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REVIEW ARTICLE

Clinical application of 2D and 3D pelvic floor ultrasound of mid-urethral slings and vaginal wall mesh

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Abstract

Introduction and hypothesis This mini-review demonstrates the clinical application of pelvic floor ultrasound for imaging women with mesh following incontinence and prolapse surgical procedures.

Methods The images are obtained using two-dimensional (2D) perineal pelvic floor ultrasound (pPFUS) and three-dimensional (3D) endovaginal ultrasound (EVUS).

Results 2D pPFUS and 3D EVUS provide confirmation of the presence or absence of vaginal wall mesh (VWM), bulking agents, and the type of mid-urethral sling (MUS). Residual mesh following excision can be located, and presence in the bladder/urethra may be demonstrated. These are crucial for surgical planning and counselling, with the potential to be useful intraoperatively also. The shape and position relative to urethral length and lumen can be assessed, which may correspond with voiding dysfunction or recurrent incontinence. Evidence of inflammation/sepsis or folding of the VWM may be useful in the investigation of pain.

Conclusions Pelvic floor ultrasound is the standard of care where imaging is available and utilised and is the only modality capable of reliably visualising mesh. It is clear that there are significant benefits and uses for the clinician for investigating complications of VWM or MUS; although many of the findings may be associated with clinical symptoms, some are incidental findings. Therefore, these scans should be performed by pelvic floor specialists with core competency in pelvic floor ultrasound and interpreted by those familiar with their significance, as an adjunct to patient history, examination and other investigations to assist in the most appropriate management plan for the patient. In addition, there is still a need for standardisation in terminology and measurement techniques, to allow for consistent and comparable reporting.

Keywords Complications · Mesh · Mid-urethral sling · Pelvic floor ultrasonography · Pelvic organ prolapse or incontinence · Transobturator tape · Tension-free vaginal tape

Introduction

Until recently, surgery using mid-urethral slings (MUS) for urinary incontinence was considered the gold standard surgical management for stress urinary incontinence [1]. Currently, there is considerable concern and controversy regarding the use of mesh for incontinence and prolapse [2]. This has been attributed to reported complication rates as high as almost 10%, including haemorrhage, organ perforation, mesh exposure, and infection or pain, some necessitating hospital admission or additional surgery [3, 4]. Therefore, despite being highly effective procedures, in response to the complications, many professional bodies in different countries have provided guidance and cautioned their use [5–10].

Management of the complications can be difficult and needs a multidisciplinary approach. Often, this will require understanding of the position, morphology and shape of the mesh implant. Although magnetic resonance imaging (MRI) and computed tomography may help in the management of some patients, particularly investigating for other causes of pain or mesh-associated inflammation and fibrosis, ultrasound is considered to be most useful, particularly for assessing the urethrovaginal or vaginal wall space [11, 12]. This is because it is the only modality that can clearly visualise the mesh implant at this location owing to the high echogenicity of its polypropylene material [13]. MRI may be more useful in

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imaging mesh located in the retropubic and intrabdominal space. Ultrasound is relatively cheap, safe and widely available, and is highly acceptable to the patient [12]. It has already been used by many clinicians in academic settings to document shapes, positions and dimensions of MUS and vaginal wall mesh (VWM) to understand their relationship to patient symptoms, complications and mechanisms of action [14–16]. This type of dynamic assessment can help to select appropriate patients for conservative or surgical management of their complications and understand why treatment may have failed [11, 17]. It may also aid in counselling patients on realistic expectations and qualm unfounded fears or concerns regarding their MUS or VWM in situ.

We provide a mini-review of the clinical application of pelvic floor ultrasound in women with mesh implants inserted for the treatment of incontinence and prolapse. The images have been obtained using 2D perineal pelvic floor ultrasound (pPFUS) and 3D endovaginal ultrasound (EVUS), as described below.

Ultrasound technique

Two-dimensional perineal pelvic floor ultrasound (2D pPFUS) and three-dimensional endovaginal ultrasound (3D EVUS), both validated imaging techniques for the pelvic floor, should be performed according to standardised methods [18, 19], with the patient in a supine position and the bladder partially filled. Images in this review have been acquired using the Flex Focus 500 ultrasound system (BK Medical, Herlev, Denmark). Other ultrasound modalities are also available for imaging the pelvic floor, such as introital ultrasound using an endovaginal transducer at the vaginal introitus. MUS (retropubic tension-free vaginal tape [TVT], trans-obturator tape [TOT], or mini-sling) and VWM are seen as highly echogenic structures, usually associated with an acoustic shadow.

The 2D pPFUS allows for non-invasive and dynamic assessment, with minimal distortion of the pelvic anatomy. The convex transducer (Type 8802; 4.3–6 MHz; BK Medical, Herlev, Denmark) is placed longitudinally over the perineum/vulva without excess pressure to simultaneously visualise the pubic symphysis, urethra, bladder, vagina, rectum and anal canal (Fig. 1a, b); images are acquired at both rest and maximal Valsalva. This mid-sagittal plane allows for evaluation of the position of the MUS relative to the length of the urethra or VWM in relation to the bladder neck in addition to the shape and mobility during rest and Valsalva. The midpoint of the MUS is usually taken as the reference point from where measurements are taken. Coronal and axial sections are then performed with the probe placed transversely with or without tilting caudally to visualise the full distribution, including symmetry, curling or folding.

High-frequency EVUS (Type 8838; 6–12 MHz, radial array 360° rotational probe; BK Medical, Herlev, Denmark) is performed at rest by placing the endocavity transducer in a neutral position in the vagina with no excess compression on the urethral complex or surrounding structures. This allows a mid-sagittal image: visualising the entire length of the urethral lumen from the bladder neck to the urethral meatus and ensuring that no pubic bone is visible (Fig. 1c, d). The 3D acquisition is mechanical; obtaining 1029 radial frames every 0.35° without any movement of the probe, creating a high-resolution 3D volume of the pelvic structures. The 3D image is then amenable to real-time manipulation and volume rendering. In the mid-sagittal plane, the caudal aspect of the bladder, full length of the urethra, sub-urethral portion of a MUS and any VWM in the anterior compartment can be seen. Anterior VWM is seen dorsal to the bladder neck, caudal and dorsal to the trigone and posterior bladder wall (Fig. 2a). The cranial-most aspect of anterior VWM may sometimes lie outside the parameters of the volume and may therefore not be visualised. Posterior VWM is seen from the perineum to the vaginal apex, within the rectovaginal space. By manipulating the 3D volume, it is possible to visualise the whole MUS up to the retropubic space and obturator fossae or VWM in the sagittal, axial (Fig. 2b) and coronal planes.

Mesh implants can be seen to have a honeycomb-like structure, allowing it to be distinguished from fibrous tissue or autologous slings. It is the author’s experience, however, that the longer a mesh implant has been in situ, the more difficult it is to clearly visualise as a distinct structure and often it will lose its honeycomb-like appearance, owing to fibrosis and the ingrowth of surrounding connective tissues.

Clinical application

Confirming surgical history and pre-operative planning

Translabial and endovaginal ultrasound have been shown to be superior to clinical examination to identify a MUS or VWM [11, 20]. Pelvic floor ultrasound can confirm or refute the presence of any polypropylene mesh in women unable to give an accurate history of previous pelvic surgery. Both translabial and endovaginal ultrasound have shown a correlation with the presence of mesh on surgical exploration [11, 20]. It is also useful to localise injected urethral bulking agents and their position in relation to the urethra or bladder neck [21]. Identifying the type of bulking agent depends on the echogenicity of the material, with Bulkamid® injections appearing less echogenic in comparison with Macroplastique®. (Fig. 3).

Complex patients may have undergone several procedures with mesh and ultrasound can demonstrate the presence and location of these [13]. The type of MUS can be determined

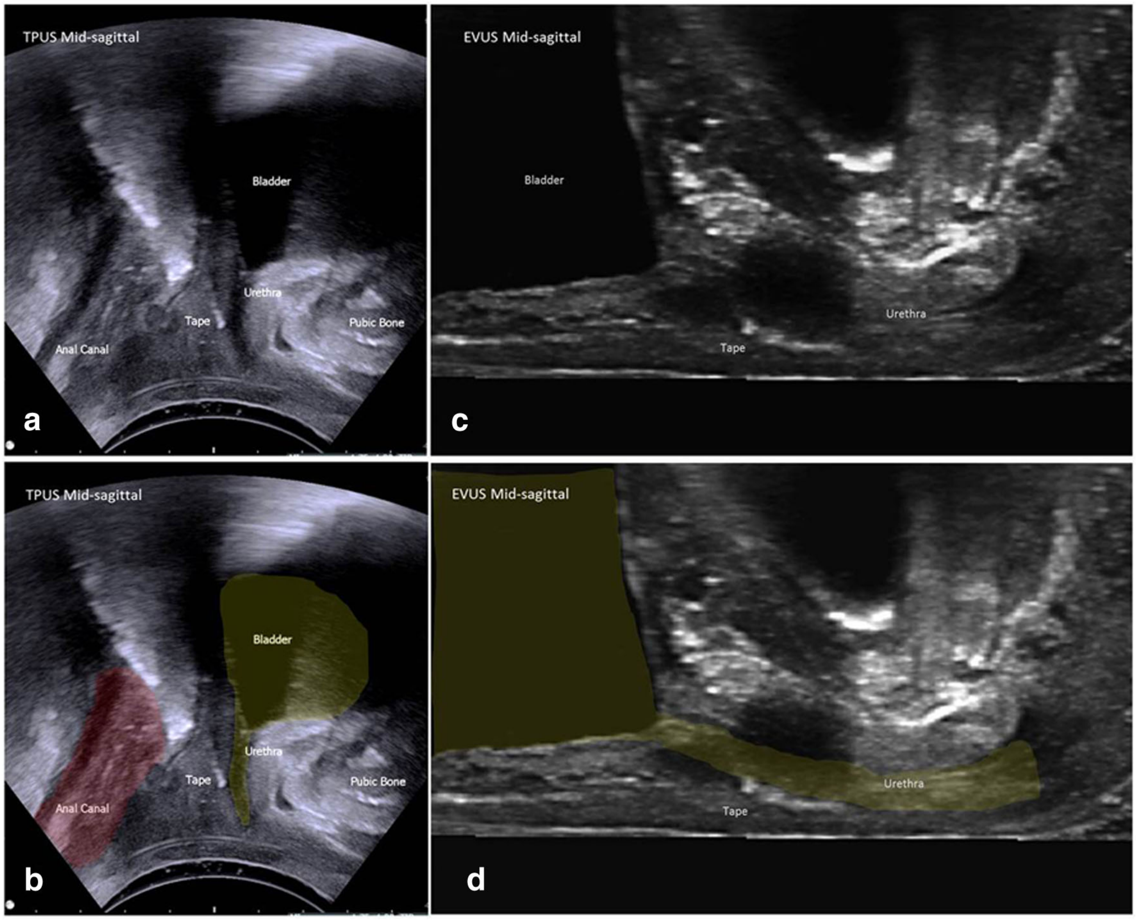

Fig. 1 Normal appearances of the anterior compartment. **a** Midsagittal view on transperineal ultrasound (*TPUS*) demonstrating the pubic bone, full length of the urethra, bladder and bladder neck. The anal canal is on the left. The mid-urethral sling (MUS) can be seen at the level of the mid-urethra, labelled as tape. **b** Demonstrates the same image as in **a** with the bladder, bladder neck and urethra highlighted in *yellow*. The anal canal is highlighted in *red*. **c** Endovaginal ultrasound (*EVUS*) image in mid-sagittal view of the anterior compartment. The full length of the urethra, bladder and bladder neck are seen, and the MUS labelled as tape, seen as the hyperechogenic structure beneath the mid-urethra with an acoustic shadow. This view allows for measurements from the MUS to bladder neck and to urethral lumen to be obtained. **d** The same image as in **c**, but with the bladder and urethral length highlighted in *yellow*

with some confidence; whether a retropubic or transobturator approach has been used can be ascertained by the position of the arms in addition to the overall shape appearance of the MUS. A TOT classically has the arms going laterally towards

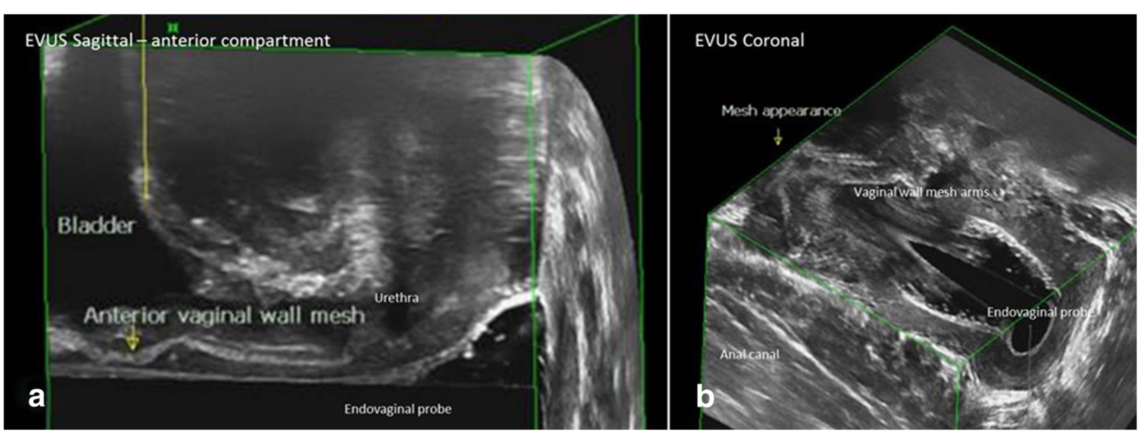

Fig. 2 Vaginal wall mesh for pelvic organ prolapse. **a** Sagittal section on endovaginal ultrasound showing the scan from a woman who was unsure if she had mesh inserted at the time of anterior colporrhaphy. The mesh is seen as a flat echogenic structure between the posterior bladder and urethra in the anterior vaginal wall (*arrow*). **b** The arms of the mesh used for pelvic organ prolapse surgery can be seen

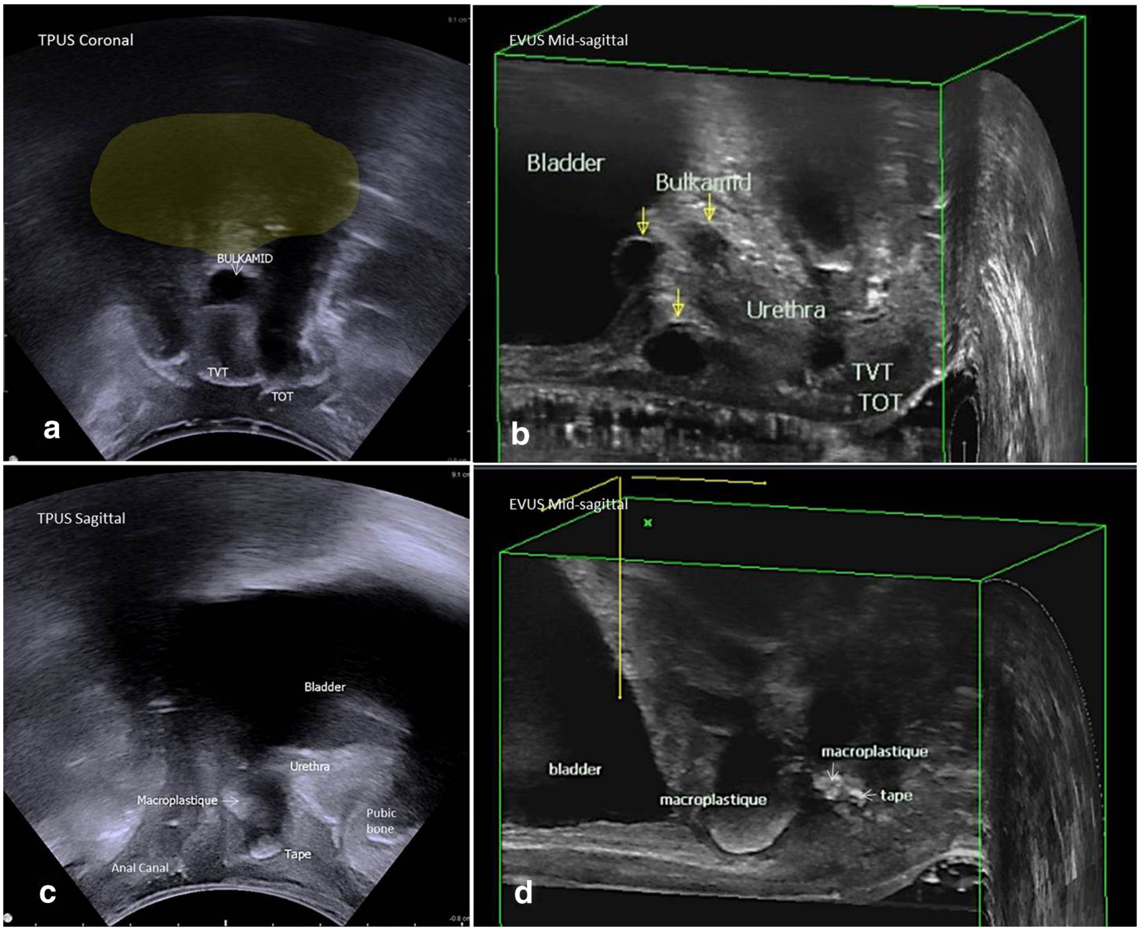

Fig. 3 Urethral bulking agents. **a** Perineal pelvic floor ultrasound coronal view showing Bulkamid® as a hypoechoic area by the bladder neck as labelled (bladder highlighted in *yellow*). This patient presented with de novo urgency and reported to have undergone a transobturator tape (*TOT*) insertion that was partially excised owing to voiding dysfunction, followed by a tension-free vaginal tape (*TVT*) insertion (as labelled). Evidence of material used for Bulkamid® injections was also seen (unknown to the patient). **b** Mid-sagittal view on endovaginal ultrasound of the anterior compartment demonstrating the bulking agent (*arrows*) bulging into the bladder and bladder neck. The two MUSs can also be seen at the distal urethra. **c** Mid-sagittal view on perineal ultrasound. Macroplastique® is seen with higher echogenicity compared with Bulkamid® injections allowing differentiation, but may obscure surrounding pelvic structures. This patient presented with a history of having had three MUSs inserted; on ultrasound it was discovered that she in fact had Macroplastique® with only one MUS, which is seen very close to the urethral lumen (labelled tape). **d** Mid-sagittal view on endovaginal ultrasound of the anterior compartment demonstrating the high echogenicity of the Macroplastique® compared with Bulkamid®

the obturator foramen, like a “sea-gull” shape. A retropubic MUS is U-shaped with the arms traversing caudally towards the pubic bone (Fig. 4) [21]. Knowing the type of MUS (TVT/TOT) also allows surgeons to plan the most appropriate surgical approach for removal. The positioning and number of anchoring arms and shape of an implant may suggest the type of VWM inserted (Fig. 2b). It is possible to visualise the distal-most aspects of a mesh used for hysteropexy or rectopexy on perineal and endovaginal ultrasound; however, there is little certainty with regard to the clinical relevance, and they are best imaged using MRI [12]. The distance of sacrocolpopexy mesh to the bladder neck was assessed by 4D pPFUS 3 years after the operation, a lower mesh position corresponding to a lower likelihood of anterior compartment prolapse recurrence. For every millimetre that the mesh was located further from the bladder on Valsalva, the likelihood of cystocele recurrence increased by 6–7% [22].

When partial or complete excision of the mesh implant has previously been performed, it is possible to differentiate between mesh and scar tissue owing to the honeycomb-like appearance of the mesh. It is therefore possible to localise any remnant or residual mesh, its size and location (Fig. 5). This is crucial for surgical planning, both pre- and intra-operatively.

In women who have had multiple MUSs or a MUS with VWM inserted, it is possible to correlate which mesh implant is causing symptoms of pain or dyspareunia by dynamic assessment on ultrasound with simultaneous clinical examination. This is useful if excision or division of only one mesh implant is planned, to avoid recurrence of symptoms.

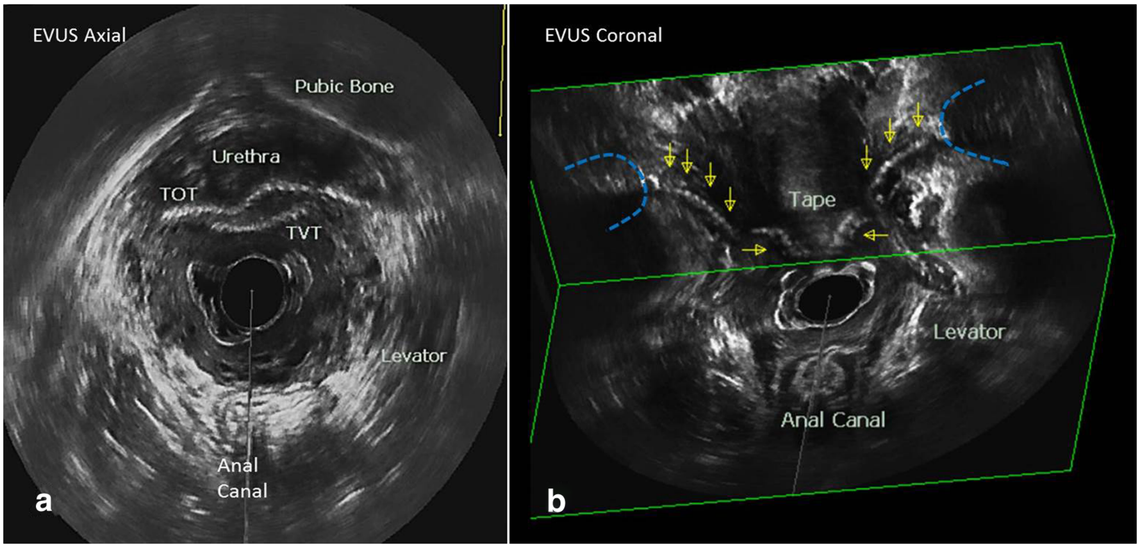

Fig. 4 Type of MUS. **a** Three-dimensional endovaginal ultrasound of a patient with a TVT and a TOT inserted (as labelled). The TOT can be seen classically with the arms going laterally towards the obturator foramen, described as a "sea-gull" appearance and the TVT as U-shaped with the arms towards the pubic bone. In this situation, it was possible to elicit which MUS was causing pain by simultaneously examining and visualising on ultrasound which MUS reproduced the patient's symptoms when palpated. **b** This coronal view on endovaginal ultrasound shows the full vaginal course of the TOT MUS (labelled as tape), indicated by the *yellow arrows*, with the arms going into the obturator foramen (seen as *dashed blue lines*). The urethra and bladder are not visible on this image

The benefits of pre-operative scanning can be extended intra-operatively to confirm location or complete excision of the mesh, whilst the patient is anaesthetised and positioned [20, 21, 23], as it may be difficult to identify the mesh on palpation.

Investigating new or recurrent lower urinary tract symptoms

The MUS position and mobility relative to the urethra and symphysis pubis [24, 25] can be demonstrated using introital ultrasound with excellent repeatability and good reproducibility of measurements [26]. Kociszewski et al. evaluated success of the TVT in 41 women with translabial ultrasound by measuring the position of the midpoint of the TVT relative to the urethral length and urethral lumen (hypoechoic aspect of the urethra) at 6 and 48 months. They described the optimal TVT position as being mid-urethra, at 40–70% of the urethral length, for a curative outcome (Fig. 6) [25]. Bogusiewicz et al. used 3D EVUS to assess MUS failure within 6 months of the original procedure; 73.8% of the failed MUSs were located at the proximal half of the urethra [27]. However, Ng et al. and Dietz et al. have shown with 3D pPFUS that TVT position can vary markedly without clear correlation with complications, symptoms or success, when assessed in relation to both the pubic symphysis [24] and the urethral length [28].

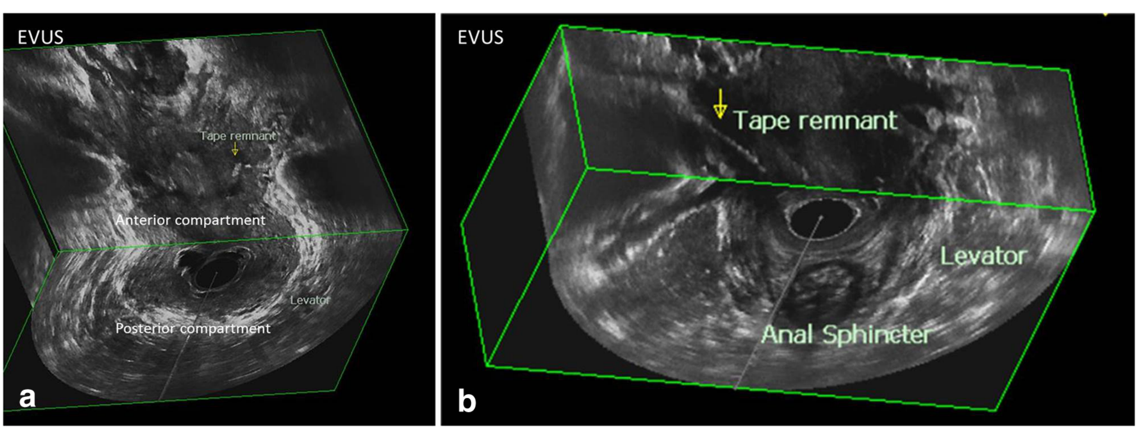

Fig. 5 Localising MUS mesh remnants. **a** Endovaginal ultrasound demonstrating a small segment of mesh localised on the *left* as labelled. There is also a hyperechoic shadow on the *right*, which represents scar tissue. The patient was unsure if she had had all her mesh removed, but continued to have pain in her right groin. **b** Endovaginal ultrasound demonstrating a segment of mesh localised on the *right* as labelled and the hyperechoic shadow on the *left* is scar tissue

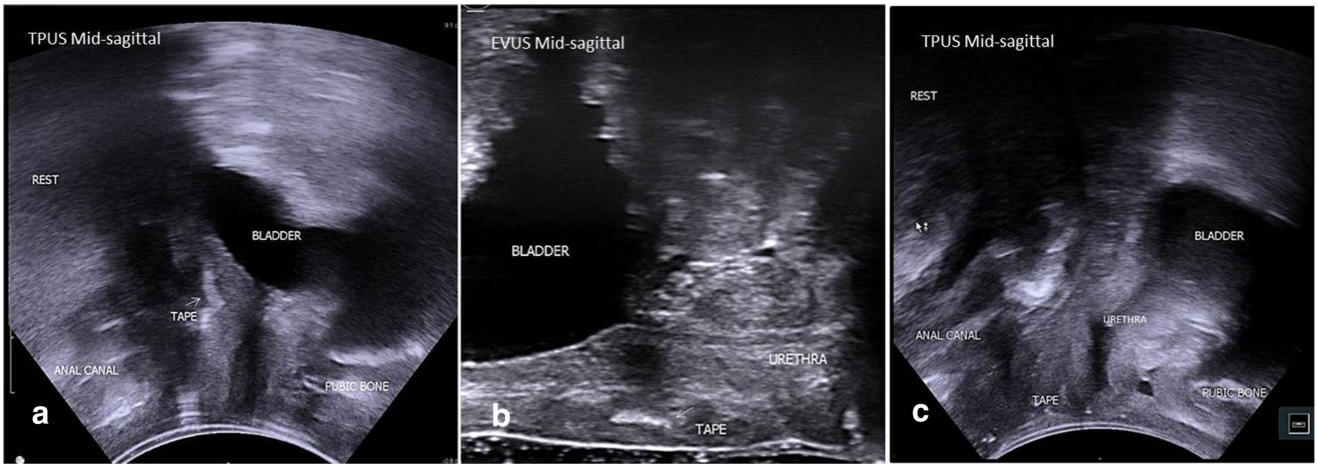

Fig. 6 Position of the MUS relative to the urethral length. **a** Perineal ultrasound showing proximal placement of the MUS. Mid-sagittal section demonstrating a MUS placed too proximally as it can be seen by the bladder neck, this patient presented with persisting stress incontinence symptoms after MUS insertion. **b** Endovaginal ultrasound showing proximal placement of the MUS. **c** Perineal ultrasound showing distal placement of the MUS, almost adjacent to the urethral meatus

Kociszewski et al. [25] also found at 6 months post-operatively significantly more obstructive complications associated with a distance less than 3 mm between the TVT and urethral lumen (<2 mm having a 2.8 times greater risk) and distances >5 mm associated with a lower cure rate. This optimal distance, however, changed to 2.5 mm by 48 months' follow-up as the MUS distance appeared to change over time [29]. Dietz et al. suggest that the actual distance relative to the urethral lumen appears to be more important in MUS efficacy rather than the position relative to the rhabdosphincter itself, as the thickness of the urethral walls can vary [30]. Angulation of the urethral axis, particularly at rest, may also be commonly observed if obstructed voiding due to the MUS is suspected and can be seen on pPFUS [31]. One mechanism of action of MUS is believed to be due to external compression of the urethra between the MUS and symphysis pubis, which is mostly evident when there is increased intra-abdominal pressure [32]. Using 4D pPFUS, a narrower distance between a TOT and the symphysis pubis during Valsalva and a more acute MUS angle have been associated with more frequent cure of stress and urge urinary incontinence [33].

Twisting or curling of the MUS seen on ultrasound may suggest laxity in the tension, which may increase the likelihood of failure with persisting stress urinary incontinence symptoms. The clinical implications of this are, however, less well known (Fig. 7) Twisting may lend to the asymmetry of the MUS, reported to be an undesirable finding, as it could suggest contact laterally with the urethra or undue compression of the urethra [34], leading to failure or voiding dysfunction.

Kociszewski et al.'s study of TVT functionality on introital ultrasound described the optimal shape of the MUS for a successful outcome in 72 women [25]. They described the suburethral TVT shape at rest and on Valsalva. Optimal surgical outcomes with the highest likelihood of cure at 42 months and lowest complication rates were seen in MUSs that were flat at rest and C-shaped on Valsalva. Reduced outcomes were seen when the MUS remained flat or C-shaped from rest to Valsalva, indicating too little or too much tension respectively (Fig. 8) [25, 29]. Hegde et al. assessed functionality on Valsalva in 50 successful TOT procedures compared with 50 failed TOTs. They found on 3D pPFUS that actually the concordance of urethral mobility with the TOT was the most crucial factor in ensuring a successful

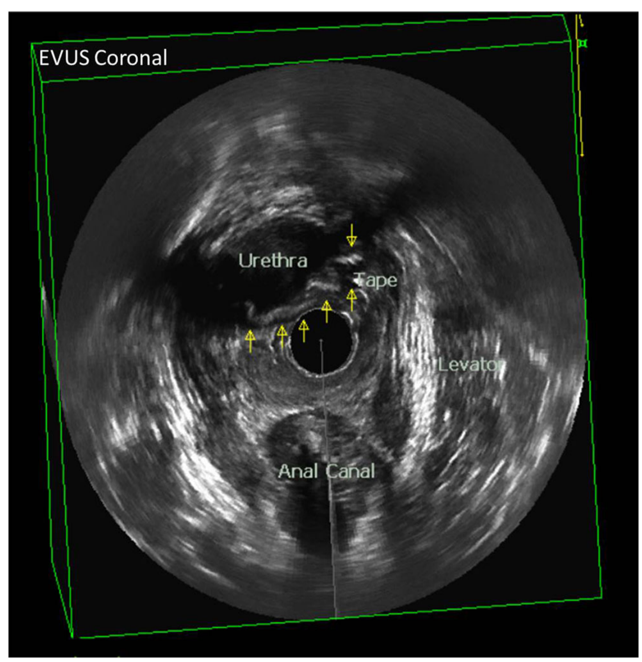

Fig. 7 Curled mid-urethral sling (MUS). Endovaginal ultrasound demonstrating a MUS both situated far from the urethral lumen and folded, suggesting laxity. This patient presented with persisting stress urinary incontinence

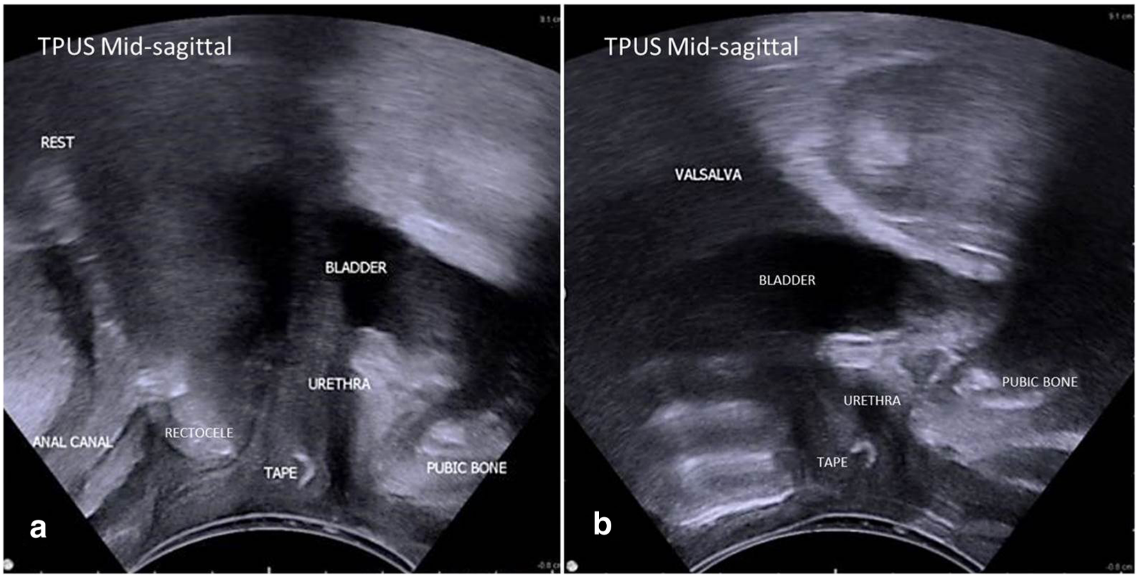

Fig. 8 Shape of the mid-urethral sling (MUS). **a** Mid-sagittal view on perineal ultrasound showing the MUS labelled as tape as a "C" shape at rest. The patient has a rectocele at rest. **b** Mid-sagittal view on perineal ultrasound showing the MUS labelled as tape, which has folded into a "C" shape on Valsalva. The urethra can also be seen to become kinked from the extra tension from the MUS. This patient presented with symptoms of voiding difficulty

outcome; if the TOT location relative to the urethral length was the same at rest and maximal Valsalva, then there was deemed to be concordance. They also found mid-urethral placement and change of shape from flat to C-shaped on Valsalva to be associated with an increased likelihood of continence [35].

Movement of the MUS over time has been debated. Kociszewski et al. demonstrated a significant change in TVT position towards the bladder neck in addition to a reduction in MUS–urethral lumen distance over a 48-month period. They suggested that this might be due to prolapse of the anterior compartment [29]. Dietz et al. also showed on 4D pPFUS a caudal displacement of the TVT in relation to the pubic symphysis over a period of 1.6 years, noting, though, that the MUS itself did not appear to shorten or contract [36]. In contrast, Majkusiak et al. performed introital ultrasound prospectively in 120 women undergoing TVT insertion and found no change in MUS position in relation to the urethral length at 6 months. It is therefore possible that any changes occur only after a longer time period [37].

The position of VWM for prolapse in relation to the urethral lumen and length, and concordance with urethral mobility or urethral funnelling, can also be identified with ultrasound. Wlazlak et al. performed introital and perineal ultrasound 24–36 months following NAZCA-TC mesh insertion for anterior compartment prolapse with a concurrent MUS. They found that if the VWM covered more than 50% of the urethral length, it contributed negatively to the effectiveness of a concomitant MUS. They also found the VWM to be rolled up in 61.1%, which had no clear implications [38]. Lo et al. similarly investigated VWM insertion with MUS on ultrasound, at a minimum of 1 year follow-up. They found that successful surgical outcomes of MUS and VWM were highest in those with mobile MUS and bladder neck and change in the following dynamic parameters: MUS and urethral lumen distance, urethral cross-sectional area at MUS level and urethral diameter [39].

Anterior VWM in 103 women was assessed on introital/transvaginal ultrasound for retraction at 6 months, and there was a significant correlation between de novo overactive bladder symptoms and mesh retraction [40], but no study has found a correlation between the complications of stress urinary incontinence and VWM.

Suspected mesh exposure or extrusion

Exposure of MUS or VWM is when the mesh is displayed, revealed, exhibited or made accessible, and extrusion is the gradual passage of the mesh out of a body structure or tissue [41]. Mesh exposure is largely diagnosed clinically; vaginal examination has been shown to be superior to ultrasound for the detection of vaginal mesh exposure or extrusion [11]. Translabial ultrasound, however, has been shown to be superior for identifying exposure or extrusion into the periurethral fascia or sphincteric unit [20]. Sometimes, however, clinical examination may not be possible owing to a narrow vaginal calibre, extensive scarring, patient discomfort, apprehension and resultant vaginismus. Therefore, some women may prefer an ultrasound probe instead and, in such cases, it is possible to visualise the proximity of the MUS or VWM to the vaginal surface and endovaginal probe, indicating exposure or extrusion [21]. VWM exposure was shown to be associated with mesh retraction or folding, a feature that can be seen on ultrasound, in a large retrospective study 3.6 months after TVM surgery in 684 women; in this cohort, they also found an association with recurrence of prolapse [42]. This association between prolapse recurrence and VWM retraction or shrinkage has been under debate, owing to the lack of longitudinal studies in this area. It has been suggested that retraction is in fact due to a suboptimal surgical technique and anchoring in addition to mesh design [36, 43].

Urethral or bladder wall extrusion or perforation should also be assessed when ultrasound is performed (Fig. 9). Volume rendering on EVUS may enhance diagnostic imaging when there is evidence of gross asymmetry in the coronal plane of the MUS or VWM arms, which may increase the suspicion of potential bladder or urethral extrusion or perforation. Definitive diagnosis, however, is with cysto-urethroscopy [21].

Investigating pain or dyspareunia

Severe pain in the immediate post-operative period could be due to formation of a haematoma, particularly if associated with voiding dysfunction, bleeding or decreased haemoglobin levels. Any modality of ultrasound allows visualisation of this to confirm the diagnosis [44].

In the long term, pain and dyspareunia are the most common complaints of mesh complications [11, 45], the specific cause of which remains largely unknown and therefore difficult to manage. It is important to establish patient expectations on what is likely to be gained from an ultrasound scan, as not all pathological conditions such as nerve entrapment are visible and not all findings are a cause of pain. In most cases, reassurance can be given regarding the correct placement and absence of an abscess or inflammation.

Hypoechogenic areas may be seen surrounding an MUS or VWM. When surgically explored, these often represent areas of inflammation, infection or fluid collection. For these women, the ultrasound scan offers a compelling argument for removal of the whole MUS or VWM if they have presented with pain (Fig. 10a). MRI may be more useful for the assessment of abscesses or more widespread inflammation, which may present as cellulitis or osteitis, particularly if there is intra-abdominal or retropubic involvement [12, 46].

The clinical implications of the positioning of the MUS in the urethral rhabdosphincter are uncertain and whether it accounts for some women's pain remains debatable (Fig. 10b, c) [32].

Some studies, as previously mentioned, have suggested shortening or contraction of VWM [16], with some reporting a reduction of up to 60% of its original length [47]. This produces a more hyperechoic wavy or thickened appearance, suggesting a concertina-like folding [20], with slightly increased acoustic shadowing present (Fig. 10d, e). Studies have shown an association between VWM retraction and vaginal pain [40], dyspareunia and chronic pain [48], with suggested links to the patient's immune response to the mesh in situ [36], although this has been refuted in large epidemiological studies [49]. Svabik et al. and Dietz et al., however, advocated that in fact, this appearance of mesh contraction was due to surgical technique and mesh design with excessive mesh material being used and anchored suboptimally to underlying tissue [36, 47]. Contrary to the proposed link of mesh folding and pain,

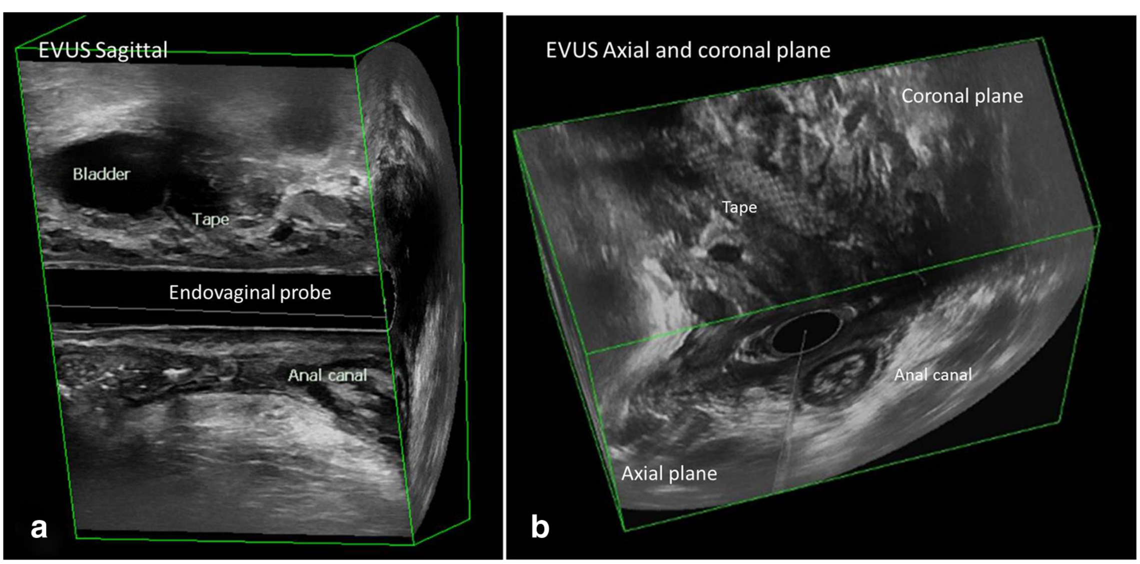

Fig. 9 A MUS in the bladder wall. **a** This sagittal view on endovaginal ultrasound demonstrates the MUS encroaching on the bladder wall. **b** Axial and coronal planes allow the direction of the MUS arms to be assessed in addition to symmetry. In this image, the arm is clearly seen in a more cranial direction than would be expected. Both **a** and **b** were from the same patient, in whom cystoscopy confirmed the presence of the MUS within the bladder wall

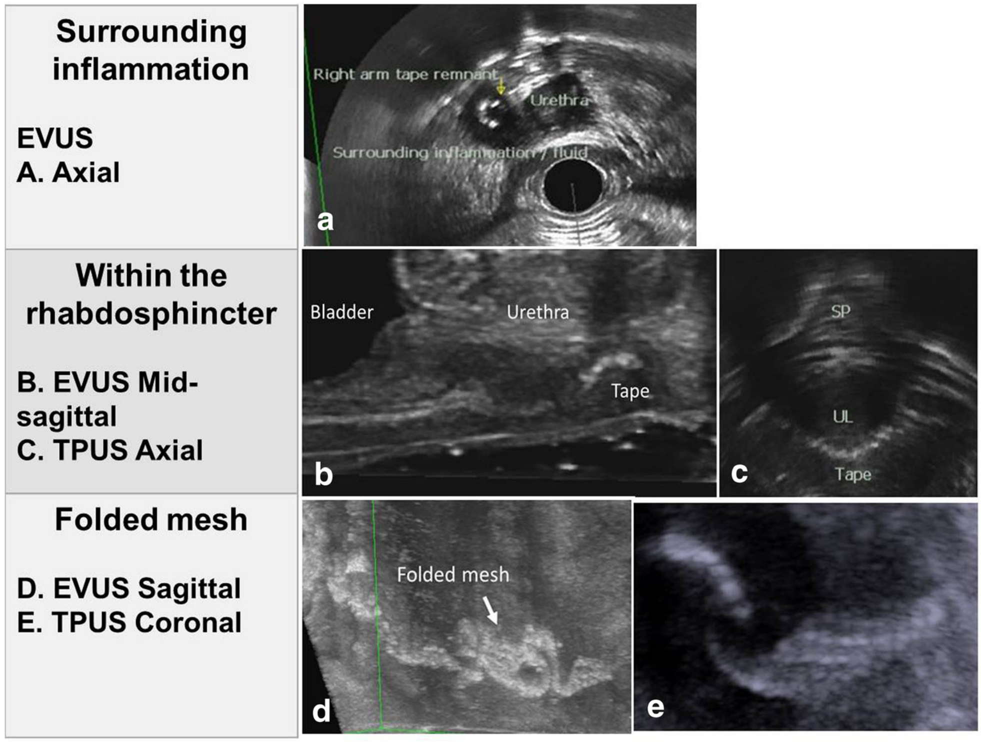

Fig. 10 Investigating pain. **a** Right arm remnant of an MUS with surrounding inflammation seen as hypoechogenicity, demonstrated by the *yellow arrow*. This was confirmed surgically. **b, c** The MUS situated within the rhabdosphincter, very close to the urethral lumen. *SP* symphysis pubis, *UL* urethral lumen. **d, e** Vaginal wall mesh (*left*) and a MUS (*right*), both curled and folded

Javadian et al. found a higher proportion of women with "flat" mesh in the posterior compartment on EVUS to have complications of pain, and women who had folding most commonly had no pain. The authors suggested that this might be due to the pulling of well-anchored mesh [50].

Discussion

We are now in an era of uncertainty regarding the future of MUS procedures and the use of VWM for prolapse repair [6]. However, mesh remains in situ for many women, particularly because of their great efficacy in managing stress incontinence combined with the unprecedented high uptake of mesh when it became available. Often, women with mesh implants have complex surgical histories, and many have already seen multiple clinicians. There are various modes of investigating these women; ultrasound can be performed (introital, perineal or endovaginal) in addition to MRI, which can be complementary. MRI is more suited to demonstrating abscesses, periostitis or abdominal and retropubic mesh, whereas ultrasound can be performed to clarify surgical history or ascertain potential causes of associated urinary symptoms, pain or dyspareunia.

There are multiple ultrasound modalities available for imaging the pelvic floor, with different probes and machines, each with their own pros and cons. The technique a urogynaecologist choses to utilise depends on the availability within their department in addition to level of experience. As this review demonstrates, most studies have been carried out with the use of a 3D/4D perineal approach, the benefits of which include great accessibility, as it is available in most gynaecology units, minimal intrusiveness to the patient, and post-processing capabilities. The endovaginal probe used in this application has the greatest field of view and frequency bandwidth of all the probes; however, it does not provide such ease for dynamic assessment of mesh and may distort the shape as it is placed in such proximity in the vagina. It is therefore useful to perform perineal pelvic floor ultrasound with endovaginal ultrasound to obtain dynamic assessment of the anterior compartment.

A patient's perception of failure of a procedure is invariably multifactorial. For this reason, studies have been unable to conclusively report singular parameters that correlate consistently with outcomes [16, 24, 25, 27–29]. Those studies that have reported outcomes such as distance of MUS along the urethra or MUS shape [25] have not always been consistently reproducible [29] or even in agreement with other studies [21, 28], suggesting trends rather than rules and the complex mechanisms of action. Therefore, all ultrasound findings must be considered collectively when correlating with symptoms, and one must keep an open mind when investigating hypothetical causes of complications.

Despite this, ultrasound clearly has clinical applicability and a definite role in the evaluation of all women with complications of mesh implants. There is still a lack of substantial agreement on optimal MUS placement or optimal VWM "flatness" in relation to surgical outcome. However, what is clear is that there are multiple components of the MUS and

VWM, such as shape, symmetry and location, to be considered in combination when assessing on ultrasound correlation with symptoms, outcomes and complications.

As mentioned previously, such complications are ideally managed in a multidisciplinary setting. Although in some countries the evolution has been towards highly skilled centres with single urogynaecologists with extensive explantation expertise, others advocate a team approach with inclusion of urologists, colorectal surgeons and allied professionals. Either surgical approach requires detailed discussions clearly documented with the patient regarding the pros and cons of surgery and most importantly the anticipated outcome must be reconciled with expectations of the patient. This highlights the value of knowledge of any associated organ extrusion or perforation, mesh implant type, location and configuration to a surgeon before surgical exploration [46].

Conclusion

Pelvic floor ultrasound is the standard of care when imaging is available and utilised, as it is the only modality capable of reliably visualising mesh in the pelvic floor. It can provide detailed information about the presence, position, shape and other characteristics of a MUS or VWM in situ. Dynamic high-resolution imaging allows for assessment of mobility and morphology of the mesh and adjacent anatomical structures enabling global evaluation. Caution needs to be exercised when interpreting findings, as some may be incidental and may not be the cause of the patient's symptoms. There is still plenty of scope for understanding in greater detail the pathophysiology behind the symptoms some women have following MUS or VWM surgery, as urogynaecologists are likely to encounter patients presenting with mesh-related queries or complications more frequently in the future. We do, however, need standardised methods for measurements and reporting, so that all outcomes can be comparable.

Pelvic floor ultrasound has not yet become widely adopted as a standard clinical tool in urogynaecology, largely because of the lack of core competency in ultrasound by many urogynaecologists. In addition to this, interpreting extrapolated data from different ultrasound modalities to something clinically relevant can be complex. More work is required to evaluate each modality, so that clinicians can make use of the ones available to them. In addition, more clinical correlation of ultrasound with surgical findings is also necessary. It is important that only those with an understanding of urogynaecology perform these pelvic floor ultrasound scans, as the findings on ultrasound must only be interpreted as an adjunct to patient history, examination and other investigations, to assist in the most appropriate management plan for the patient.

Compliance with ethical standards

Financial disclaimer/conflicts of interest Miss Thakar is president of the International Urogynecological Association. All other authors claim that they have no conflicts of interest.

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