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REVIEW ARTICLE

Pelvic floor ultrasound in incontinence: what's in it for the surgeon?

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Abstract There is increasing interest in imaging techniques such as magnetic resonance and ultrasound amongst pelvic floor surgeons, as evidenced by the number of workshops and conference presentations in this field. Ultrasound is employed more commonly, due to much lower costs, greater accessibility and practicability. Consequently, this review focuses on sonography. At this time, imaging is probably under-utilised in urogynaecology and female urology, although it has the potential to greatly benefit our patients. In this review, I will outline the main uses of imaging in the work-up of women with urinary incontinence, before and after treatment, and focus on areas in which this benefit to patients and clinicians is most evident.

Keywords Imaging · Ultrasound · Urinary incontinence · Urogynecology

Introduction

In 2011, general obstetrics and gynaecology, reproductive endocrinology, gynaecological oncology and maternofetal medicine in the developed world cannot possibly be practised without using imaging every day. It is so much part of routine that we have ceased to notice. Urogynecology is inexplicably different even though the history of imaging in this field reaches back to the 1920s. Radiological techniques were first described to describe bladder appearance and descent, and later for central and posterior compartment prolapse. With the advent of B mode real-time ultrasound, this technique became an obvious alternative, whether via the transperineal [1, 2] (see Fig. 1) or the vaginal route [4]. More recently, magnetic resonance imaging has also developed as an option, although the difficulty of obtaining functional information, and of course cost and access problems, have hampered its general acceptance.

The uptake of new diagnostic technology depends on a number of factors, some of which are unrelated to clinical utility. In general, gynaecologists have been more ready to use ultrasound imaging than their urological colleagues, simply because such systems are commonly available in gynaecology units. This is particularly true in central and northern Europe, where sonographic imaging has been firmly in the hands of gynaecologists ever since its introduction, rather than just another (and minor) diagnostic technique utilised in radiology departments. Consequently, German language urogynaecologists were the first to publish recommendations for the use of ultrasound in pelvic floor dysfunction [5].

This review will focus on clinical utility in the work-up of the incontinent patient, both in the context of preoperative investigations, and in the diagnostic work-up, and in the context of dealing with treatment failure and postoperative complications.

Instrumentation and basic methodology

Basic requirements for translabial pelvic floor ultrasound include a B mode capable 2D US system with cine loop function, a 3.5–6 Mhz curved array transducer and a videoprinter. Such systems have been available since the early 1990s and are cheap and very widespread. A midsagittal view is obtained by placing a transducer (usually a curved array with frequencies between 3.5 and 8 MHz) on the perineum (see Fig. 1), after covering the transducer with a glove, condom or thin plastic wrap.

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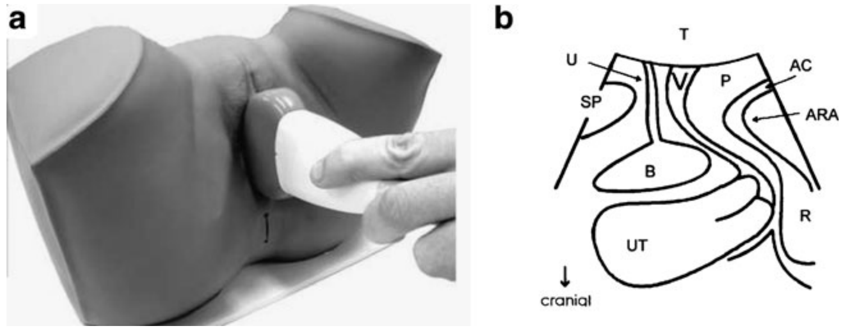

Fig. 1 Transducer placement (*left*) and field of vision (*right*) for translabial/ perineal ultrasound, midsagittal plane. Adapted from: ref. [3], with permission

Sterilisation as for intracavitary transducers is usually considered unnecessary. We use mechanical cleaning and alcoholic wipes for disinfection.

Powdered gloves can impair imaging quality due to reverberations. It may be necessary to test locally available gloves or probe covers for their effect on image quality. Imaging is usually performed in dorsal lithotomy, with the hips flexed and slightly abducted, or in the standing position. The pelvic tilt can be improved by asking the patient to place heels close to the buttocks and then move hips towards the heels. Bladder filling should be specified; usually prior voiding is preferable. The presence of a full rectum can impair diagnostic accuracy and sometimes necessitates a repeat assessment after bowel emptying. Parting of the labia can improve image quality. The author feels that imaging conditions are usually optimal in pregnancy and poorest in menopausal women with marked atrophy, most likely due to varying hydration of tissues. Vaginal scar tissue can also impair visibility. Obesity rarely seems to be a problem.

The transducer can initially be placed firmly on the perineum and the symphysis pubis without causing discomfort, unless there is marked atrophy or vulvitis. The resulting image includes the symphysis anteriorly, the urethra and bladder neck, the vagina, cervix, rectum and anal canal (see Fig. 1b). Posterior to the anorectal junction a hyperechogenic area indicates the central portion of the levator plate, i.e. the puborectalis muscle. The cul-de-sac may also be seen, filled with a small amount of fluid, echogenic fat or peristalsing small bowel. Parasagittal or transverse views may yield additional information, e.g. enabling assessment of the puborectalis and iliococcygeus muscles and their insertions on the arcus tendineus of the levator ani, and for imaging of implants.

While there has been disagreement regarding image orientation in the midsagittal plane, the author prefers an orientation as on conventional transvaginal ultrasound (cranioventral aspects to the left, dorsocaudal to the right). The latter also seems more convenient when using 3D/4D systems.

3D/4D imaging

The introduction of 4D ultrasound has had a major impact on pelvic floor imaging. This is mainly due to the fact that 4D ultrasound gives access to the axial plane to a degree and with an ease that far surpasses what was possible using intracavitary transducers in the past. A single volume obtained at rest with an acquisition angle of 70° or higher will include the entire levator hiatus with symphysis pubis, urethra, paravaginal tissues, the vagina, anorectum and levator ani muscle from the pelvic sidewall to the posterior aspect of the anorectal junction.

Any system that allows satisfactory 3D/4D imaging using an abdominal obstetric probe will be suitable provided the acquisition angle is sufficient to include the entire levator hiatus (i.e. between 70° and 85°). Optimally one should be able to obtain volumes at an acquisition angle of 80–85° and store at least 5 s worth of sequential volumes on the system's hard disc for later evaluation.

Display modes

Figure 2 demonstrates the two basic display modes currently in use on 3D ultrasound systems. The multiplanar or orthogonal display mode shows cross-sectional planes through the volume in question. For pelvic floor imaging, this usually means the midsagittal (top left), the coronal (top right) and the axial plane (bottom left). Imaging planes on 3D ultrasound can be varied in arbitrary fashion to enhance the visibility of any anatomical structure, either at the time of acquisition or offline at a later time. Orthogonal displays, i.e. the simultaneous representation of three planes at right angles to each other- are particularly useful after sling surgery and for urethral pathology.

The three orthogonal images are complemented by a 'rendered image', i.e. a semitransparent representation of all voxels in an arbitrarily definable 'region of interest'. The bottom right-hand image in Fig. 2 shows a standard rendered image of the levator hiatus, with the rendering direction set from caudally to cranially, which is the most appropriate for imaging the hiatus. The possibilities for post-processing are restricted only by the software used for this purpose.

4D imaging implies the real-time acquisition of volume ultrasound data, which can then be represented in orthog-

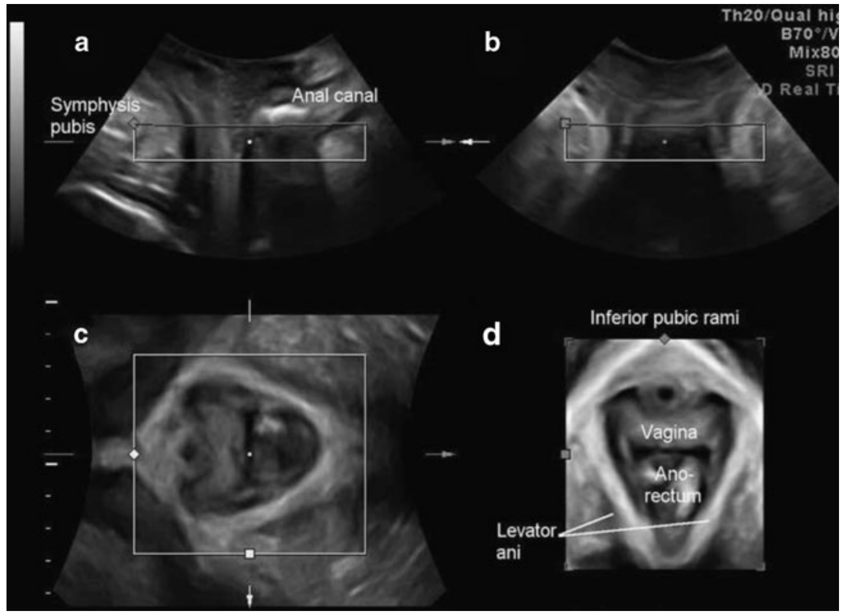

Fig. 2 Standard representation of 3D pelvic floor ultrasound. The usual acquisition/ evaluation screen on Voluson type systems shows the three orthogonal planes: sagittal (**a**), coronal (**b**) and axial (**c**); as well as a rendered volume (**d**) which is a semitransparent representation of all grayscale data in the rendered volume (i.e. the box visible in (**a**–**c**)). Adapted from: ref. [6], with permission

onal planes or rendered volumes. Many systems are now capable of storing cine loops of volumes, which is of major importance in pelvic floor imaging as it allows enhanced documentation of functional anatomy. Offline analysis packages allow distance, area and volume measurements in any user-defined plane (oblique or orthogonal) which is much superior to what is possible with DICOM viewer software on a standard set of single plane MRI images.

Functional assessment

Valsalva

The Valsalva manoeuvre, i.e. a forced expiration against a closed glottis and contracted diaphragm and abdominal wall, is routinely used to reveal increased urethral and bladder neck mobility. This displacement can be quantified using a system of coordinates based on the inferoposterior symphyseal margin (see Fig. 3). In the axial plane, the hiatus is distended, and the posterior aspect of the levator plate is displaced caudally, resulting in a varying degree of perineal descent. One ought to take care to let the transducer move with the tissues, avoiding undue pressure on the perineum.

In young nulliparous women, a Valsalva is frequently confounded by levator activation [7] as any obstetrician is able to observe on a daily basis. Levator co-activation during Valsalva is highly inconvenient- not just in Labour Ward during the expulsive phase of a woman's first vaginal delivery, but also when we assess women for pelvic floor dysfunction. Levator co-activation is visible as a reduction in the anteroposterior diameter of the levator hiatus on Valsalva (see Fig. 4). It has to be avoided in order to obtain an accurate assessment of pelvic organ descent. Any imaging assessment of organ descent requires real-time observation of the effect of a Valsalva manoeuvre in order to correct suboptimal efforts, especially if leakage from bladder or bowel is likely. At times, levator co-activation can prevent adequate assessment in the supine position, in particular in women with a strong, intact levator shelf. Sometimes it is necessary to repeat imaging in the standing position which seems to increase the likelihood of an adequate bearing- down effort. Other confounders are bladder filling [8], duration of Valsalva maneuver (which should be continued for at least 5 s) [9] and abdominal pressure. The latter is the one most commonly mentioned, but it seems that the vast majority of patients are able to generate pressures that are sufficient for a reproducible assessment (own unpublished data).

Pelvic floor muscle contraction

Since pelvic floor muscle exercises are generally recognised as first- line treatment in urinary (and faecal) incontinence [10], it is sensible to determine levator muscle function in women presenting with such symptoms. Ultrasound is a highly useful tool in the assessment of the pelvic floor musculature, both in purely anatomical terms (see below) and for function. A levator contraction will reduce the size of the levator hiatus in the sagittal plane and elevate the anorectum, changing the angle between levator plate and symphysis pubis. As an indirect effect, other pelvic organs such as uterus, bladder and urethra are displaced cranially (see Fig. 5), and there is compression of urethra, vagina and anorectal junction, explaining the importance of the levator ani for urinary and faecal continence as well as for sexual function.

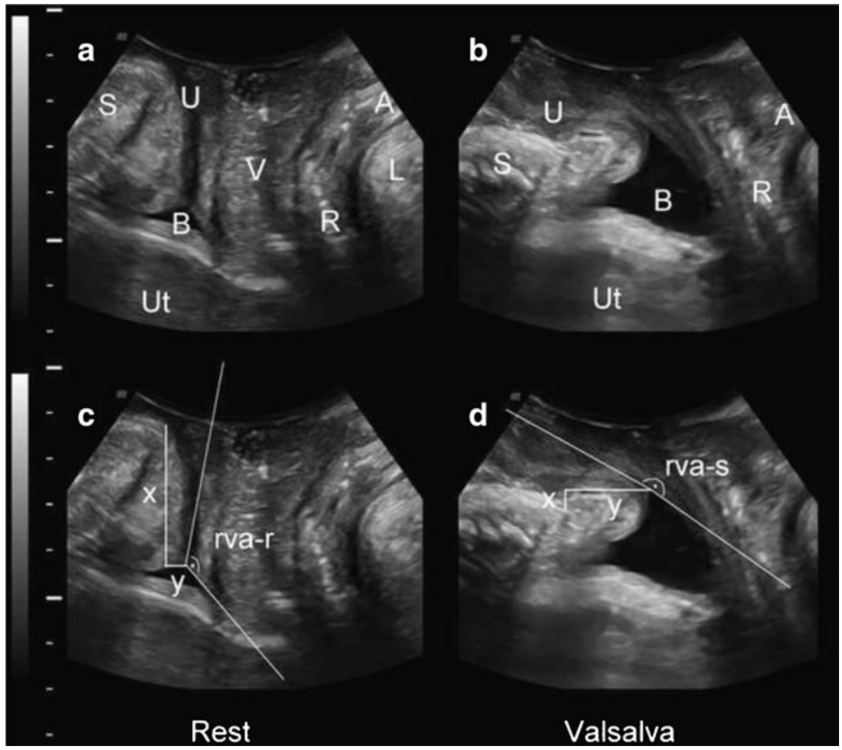

Fig. 3 Determination of bladder neck descent and retrovesical angle: ultrasound images show the midsagittal plane at rest (**a**, **c**) and on Valsalva (**b**, **d**). *S* symphysis pubis, *U* urethra, *B* bladder, *Ut* uterus, *V* vagina, *A* anal canal, *R* rectal ampulla, *L* levator ani. The *lower images* demonstrate the measurement of distances between inferior symphyseal margin and bladder neck (vertical, *x* and horizontal, *y*). and the retrovesical angle at rest (*rva-r*) and on Valsalva (*rva-s*)

In its most basic form, transabdominal B mode imaging can demonstrate elevation of the bladder base on pelvic floor muscle contraction, but quantification is difficult and repeatability is lower than for translabial ultrasound [11]. The latter has been employed for the quantification of pelvic floor muscle function, both in women with stress incontinence and continent controls [12] as well as before and after childbirth [13, 14] A cranioventral shift of pelvic organs imaged in a sagittal midline orientation is taken as evidence of a levator contraction. This shift in organ position can also be used for visual biofeedback teaching [15], which can be remarkably effective. The resulting displacement of the internal urethral meatus is measured relative to the inferoposterior symphyseal margin (see Fig. 5). Care has to be taken to avoid concomitant activation of the abdominal muscles, especially the rectus abdominis or the diaphragm, as this would tend to cause caudal displacement of the bladder neck.

Another means of quantifying levator activity is to measure reduction of the levator hiatus in the midsagittal plane [16], or to determine the changing angle of the hiatal plane relative to the symphyseal axis (see Fig. 5). As mentioned, the method can be utilised for pelvic floor muscle exercise teaching by providing visual biofeedback [15] and has helped validate the concept of ‘the knack’, i.e. of a reflex levator contraction immediately prior to increases in intra-abdominal pressure such as those resulting from coughing [17]. Correlations between cranioventral shift of the bladder neck on the one hand and palpation/ perineometry on the other hand have been shown to be good [18].

Translabial ultrasound in the investigation of urinary incontinence

Since the late 1980s, there have been a number of reports demonstrating the equivalence or superiority of translabial ultrasound over fluoroscopic imaging or cysto-urethrography, and those comparisons utilised imaging with a full bladder [19–21]. If the purpose of the assessment is the actual documentation of stress urinary incontinence then it should be undertaken with a full bladder, as with X-ray imaging. However, since urodynamic stress incontinence by definition requires urodynamic testing, this is not usually necessary. In order to maximise pelvic organ mobility, bladder emptying is required [8]. After this, one can obtain a residual urine measurement at the time of an assessment for urethral and bladder neck, using the formula (X*Y*5.6)= residual urine in ml, with X and Y the largest bladder diameters measured at right angles to each other, in the midsagittal plane [22].

Provided that residual urine volume is below 50 ml, detrusor wall thickness can be measured, either by vaginal or translabial ultrasound. While detrusor wall thickness (DWT) has probably been overrated as a diagnostic tool in the context of detrusor overactivity [23, 24], increased DWT is very likely associated with symptoms of the overactive bladder [24, 25], and may be a predictor of postoperative de novo urge incontinence

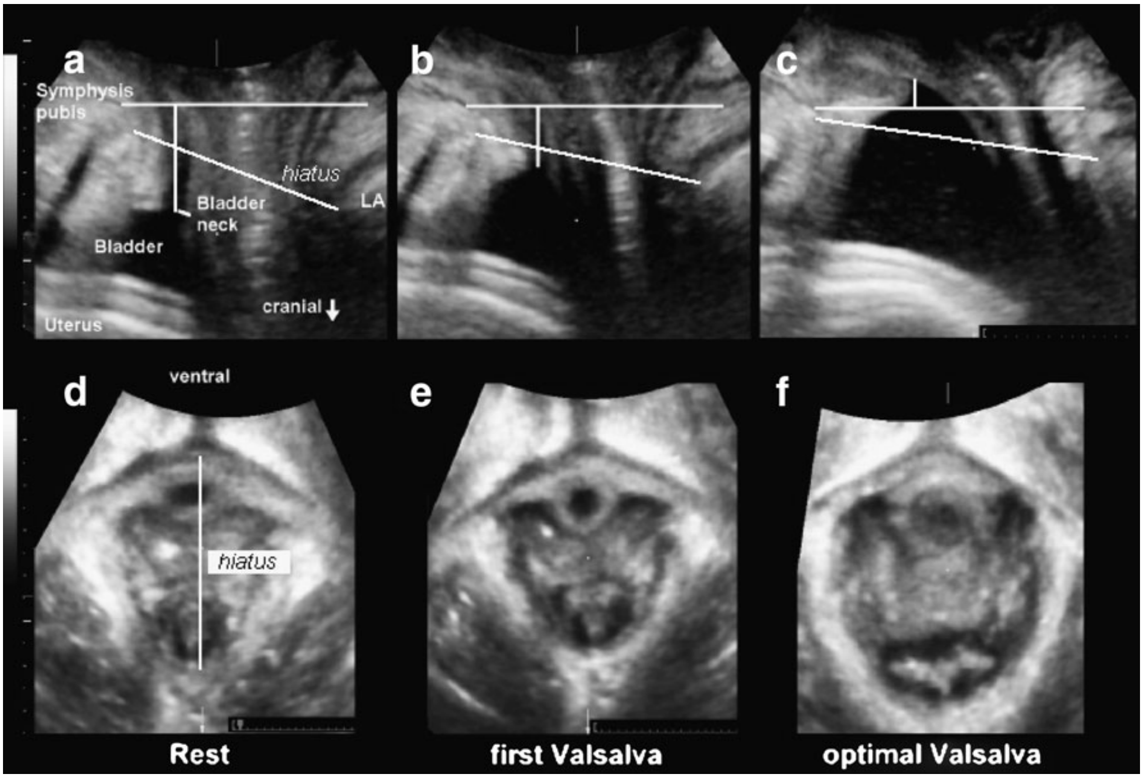

Fig. 4 Levator co-activation as a confounder of a valsalva effort. The top row of images shows the midsagittal, the bottom row the axial plane. **a**, **d** demonstrate findings at rest, **b**, **e** a suboptimal Valsalva confounded by PFM activation, and **c**, **f** a full, appropriate Valsalva. It is evident that, while there is some bladder neck descent on Valsalva in (**b**), the levator hiatus in **e** is in fact smaller than in (**d**), indicating a confounding PFM contraction. Adapted from: ref. [6], with permission

and/or detrusor overactivity after anti-incontinence procedures [26].

Bladder neck mobility

Bladder neck position and mobility can be assessed with a high degree of reliability [27]. Points of reference are the central axis of the symphysis pubis [20] or its inferoposterior margin [21], see Fig. 3). The full bladder is less mobile [8] and may prevent complete development of pelvic organ prolapse. It is essential to not exert undue pressure on the perineum so as to allow full development of pelvic organ descent. Measurements of bladder neck position are performed at rest and on maximal Valsalva, and the difference yields a numerical value for bladder neck descent (BND). On Valsalva, the proximal urethra may be seen to rotate in a postero-inferior direction. The extent of rotation can be measured by comparing the angle of inclination between the proximal urethra and any other fixed axis. Some investigators measure the retrovesical angle (RVA or posterior urethrovesical angle PUV) between proximal urethra and trigone (see Fig. 3), others determine the angle between the central axis of the symphysis pubis and a line from the inferior symphyseal margin to the bladder neck [28]. The reproducibility of bladder neck descent seems good, with intraclass correlations were between 0.75 and 0.98, indicating 'excellent' agreement [29].

There is no definition of 'normal' for bladder neck descent although the author would propose a cut-off of 30 mm which is still below the 95th percentile of findings in young nulligravid continent women [29]. Bladder filling, patient position and catheterization all have been shown to influence measurements (see [30] for an overview) and it can occasionally be quite difficult to obtain an effective Valsalva manoeuvre, especially in nulliparous women who routinely co-activate the levator muscle [7]—see Fig. 4. Slight variations in methodology seem to result in substantial differences in reported reference measurements in nulliparous women [31, 32]. The author has obtained measurements of 1.2–40.2 mm (mean, 17.3 mm) in a group of 106 stress-continent nulligravid young women of 18–23 years of age [29].

The etiology of increased bladder neck descent is likely to be multifactorial. The wide range of values obtained in young nulliparous women suggests a congenital component. Vaginal childbirth is probably the most significant environmental factor [33, 34], with a long second stage of labour and vaginal operative delivery associated with increased postpartum descent. This association between increased bladder descent and vaginal parity is also evident

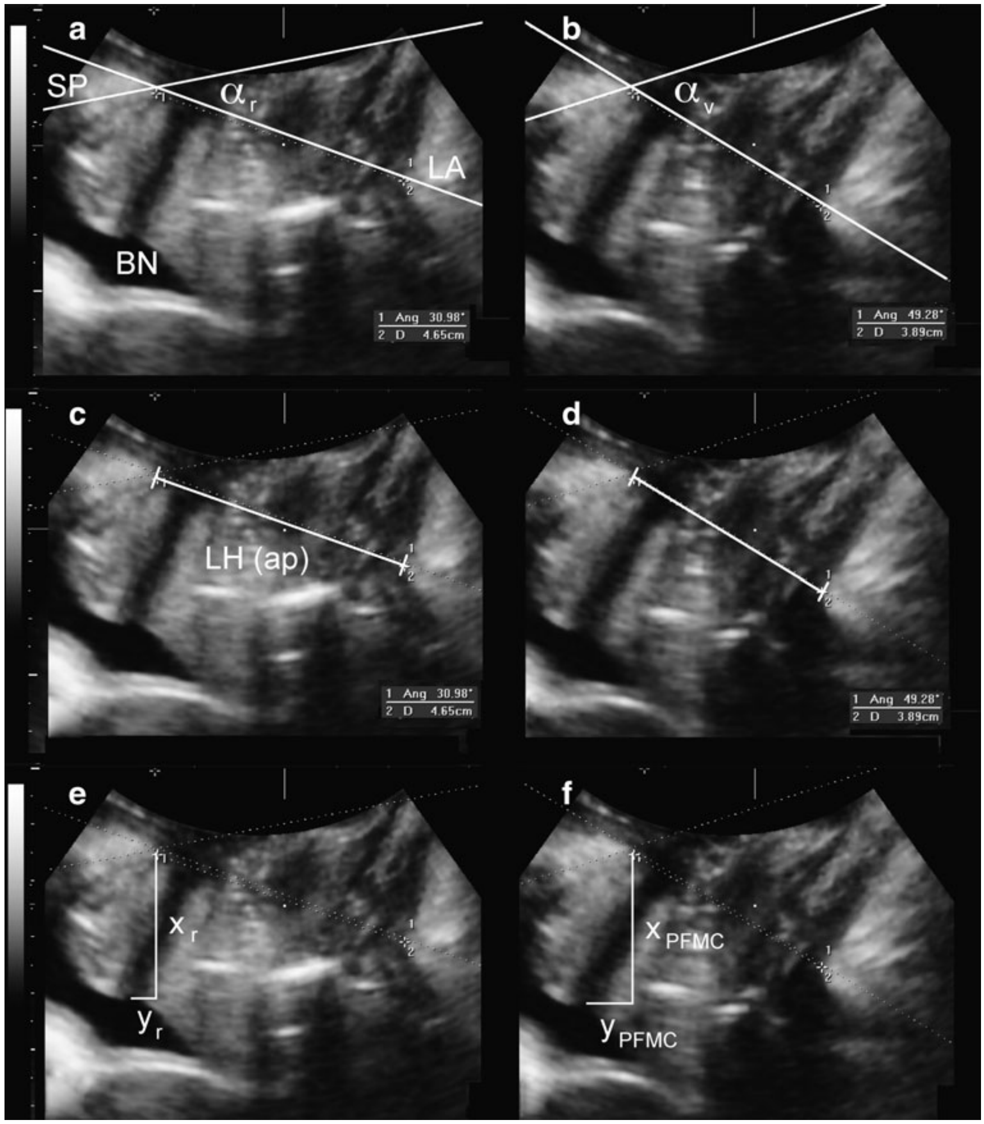

Fig. 5 Three methods of determining the effect of a pelvic floor muscle contraction (*PFMC*) in the midsagittal plane, using 2D translabial ultrasound. The *left-hand images* in each pair (**a**, **c**, **e**) represent the resting state; the *right-hand images* show findings on PFMC. The *top* pair illustrates measurement of the levator plate angle (angle between symphyseal axis and levator hiatus in the midsagittal plane), the *middle* pair shows reduction of the anteroposterior diameter of the levator hiatus (*LH* (*ap*)), and the *bottom* pair illustrates bladder neck displacement on PFMC, analogous to the way bladder neck descent is measured on Valsalva

in older women with symptoms of pelvic floor dysfunction [35]. Bladder neck descent has long been held to be associated with stress incontinence, both before and after childbirth [36, 37], and in later life [38], and this is very likely true, even if multiple other factors confound this relationship.

Most recently, it has been shown that it is mid-urethral mobility, not mobility of the bladder neck, which is most important for continence [39], and this is consistent with the commonly held belief that the mid-urethra is the locus of the most substantial urethral fixation and, hence, pressure transmission. Ultrasound can determine not just bladder neck mobility, but also segmental urethral mobility, since modern systems have sufficient resolution to demonstrate the entire urethra and its mobility relative to the symphysis pubis [40]. Using this methodology, it has been shown that both stress urinary incontinence and urodynamic stress incontinence are most strongly associated with mid-urethral mobility [39], and that the effect of modern suburethral slings is largely limited to this location [41]. Rather surprisingly, it seems that traumatic alteration of urethral supports in childbirth is unlikely [42] and that urethral mobility is not significantly affected by pelvic floor muscle trauma [43].

It is likely that some degree of bladder neck mobility is a prerequisite for successful dynamic compression of the urethra by suburethral slings, which clearly is the mechanism by which such slings work [44]. It appears reasonable to assume that low mobility of the urethra should reduce the likelihood of cure and increase the likelihood of postoperative voiding dysfunction. In the author's opinion it seems that modern sling procedures work best if there is a mild degree of hypermobility (that is, between 2.5 and 4 cm of BND). However, to date there is no proof for this concept, and suburethral slings can be curative even in patients with minimal mobility. There clearly are several other predictors of outcome, the most obvious one being urethral quality [45, 46].

Funnelling and stress incontinence

In patients with stress incontinence, but sometimes also in asymptomatic women, funnelling of the internal urethral meatus may be observed on Valsalva and occasionally even at rest [47]. Funnelling is often (but not necessarily) associated with leakage, and an open retrovesical angle. In the experience of the author, the commonest findings in women with stress urinary incontinence are 2–5 to 4 cm of bladder neck descent, an open retrovesical angle and funnelling (see Fig. 3). Other indirect signs of urine leakage on B mode real-time imaging are weak grayscale echoes (‘streaming’) and the appearance of two linear (‘specular’) echoes defining the lumen of a fluid- filled urethra. Its anatomical basis is unclear [48]. Marked funnelling has been shown to be associated with poor urethral closure pressures [49, 50]. Urine leakage may be demonstrated on imaging with the help of colour Doppler [51, 52], see Fig. 6, (velocity or power Doppler, or a combination of both) and may help determine leak point pressure [53]. To improve the detection of funnelling, some investigators have tried to use contrast medium [54], but this technique has not been developed further.

There is another aspect to urethral and anterior vaginal wall mobility in patients with incontinence that has been insufficiently investigated to date, and that is the relationship between urethra and trigone. Clinical examination is limited to grading anterior compartment prolapse, which we call ‘cystocele’. In fact, imaging can identify two distinct types of cystocele that can, with care, be distinguished clinically [55] and that have very different functional implications [56]. A cystocele with intact retrovesical angle (first described on X-ray cysto-urethrography as Green Type III in the 1960s [57]) is generally associated with voiding dysfunction, a low likelihood of stress incontinence, and major trauma to the levator ani, while a cystourethrocele (Green Type II) is associated with above average flow rates and urodynamic stress incontinence. On clinical examination, these two very different entities are generally grouped together, which may well be why studies of voiding dysfunction and prolapse have yielded such varying results. An associated issue is that of urethral kinking, a common phenomenon in women with Green Type III cystocele with intact retrovesical angle. Ultrasound, in particular the urethral motion profile, will likely help us to investigate these dynamic alterations and their impact on function in more detail.

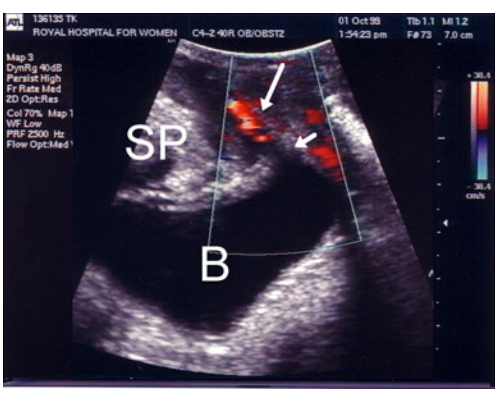

Fig. 6 Stress urinary incontinence demonstrated during Valsalva maneouver, using colour Doppler ultrasound. *SP* symphysis pubis, *B* bladder. The *short arrow* indicates the open bladder neck, and the *long arrow* indicates the Doppler signal caused by urine flow through the urethra

In a recent paper in this journal it was claimed that ‘there is no consistent, characteristic pattern of urethrovesical motion that could be identified by experts to correlate with stress incontinence’ [58]. The assessment was based on video recordings of perineal ultrasound during one single cough in the standing position. The anatomical features associated with stress incontinence are however easier to observe during a Valsalva, and in the supine position. The Valsalva has been shown to result in greater urethral displacement [32] and leakage at lower pressures [59], and it may well be the more appropriate test to demonstrate urethral and bladder neck mobility under load since its effect on urethrovesical anatomy is much easier to document. If performed properly, avoiding the above-mentioned confounders, a large proportion of patients with stress urinary incontinence will show the findings illustrated by Green on cysto-urethrography several decades ago [60], that is, urethral/bladder neck hypermobility, an open retrovesical angle and funnelling, as shown in Fig. 3.

Urethral rhabdosphincter

The urethral musculature can be imaged by transvaginal [61], intraurethral [62] and translabial ultrasound [63]. Intravaginal transducers, while providing higher resolutions and theoretically greater precision in determining sphincter volume, insonate this circular structure transversely. This implies that the circular fibres of the rhabdosphincter, depending on their location, are insonated at highly variable angles- some aspects of the sphincter are perpendicular, others are parallel to the incident beam. As a result, echogenicity varies markedly, which has led to misconceptions regarding the shape of the rhabdosphincter. On translabial imaging, resolutions are lower, but the entire rhabdosphincter is insonated at identical angles (i.e. perpendicular to the incident beam), avoiding artefacts and giving the appearance of a doughnut (see Fig. 7). There seems to be an association between sphincter volume and maximum urethral closure pressure and with stress incontinence [64],

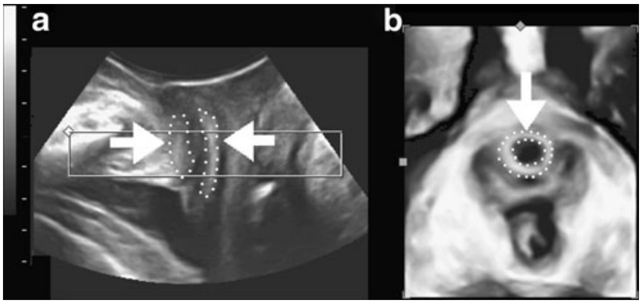

Fig. 7 The urethral rhabdosphincter as imaged in the midsagittal (**a**) and axial plane (**b**). In the midsagittal plane, the rhabdosphincter is visible as an iso-to hyperechoic zone ventral (*left*) and dorsal (*right*) of the hypoechoic longitudinal smooth muscle and mucosa of the urethra, in the axial plane it is shown as a closed doughnut-like circular hyperechogenic structure surrounding the hypoechoic longitudinal smooth muscle and mucosa

and maybe even with surgical outcomes [65]. Interestingly, increased rhabdosphincter thickness has recently been demonstrated after duloxetine treatment [66].

Translabial ultrasound is highly useful in the diagnosis of paraurethral abnormalities. Occasionally a "cystocele" will turn out to be due to a urethral diverticulum (see Fig. 8), a Gartner duct cyst or an anterior enterocele, all rather likely to be missed on clinical examination. Exclusion of a urethral diverticulum is a frequently forgotten benefit of pelvic floor ultrasound [68]. The literature seems to largely ignore this fact, as it is commonly assumed that MR is the diagnostic method of choice [69]. One would hope that at some stage our colleagues come to realize that multiplanar translabial imaging is not just simpler and cheaper, but that it provides superior spatial resolution of paraurethral abnormalities.

Effects of prolapse on urethral function

Prolapse can affect urinary continence in various ways, and ultrasound will demonstrate such effects better than any other modality. The issue of cystocele and urethral kinking has already been mentioned, but prolapse in other compartments may also matter for continence. In fact, the greatest effect of prolapse on voiding may not be due to cystocele but to enterocele [70], which may be explained by more immediate and direct transmission of intra-abdominal pressures onto the urethra in women with enterocele. Either way, translabial ultrasound easily demonstrates uterine prolapse, enterocele and rectocele, all of which can compress the urethra and mask stress incontinence. A special case is the incarcerated, retroverted fibroid uterus, with distortion/compression of the bladder neck by the cervix.

It is generally assumed that levator function and morphology is important for continence, and the effectiveness of pelvic floor muscle exercises in incontinent women seems to support this concept. Put another way, it is generally assumed that stress incontinent women suffer from some abnormality of levator ani structure and/or function. While this may be true for functional aspects such as reflex activity [71], it is doubtful as to whether

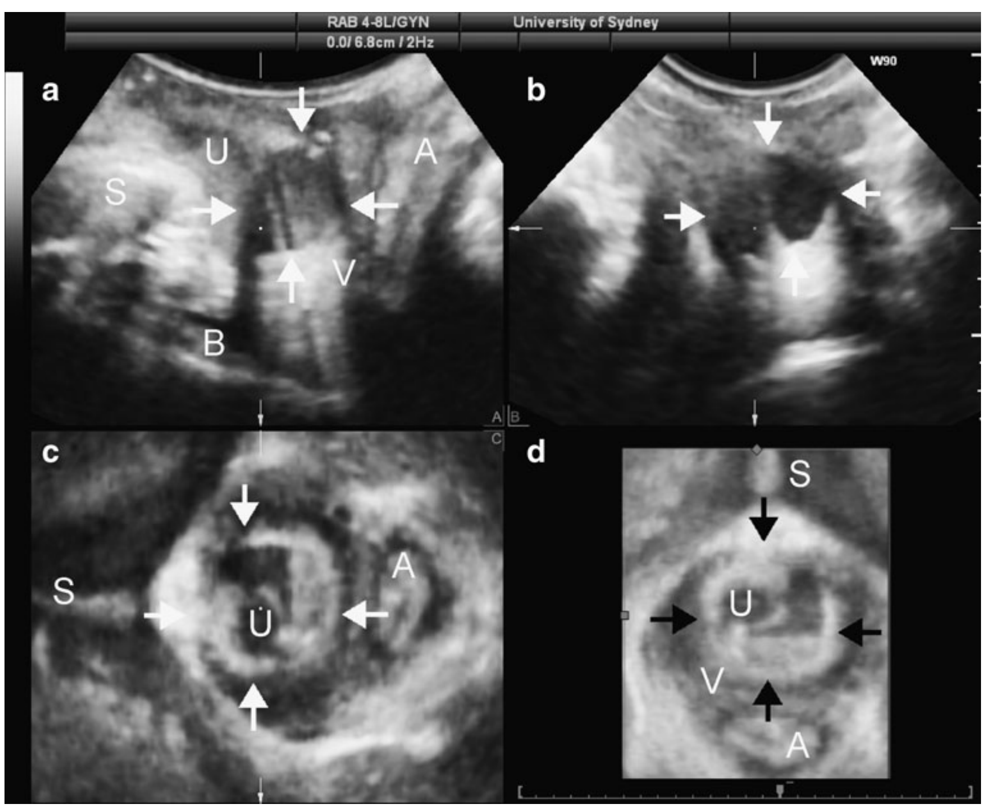

Fig. 8 Urethral diverticulum as seen on 3D translabial ultrasound, The extent of the diverticulum is clearly apparent, both in sectional planes (**a**–**c**) and in the rendered volume (**d**). Adapted from: ref. [67], with permission

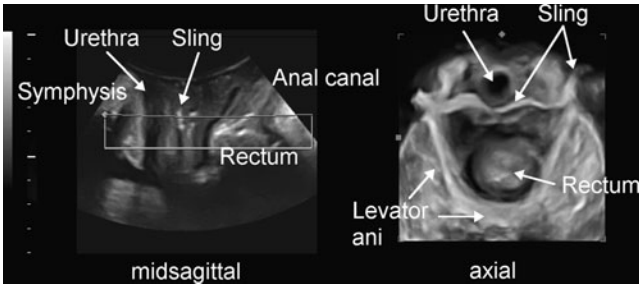

Fig. 9 A transobturator sling as imaged in the midsagittal plane (*left*) and in an axial rendered volume (*right*). Adapted from: [6], with permission

morphological abnormalities of the levator ani are associated with urinary continence. Over the last 5 years, translabial ultrasound has confirmed 60-year-old clinical data [72] and MRI studies [73] showing that major tears of the levator ani, in particular of the puborectalis muscle, are common in vaginally parous women [74–76]. However, it seems that levator trauma is not a risk factor for stress urinary incontinence [77], and that it has little, if any, effect on urethral mobility [43]. The effect of such trauma on the success of conservative treatment with PFM exercises remains to be elucidated.

Postoperative imaging

Translabial ultrasound has been used in the evaluation of postoperative findings after anti- incontinence surgery for over two decades [78–81]. Findings after anterior colporrhaphy are very variable, depending on suture placement, but Burch and Marshall Marchetti colposuspensions usually produce typical postoperative findings, with bladder neck immobilisation, a varying degree of anteriorisation, and a 'colposuspension ridge' under the trigone [82–84]. Fascial slings frequently also cause such a ridge, and bladder neck immobilisation may be even more pronounced than after colposuspension. Over-elevation seen on ultrasound may be a marker for postoperative voiding dysfunction and symptoms of the overactive bladder [85]. Laparoscopic colposuspensions cause a similar, if often less pronounced, distortion of the bladder neck [86], and urethropexies are distinct in that they elevate the internal urethral meatus rather than the trigone [87]. All those procedures, with rare exceptions, produce sonographic appearances that are highly unphysiological.

Pelvic floor ultrasound has become even more useful with the advent of modern suburethral slings. These synthetic implants, usually of wide-weave polypropylene mesh, are highly echogenic and easily identified in the anterior vaginal wall. There is no doubt as to which imaging method is most appropriate, since those implants cannot be seen with plain X-ray, CT or MR [88–90]. These new procedures, the first of which was the tension- free vaginal tape or TVT [91], are highly successful in most hands. Such slings have been assessed by vaginal and translabial ultrasound for the last 10 years [92–95], and sonography has been shown to be of great utility for research and clinical practice. The therapeutic effect of suburethral slings, i.e. dynamic compression at times of increased intra-abdominal pressure, is easily observed on real-time ultrasound [44], and initial concerns about sling migration or shrinkage/ contraction have been allayed [96]. However, at times such tapes may result in substantial complications, the diagnosis and management of which is greatly helped by imaging. Ultrasound can confirm the presence of such a sling (see Fig. 9) or detect one in women who are not aware of the type of previous surgery, distinguish between transobturator and transretzius slings [97], compare the results of different insertion techniques [98] and even allow an educated guess regarding the exact type and material of the sling [99].

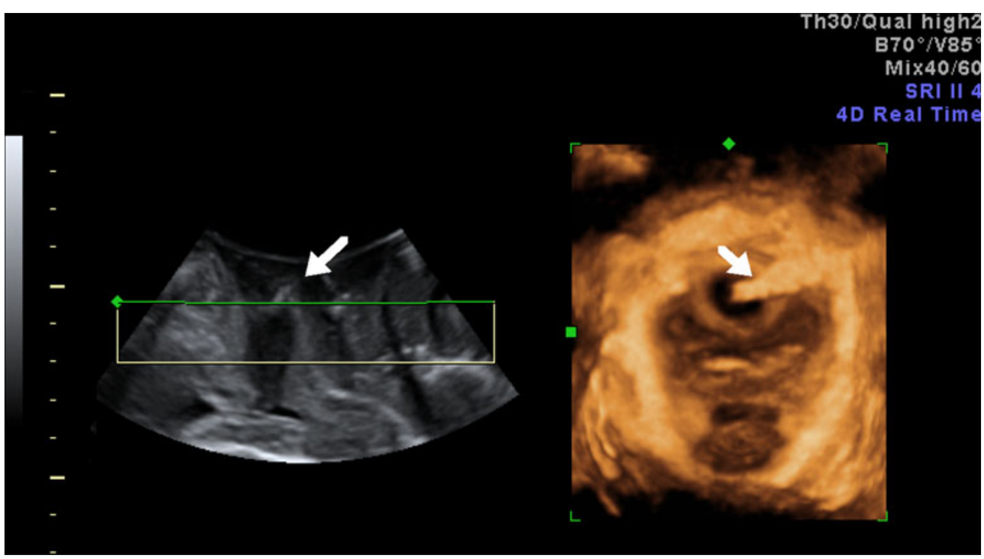

Fig. 10 A TVT that has perforated the urethra as imaged in the midsagittal plane (*left*) and in an axial rendered volume (*right*), indicated by *arrow*

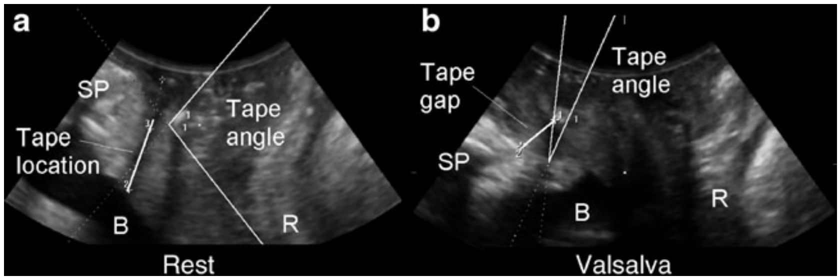

Fig. 11 Parameters of tape 'tightness'. The most useful such parameter seems to be the gap between the posterior symphyseal margin and the sling on Valsalva ('tape gap'). Tape gaps of less than 7 mm are very likely to be obstructive, and those over 15 mm are much less likely to provide sufficient dynamic compression, leaving the patient stress incontinent

It is easy to confirm whether the sling is placed at the conventional mid-urethral level, although tape location along the urethra may not be as important as sometimes assumed [100, 101]. Location relative to the rhabdosphincter may matter more, especially in the long run. Perforation/erosion or near-perforation/erosion are readily apparent [102] (see Fig. 10). In addition, the functional impact of a suburethral sling can be assessed on Valsalva manoeuvre. The appearance of the sling (straight line, angled line or c-shape) can be quantified with the 'tape angle' [103] and will suggest the degree of tension. The gap between sling and symphysis pubis on Valsalva seems to be a highly reproducible and valid parameter of sling 'tightness' [103], see Fig. 11. A tight c-shaped appearance at rest and a tape gap of less than 7 mm on Valsalva makes functional obstruction very likely and suggests that tape division would be beneficial in a patient with worsened symptoms of bladder irritability or clinically significant voiding dysfunction. On the other hand, a wide tape gap and a sling that remains a straight line on Valsalva suggests insufficient tension, or a failure of sling anchoring. Many women would have been spared the suboptimal outcomes of several recently developed minislings if manufacturers had used ultrasound outcome measures of sling tension and anchoring in their pre-marketing clinical studies.

Finally, ultrasound is useful for confirming the success of sling division, especially if there are persistent symptoms. It is not always easy to divide a suburethral sling, and sometimes we fail in such an endeavour. Successful sling division results in a clear separation of the two halves of the implant (see Fig. 12), and the resulting gap is seen to widen on Valsalva, usually to at least 5–7 mm.

Conclusions

So, what's 'in it' for the pelvic reconstructive surgeon when it comes to using imaging in the incontinent patient? Firstly, one will be able to document the typical anatomical findings of stress urinary incontinence and exclude a high residual urine or unexpected incidental pathology such as a urethral

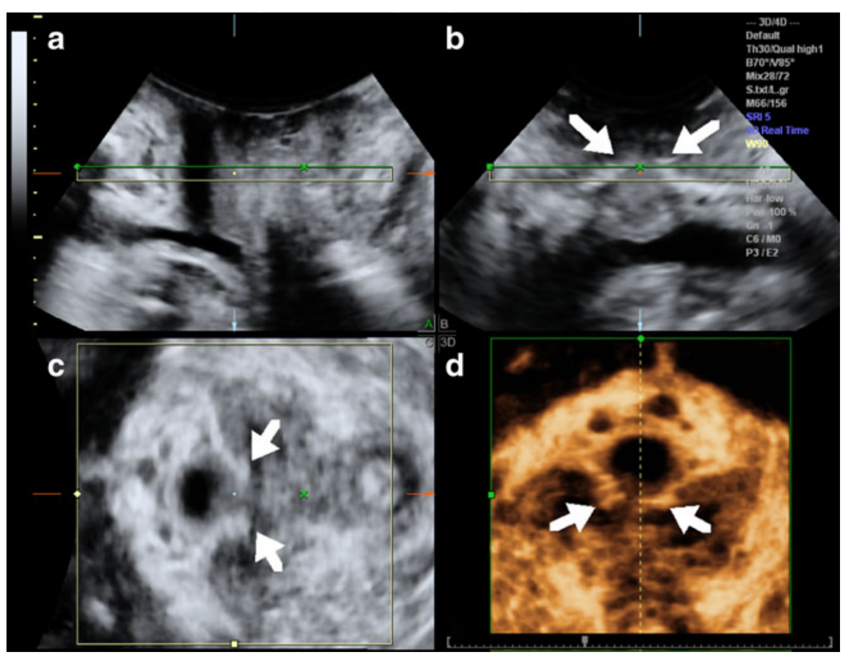

Fig. 12 Successful tape division in patient with obstructed voiding after TVT. The tape is invisible in the midsagittal plane (**a**). In the coronal (**b**) and axial (**c**) planes and in the rendered volume (**d**), the cut ends of the tape are clearly evident (*arrows*), with a gap between the cut ends of about 5–7 mm at rest. Adapted from: ref. [3], with permission

diverticulum. Occasionally one will identify evidence of previous surgery not recalled by the patient, e.g. a colposuspension or a synthetic sling. Hopefully, this will result in the avoidance (or at least optimised management) of intra- and postoperative complications. At the same time one will probably want to teach the patient how to contract her pelvic floor and provide visual biofeedback. In addition, there are potential benefits in identifying (frequently coexisting) prolapse, although the utility of distinguishing an enterocele from a true rectocele or a rectal intussusception will largely depend on the surgeon's operative approach. More importantly, imaging will allow simplified postoperative clinical audit, helping with the management of complications and operative failure. If a sling looks to be unusually loose, dividing it is unlikely to do any good — and if some new implant looks excessively mobile — then implant anchoring is likely to be insufficiently secure. As we are constantly exposed to new surgical methods and devices, imaging may be useful in shortening learning curves and can help in distinguishing industry hype from reality.

From the above discussion, it should be clear that ultrasound can be of great utility to the pelvic reconstructive surgeon. This is now quite obvious, considering the increasing prevalence of suburethral slings and intravaginal mesh implants, and the rediscovery of pelvic floor trauma as a major etiological factor in pelvic floor dysfunction. A full clinical assessment in urogynecology ideally should include imaging, especially in complicated and recurrent cases. Ultrasound and magnetic resonance imaging already have a substantial impact on clinical research and audit, as evidenced by the current literature. Imaging techniques will very likely help us to further elucidate the etiology and pathophysiology of pelvic floor dysfunction, help assess the outcomes of conservative and surgical treatment, and assist in the development of entirely new therapeutic concepts.

As was the case for urodynamic testing from the 1980s onwards, there currently is a substantial unmet need for training and teaching in urogynecological imaging. This is particularly true for ultrasound, given that it has much greater clinical utility compared with MR. It will depend largely on the provision of training and teaching resources as to when imaging will become an obvious, indispensable part of everyday clinical practice. However, I have no doubt that it is just a question of time.

Conflicts of interest The author has, within the last ten years, been the recipient of speaker's fees from GE Medical and Astellas, has consulted for AMS, CCS and Materna Inc., and has received equipment loans from Bruel&Kjaer, Toshiba and GE Medical.

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