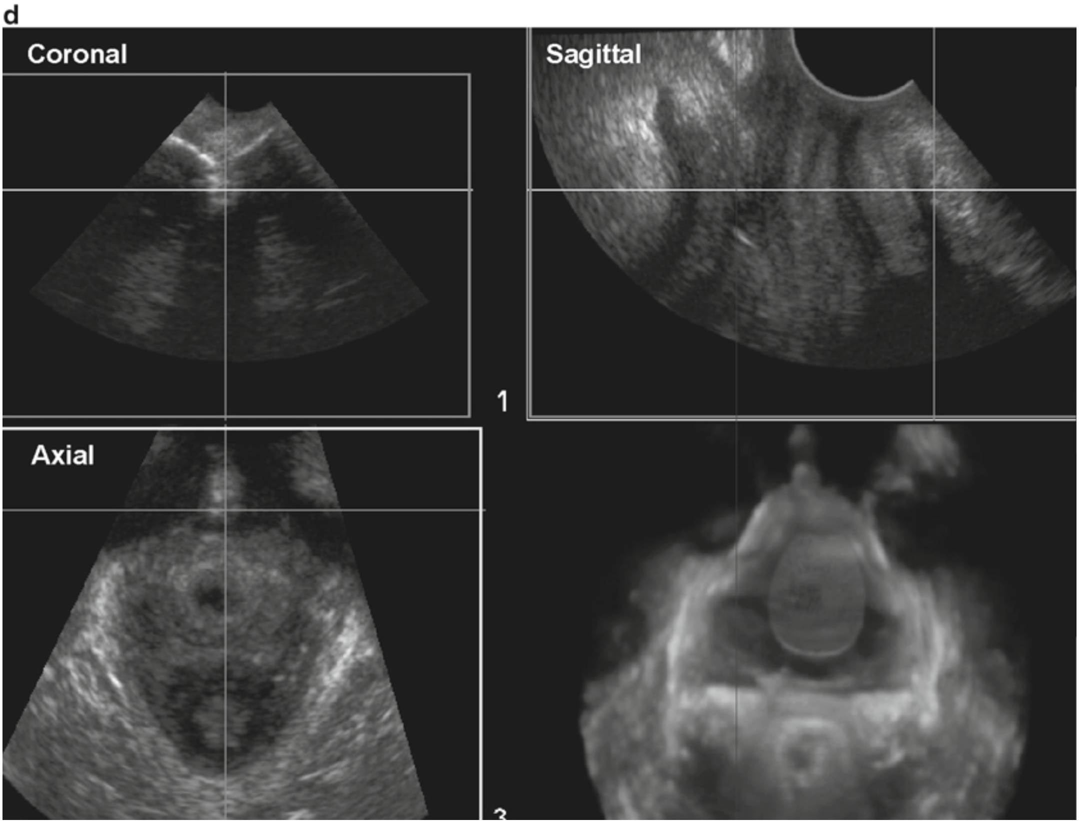

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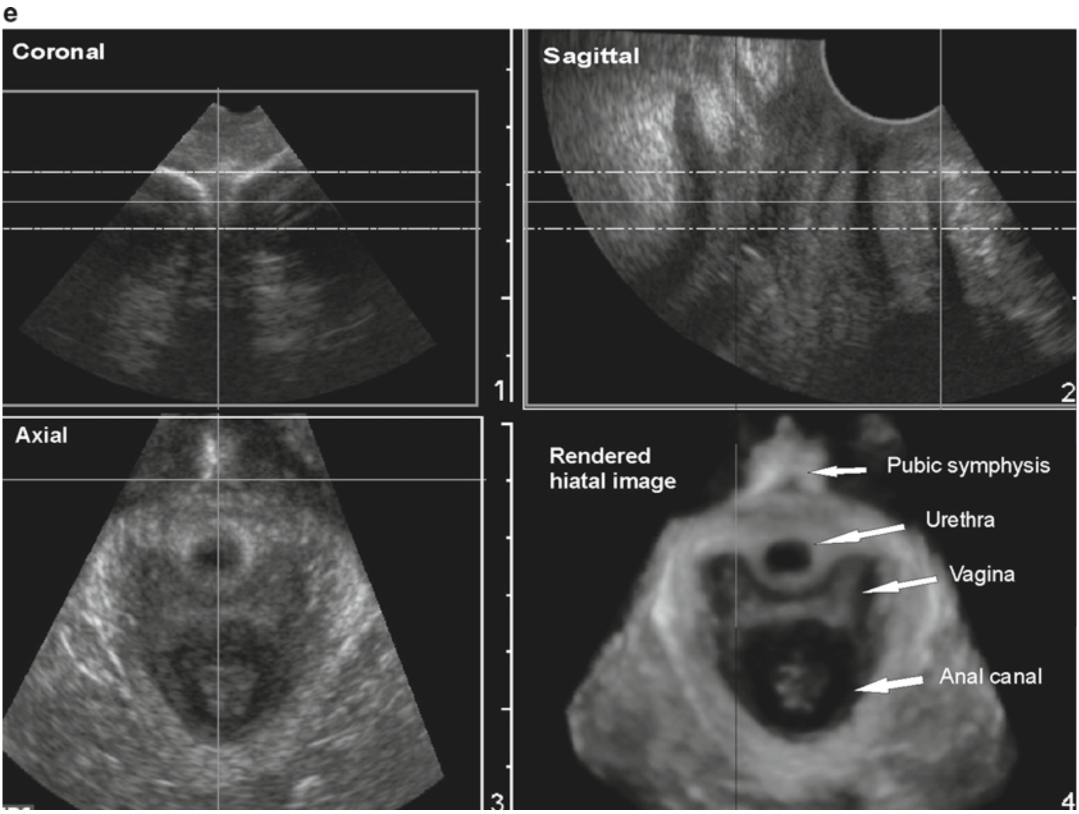

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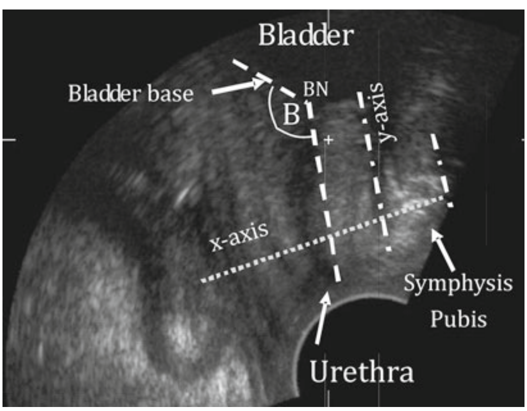

Fig. 3.20 The posterior urethrovesical angle measurement method with perineal ultrasound described by Schaer et al. [7]. The rectangular coordinate system was constructed with *y*-axis is at the inferior symphysis pubis and *x*-axis is perpendicular through the mid-symphysis pubis. The posterior urethrovesical 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

and during dynamic maneuvers—pelvic floor contraction (squeeze), coughing and straining (Valsalva). 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 [10]. During Valsalva maneuver deviation of the indices of bladder neck mobility and concomitant funneling of the proximal urethra can be observed in incontinent women (Fig. 3.21). Correlation between ultrasound findings of bladder neck descent measurements and urodynamic testing has been inconsistent [16, 17] and largely do not help distinguish continent and incontinent women [18]. Transperineal ultrasound has also been used in the assessment of patients with urinary incontinence by imaging the urethral support and morphology and by measuring the urethra and its sphincter. A recent study showed that translabial 3D US is reliable in calculated

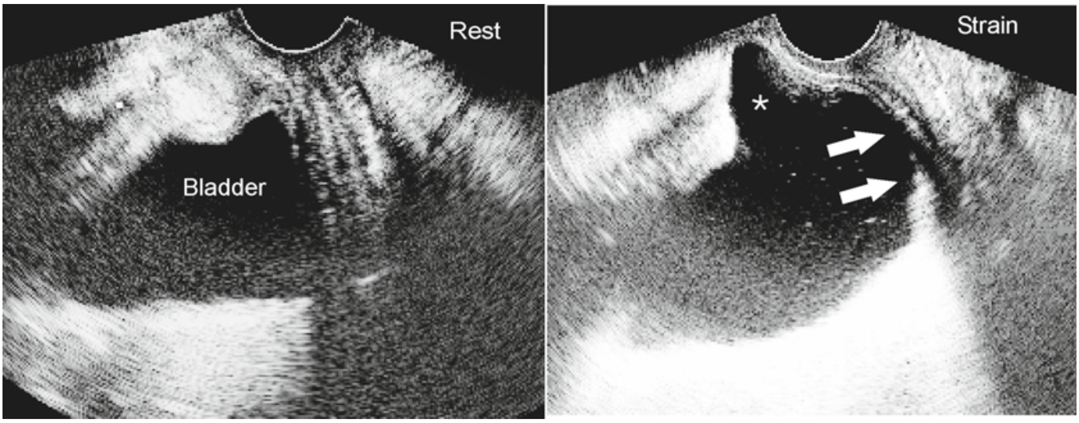

Fig. 3.21 Transperineal ultrasound of the sagittal bladder neck with the outline of the bladder easily seen on the rest image. The strain image shows descent of the bladder wall (*arrows*) and funneling (marked with *asterisk*)

volumes of the urethral sphincter in nulliparous women [19]. One ultrasound study showed that women with stress urinary incontinence have urethral sphincters that are shorter, thinner, and smaller in volume [20].

There are many measurements described to characterize the dimensions of the pelvic floor (or levator) hiatus. These measurements are usually done using 3D TPUS in the plane of minimal hiatus which is the shortest distance between the lower edge of the pubic symphysis and the edge of the levator plate posteriorly. The majority of the MLH border is lined with pubovisceralis muscle [21, 22]. It has been referred to as the puborectalis, pubovisceralis or pubococcygeus by multiple authors as the borders of these muscles cannot be delineated by transperineal imaging. In this chapter we will refer to the muscle that borders levator hiatus as the pubovisceralis muscle. The levator hiatus plane has defined reference points of inferior edge of the pubic symphysis and the anorectal angle. This plane is also referred to as "plane of minimal hiatal dimensions" [23]. Multiple biometric indices are described for this plane that can be obtained on the multiplanar image in axial (transverse) plane or on a rendered image. These measurements can be performed on volumes obtained at rest, pelvic floor contraction or during a Valsalva maneuver. In addition to measurements, PRM integrity can be assessed. The measurements include linear measurements of the anterior-posterior hiatal diameter, lateral hiatal diameter, levator ani (PRM) thickness and angle. The most common biometric measurement used is anteroposterior hiatal diameter, which is measured in the plane of minimal dimensions and defined as the distance between lower edge of the pubic symphysis and the anorectal angle [15]. This measurement has been shown to consistently decrease with pelvic floor contraction. The levator hiatus measurements are reliable [15, 24] and can be easily learned [24]. The pelvic floor contraction is shown to decrease the hiatal area dimensions. The PRM inner perimeter is defined by a curvilinear measurement along the inner border of the pubovisceralis muscle to its insertion site on the pubic ramus. The pelvic floor hiatus inner area is defined as the area within the pubovisceralis muscle inner perimeter enclosed anteriorly by two straight lines, connecting the pubovisceralis insertion point on the pubic rami to the inferior edge of the symphysis pubis. The pelvic floor hiatus outer area is contained within the outer border of the puborectalis; it has the same borders as the pelvic floor hiatus inner area anteriorly. The puborectalis area has been calculated. The measurement is obtained by subtracting the pelvic floor hiatus from the outer area. This measurement represents the cross-sectional area of the puborectalis [15].

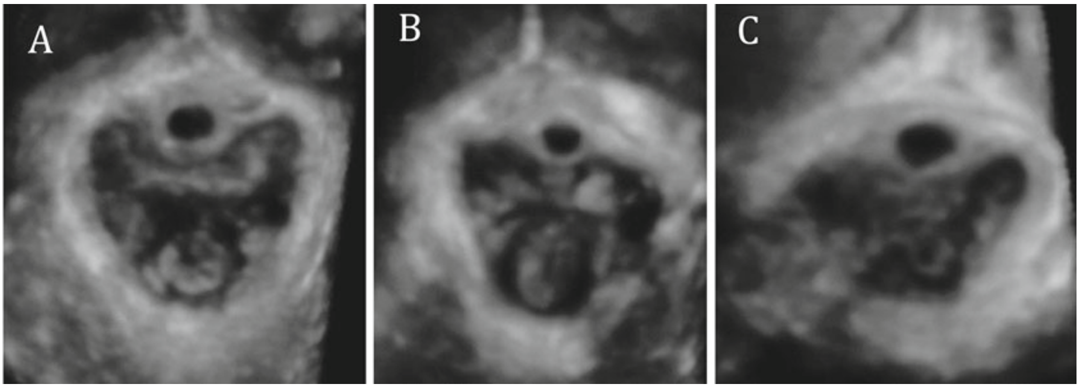

Fig. 3.22 3D TPUS of the axial 10 mm thick slice rendered hiatal image showing of normal hiatal structures (**a**) and example of the PRM injury (**b**, **c**). Note how urethra and vagina shift away from the midline to the side where the PRM injury is greater

Using 3D TPUS and vaginal manometry Jung et al. [25] characterized high-pressure zone of the vagina. They demonstrated that using vaginal fluid-filled bag the progressive distention initially increased lateral and only then anteroposterior dimensions of the pelvic floor hiatus and that anterior-posterior and not lateral dimensions decreased with pelvic floor contraction. This provides evidence that the PRM is responsible for creating high-pressure zone in the vagina.

3.5.2 TLUS/TPUS: Pelvic Floor (Levator) Hiatus and Pelvic Floor Musculature

Series of studies by MRI and 3D ultrasound have identified defects in the levator ani muscles in parous women. These morphological defects vary from minor abnormalities to major muscle damage. There is no agreement on classification of these defects [26, 27]. MRI studies have shown that the most common injury related to childbirth is an avulsion injury of the insertion of the pubovisceralis muscle on the pubic ramus [28] (Fig. 3.22).

There are series of studies that assess pelvic floor morphologic changes related to vaginal delivery. Many studies report that vaginal delivery is associated with levator muscles injury. Dietz and Lanzarone [29] showed that in a third of women delivering vaginally, the avulsions were associated with stress urinary incontinence at 3 months postpartum. Further data from the same group [30] suggests that levator trauma is associated with prolapse of anterior and apical compartment and not with bladder dysfunction or urinary incontinence. They also demonstrated that larger levator hiatus was correlated with POP. Further studies analyzing large retrospective cohort suggested that levator ani avulsions are associated with prolapse in women with previous pelvic surgery [31].

3.5.3 Anal Sphincter Complex and Anal Canal TPUS

When assessing anal canal the transducer can be oriented in either sagittal or axial orientation. Using endovaginal transducer positioned on the perineum and oriented caudally the sagittal image usually visualizes the anal canal and the anorectal angle (Fig. 3.17). Using 2D ultrasound the anorectal angle can easily be seen and measured. The dynamic changes in the displacement of the anorectal angle can provide visual biofeedback for levator ani activity and are easily understood and readily accepted by women [32].

When capturing 3D TPUS the sagittal orientation of the anal canal is optimal. The image is further optimized by assuring that the anorectal

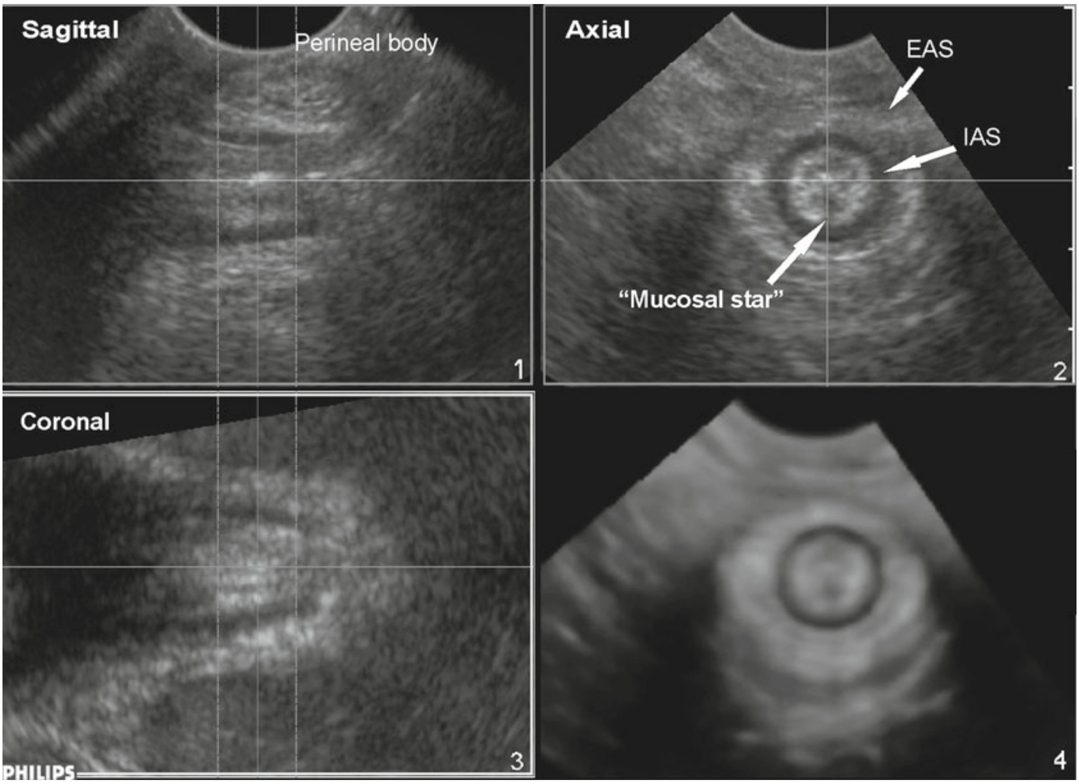

Fig. 3.23 3D TPUS of the normal anal canal: the multi-planar image with three orthogonal planes shown: sagittal, coronal, and axial identified. The rendered thick slice (10 mm) allows for integrated evaluation of the mid-anal sphincter portion. In the sagittal plane the perineal body is seen as an oval-shape 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)

angle is visible. Alternatively anorectum can be visualized with 2D or 3D in the axial plane with when the transducer marker is oriented to 3 or 9 o'clock. Images can be captured at rest and during sustained anal sphincter and pelvic floor contraction. The offline assessment of 3D TPUS static images allows for volume rotation with symmetrical viewing of anal sphincter structures in standard coronal, sagittal and transverse (axial) planes. Additionally the sphincter structures can be further characterized using thick slice or multi-slice assessments tools. The inner portion of the axial sphincter image has been called "mucosal star" [14] (Fig. 3.23). The visualization of the mucosal folds of the anal canal differentiates TPUS from endoanal technique, where inserted transducer flattens 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 is encircled by the echogenic external anal sphincter (EAS). As with other structures use of tomographic sonography with 3D volume processing can enhance visualization (Fig. 3.24).

Contractions of the PRM are thought to decrease the anorectal angle and increased pressure in the proximal part of the anal canal, and when the EAS contracts, there is increased pressure in the distal part of the canal [33]. On 3-dimensional ultrasound, these contractions and associated measurements are well captured [34].

Use of TPUS also allows visualization of the sphincter defects. Limited data is available on clinical diagnostic utility of TPUS for imaging of

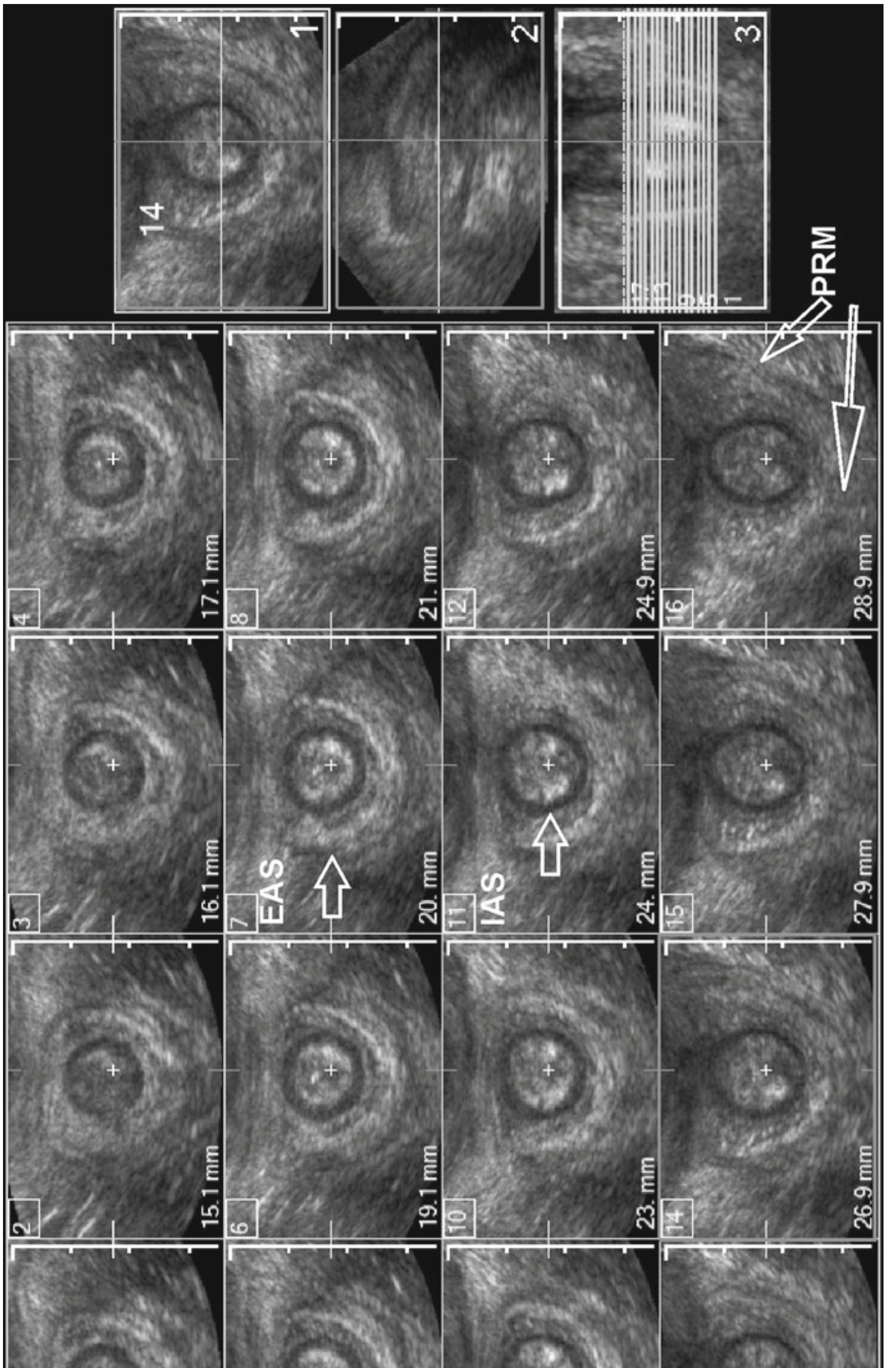

Fig. 3.24 3D transperineal ultrasound of the anal canal with 1 mm slices from the anal verge to the anorectal angle. IAS, EAS, and posterior portion of the PRM shown

anal sphincter. Endoanal ultrasound is the gold standard of assessing anal sphincter defects. A recent study compared transperineal and endovaginal ultrasounds to the endoanal ultrasound technique in evaluating women with postpartum anal sphincter injuries. The study found while TPUS was useful in identifying normal anatomy, the sensitivity for assessing anal sphincter defects was inferior to the gold standard—the endoanal approach [35].

3.5.4 3D US and MRI

MRI has gained in importance as a diagnostic and research tool for assessment of pelvic floor disorders. It certainly has capability of high-resolution superb imaging of the soft tissues of the pelvic floor and has been one of the modalities of choice for evaluation of the pelvic floor. However, the major technical limitation of MR imaging is its poor ability to fully capture present-time pictures as its spatial resolution is often spared as imaging time becomes faster. Other clinical limitation includes its high cost, time and space constrains, and limited availability. The utility of 3-dimensional ultrasound has been studied and compared to MR imaging [15, 25, 27, 36]. Some studies have shown poor correlation between MR imaging and ultrasound, but some authors believe that this is because previous studies did not use the same plane on ultrasound as was used on MRI [36]. Another study showed that the two modalities correlate at rest, but there is no correlation during maximum Valsalva. This is likely because of the physical limitations of MR imaging. When using MRI, it is difficult to predict the end point during Valsalva and because MRI is not done under real time, the true plane needed to adequately evaluate pelvic floor function is not as available to the degree that it is in ultrasound [36]. In more recent studies, transperineal 3D US has shown to be as effective, if not better, than MRI in imaging the pelvic floor [36]. With 3D US cine loop capabilities the functional pelvic floor anatomy assessment has superior spatial and temporal resolution, where multiple volumes of imaging obtained per second [37]. Dynamic 3D ultrasound, also known as 4D ultrasound, acquires volume datasets that can be used to produce single slices in any arbitrarily defined plane [38].

3.5.5 TLUS/TPUS in the Evaluation and Treatment of Urinary Incontinence

Transperineal or introital ultrasound has been used in assessment of bladder neck position before and after incontinence procedures and in assessment of implanted materials in treatment of stress urinary incontinence.

Bernstein showed that pelvic floor muscles thickness and function could be visualized by perineal ultrasound. He also demonstrated that pelvic floor muscle were thinner in women older than 60 years old and in women with SUI compared with continence controls. After pelvic floor muscle training all groups showed increase in muscle thickness and 60 % of SUI women showed subjective and objective improvement with UI. Dietz et al. [32] used translabial ultrasound as biofeedback in teaching women to perform a proper pelvic floor muscle contraction. They proved that translabial ultrasound is a useful adjunct in pelvic floor muscle training.

Prolene mesh, that is used for minimally invasive slings is highly echogenic and can easily be visualized with TPUS (Fig. 3.25). Schuettoff et al. [39] compared use of MRI and introital US and suggested that ultrasound is most suited for assessment for suburethral and periurethral mesh portion, whereas MRI is more suitable for retropubic mesh evaluation. Ultrasound can also show the spatial relationship between a suburethral sling, the urethra, and the symphysis pubis. Yalcin et al. published a pilot study in a group of women with SUI after Tension-free vaginal tape (TVT) operation [40]. It showed that bladder neck mobility measured on x-y coordinate system could discriminate successful and failed slings; however these measurements had large overlap. It has been shown to move variably as an arc around the posterior symphysis pubis. Movement closes the gap between the mesh and the bony

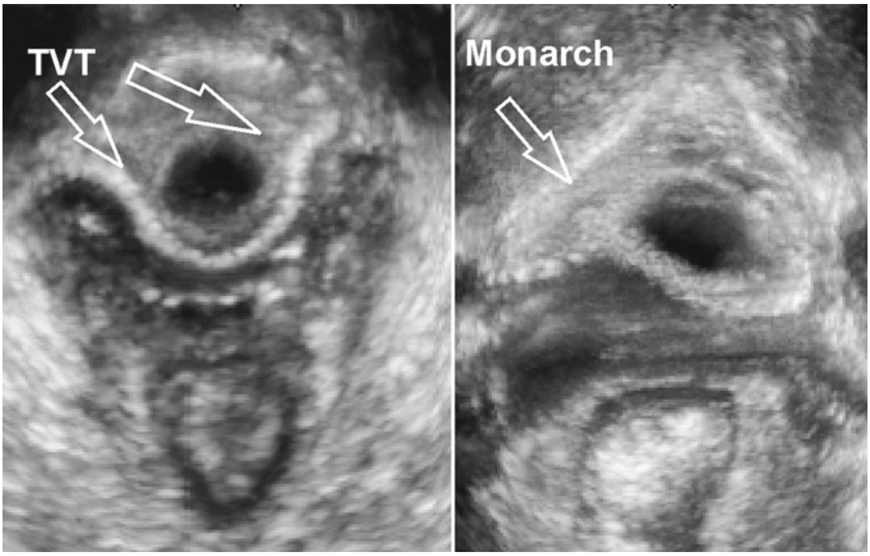

Fig. 3.25 3D transperineal ultrasound of the hiatus—axial image with 10 mm rendered thick slice—the mesh sling (TVT and Monrach) are shown

structure of the pelvic, thereby, compressing the urethra during increases in intra-abdominal pressure. The ability to visualize the variability in the location and the movement of the sling allows clinicians to understand why there is variability in the actual efficacy of the sling and to help determine if the sling needs to be adjusted [41]. Using 3D TPUS investigators showed that mid-urethral position is not necessary for minimally invasive slings success in treatment of SUI [42, 43].

Urethral bulking agents are used to improve continence by enhancing urethral coaptation. Periurethral collagen has been imaged by perineal ultrasound. Using perineal (introital) ultrasoundElia and Bergman found that optimal location of collagen implant was less than 7 mm from the bladder neck [44]. With use of 3D ultrasound, Defreitas et al. suggest 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 [45]. Poon and Zimmern describe 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. If there is no improvement but a circumferential pattern is seen on ultrasound, the injection is considered optimal and the patient is offered an alternative treatment [46].

3.5.6 TLUS/TPUS and Pelvic Organ Prolapse

TLUS/TPUS has been increasingly used as an adjunct in diagnostic evaluation of POP. There are many studies reporting use of TPUS to assess POP. In a pilot study, Beer-Gabel et al. [12] used dynamic transperineal ultrasound to identify pelvic floor descent. The assessment of anorectal angle was comparable to defecography. Rectoceles were also easily identified. Dietz and Steensma [47] showed that rectovaginal septal defects could be easily identified on translabial ultrasound, but a third of women with rectocele showed no sonographic abnormalities. Grasso et al. [48] reported a good to excellent correlation of introital ultrasound finding and defecography in evaluation of anorectal angle, presence of intussusception and rectocele. Recently Weemhoff et al. [49] reported that TPUS finding of intussusception was predictive of abnormal evacuation proctography, however prediction of enterocele findings was poor compared with evacuation proctography.

Some studies attempted to correlate clinical findings by Pelvic Organ Prolapse Quantification system (POP-Q) to the ultrasound findings. The reference for measurement in the ultrasound findings is different from the reference that is used in POP-Q, i.e., hymen. For ultrasound measurements of the prolapse the reference line is usually drawn parallel to the infero-posterior margin of pubic symphysis [50].

In a study by Lone et al. [51], the authors assessed the relationship between validated POP-Q measures and assessment made by dynamic 2D-TPUS. In this study only women with prolapse at or above the hymen were included for analysis. They also adjusted for reference points to minimize difference between the reference lines used with POP-Q and TPUS. They found that proportion of correctly assessed prolapse was around 60 % for anterior and posterior compartment (using points Ba and Bp) and only 33 % for the apical compartment (using point C).

3.6 Summary

2D and 3D Transperineal and Translabial pelvic floor ultrasound allows evaluating many aspects of pelvic floor anatomy and function and can compliment a careful physical examination. It shows promise in investigation of pelvic floor disorders. However no universal standard for its use exists to date. Some of the promising applications of the TLUS/TPUS include assessment of pelvic floor muscles integrity and biometry. TLUS/TPUS can be a useful adjunct to the pelvic floor muscle training and biofeedback. Some other potentially useful applications of TLUS/TPUS include investigation of posterior vaginal wall prolapse and assessment of implanted materials. Lack of standardized terminology and objective parameters and validation of diagnosis and assessment of pelvic floor disorders dampen the broader clinical application of TLUS/TPUS. In 2011, an international panel aimed to perform a meta-analysis to analyze pelvic floor ultrasound literature. They deemed the production of a systematic review impossible based on the type and quality of published literature [9]. They identified research priorities and advised on more coordinated and structured research effort into internal and external validity of pelvic floor ultrasound in assessment of pelvic floor disorders.

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