Int Urogynecol J (2011) 22:1221–1232
DOI 10.1007/s00192-011-1459-3

REVIEW ARTICLE

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

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Received: 1 March 2011 / Accepted: 10 May 2011 / Published online: 9 June 2011

Abstract Pelvic reconstructive surgeons have suspected for over a century that childbirth-related trauma plays a major role in the aetiology of female pelvic organ prolapse. Modern imaging has recently allowed us to define and reliably diagnose some of this trauma. As a result, imaging is becoming increasingly important, since it allows us to identify patients at high risk of recurrence, and to define underlying problems rather than just surface anatomy. Ultrasound is the most appropriate form of imaging in urogynecology for reasons of cost, access and performance, and due to the fact that it provides information in real time. I will outline the main uses of this technology in pelvic reconstructive surgery and focus on areas in which the benefit to patients and clinicians is most evident. I will also try and give a perspective for the next 5 years, to consider how imaging may transform the way we deal with pelvic floor disorders.

Keywords Cystocele · Female pelvic organ prolapse · Imaging · Levator ani · Pelvic floor · Rectocele · Ultrasound · Uterine prolapse

Introduction

The history of imaging in pelvic floor dysfunction reaches back to the 1920s. Radiological techniques were first described to describe bladder appearance and descent [1, 2], and later for central and posterior compartment prolapse [3]. With the advent of B Mode real-time ultrasound, this technique became an obvious alternative, whether via the transperineal [4, 5] (see Fig. 1) or the vaginal route [6]. More recently, magnetic resonance imaging has also developed as an option [7], although the difficulty of obtaining functional information, and cost and access problems, have hampered its general acceptance.

Clinical examination techniques, in particular if the examiner is insufficiently aware of their inherent shortcomings, are rather inadequate tools with which to assess pelvic floor function and anatomy. This is true even if one uses the most sophisticated system currently available, the prolapse quantification system of the International Continence Society (ICS Pelvic Organ Prolapse Quantification system (POP-Q)). To give two examples: the result of a clinical assessment for female pelvic organ prolapse (FPOP) is to a large extent determined by confounders that are generally unrecognised, such as bladder [8, 9] and rectal filling, levator co-activation [10, 11] and duration of a Valsalva manoeuver [12]. It is not surprising that findings in theatre frequently differ from those obtained in the outpatient setting, given that all those confounders conspire to produce false-negative results. In order to avoid unpleasant surprises, one would do well to ensure bladder (and, if possible, rectal) emptying, a sufficiently long Valsalva (at least 5 s), a maximal Valsalva effort, and relaxation of the levator ani. The latter three factors may require visual or tactile biofeedback, which is greatly facilitated by real-time imaging. Many women will not perform an optimal Valsalva when asked and need to be taught how to optimise their effort, and ultrasound allows visual biofeedback for this purpose.

Secondly, we routinely overlook major anatomical abnormalities of the levator ani muscle [13, 14] which are present in a large minority of women seeking treatment for FPOP [15–18]. These defects are rarely diagnosed clinically and

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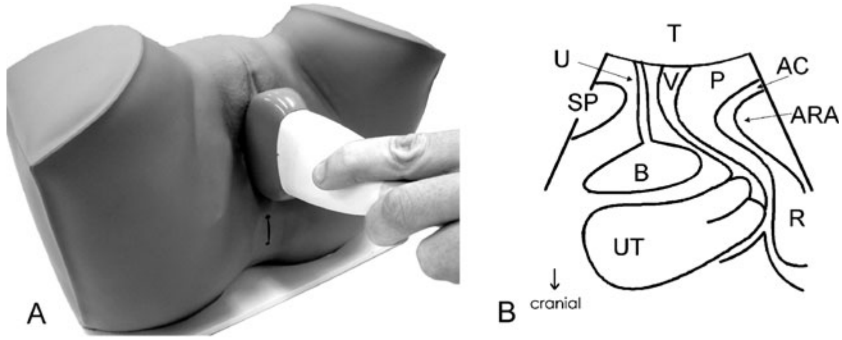

Fig. 1 Transducer placement (*left*) and field of vision (*right*) for translabial/perineal ultrasound, midsagittal plane. Reproduced from [78], with permission. *SP* symphysis pubis, *U* urethra, *V* vagina, *T* transducer, *AC* anal canal, *ARA* anorectal angle, *R* rectum, *Ut* uterus, *B* bladder

have only very recently found their way into our textbooks, although they can be palpated [19, 20], and even though the first textbook mention of such defects dates back to 1938 (see Fig. 2). Howard Gainey, an obstetrician from Kansas City, was the first to describe levator trauma in parous women [21] in 1943. In editorial comments, two reviewers stated 'I am convinced that there is more to the examination of the postnatal patient than I have been practising' and 'None of us has learned to examine the pelvis completely'. That's as true today as it was in 1943. Our examination skills are limited, focusing on surface anatomy, rather than true structural abnormalities. This is probably the main reason why there is such a multitude of surgical procedures for female organ prolapse, such confusion regarding pathophysiology, and such a constant search for improvement. We know that we are not doing very well in repairing FPOP, and I believe that this is largely due to insufficient diagnostics. In

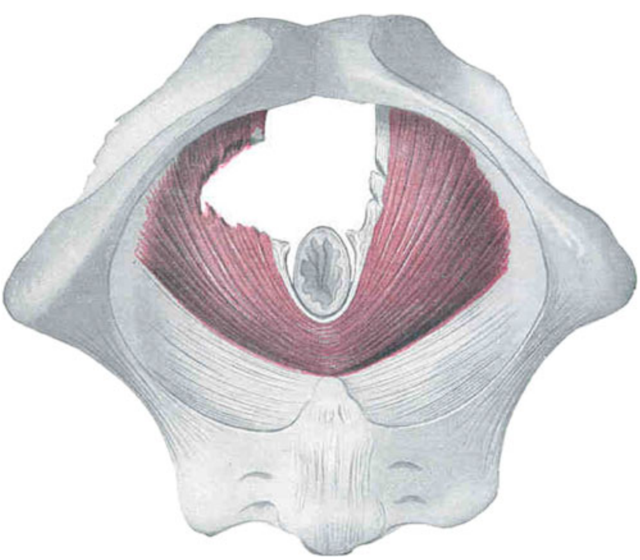

Fig. 2 Right-sided avulsion seen from caudally. This illustration is not entirely correct, as in most cases there appears to be very little or no muscle left on the bone since the tear occurs at the insertion rather than in the muscle belly. However, the figure correctly describes the most common form of trauma, affecting the right puborectalis muscle, with retraction of muscle fibres perianally, and its most common cause at the time (i.e. forceps delivery). Reproduced with permission from [79]

the following text, I will try to outline the benefits of pelvic floor ultrasound as the main diagnostic tool available to the pelvic reconstructive surgeon.

Instrumentation and basic methodology

The basic requirements for pelvic floor ultrasound via the perineal route include a 2D US system with cine loop, an abdominal 3.5–8-Mhz curved array transducer and a videoprinter, as described in this journal very recently. A midsagittal view is obtained by placing the transducer on the patient's perineum between the clitoral area and the anus. 3D/4D imaging is particularly useful on assessing women with pelvic organ prolapse, since translabial 3D ultrasound gives easy access to the axial plane (see Fig. 3). 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 pubovisceral (puborectalis/pubococcygeus part of the levator ani) muscle from the pelvic sidewall in the area of the arcus tendineus of the levator ani to the posterior aspect of the anorectal junction (Fig. 3).

The three orthogonal images are complemented by a 'rendered image', i.e. a semitransparent representation of all voxels in an arbitrarily definable 'box'. 4D imaging implies the real-time acquisition of volume ultrasound data, which can then be represented in orthogonal 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. Even on 2D single-plane imaging, a static assessment at rest gives little information compared with the evaluation of manoeuvres such as a levator contraction and Valsalva. Their observation will allow assessment of levator function and delineate levator or fascial trauma more clearly.

Once the levator hiatus is identified in the midsagittal plane, it is possible to determine the 'plane of minimal hiatal dimensions', which is located in an oblique axial plane (see Fig. 4). Measurement of hiatal dimensions seems useful since the levator hiatus can be interpreted as the largest potential

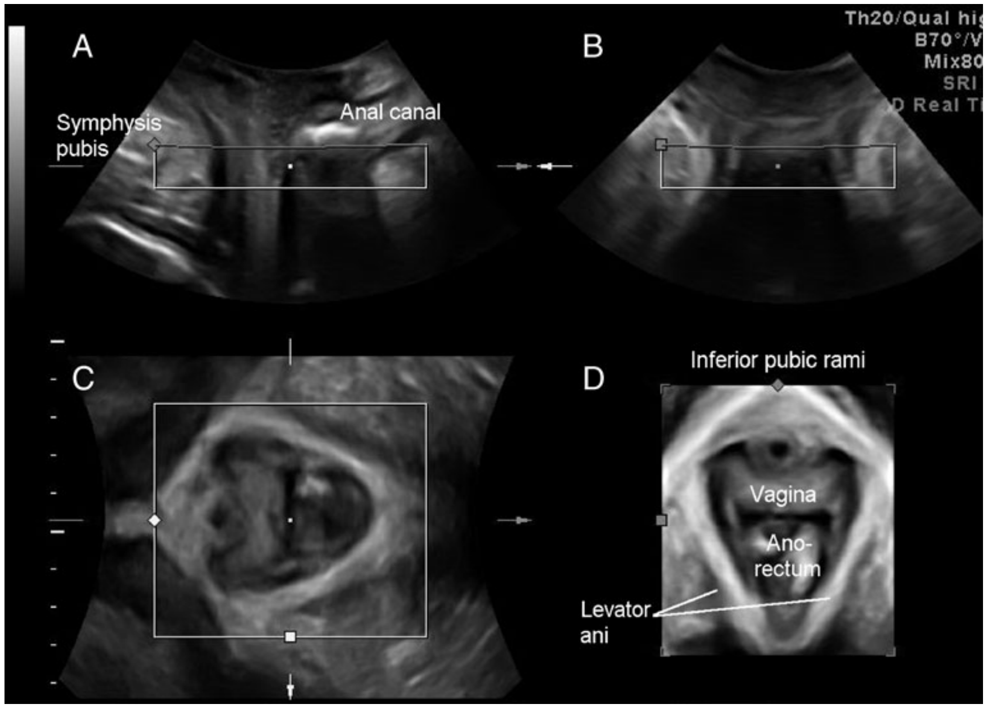

Fig. 3 Standard representation of 3D pelvic floor ultrasound. The usual acquisition/evaluation screen on Voluson type systems shows the three orthogonal planes: sagittal (**a**), coronal (**b**) and axial (**c**); as well as a rendered volume (**d**) which is a semi-transparent representation of all grayscale data in the rendered volume (i.e. the *box* visible in **a**–**c**). From [80], with permission

hernial portal in the human body, and since hiatal dimensions are strongly [22] and independently [23] associated with prolapse. Hiatal area can be determined in a simple axial plane placed at the location of the minimal anteroposterior diameter of the hiatus [24], and such measurements are highly reproducible [25–27] and comparable to assessment of the hiatus on magnetic resonance imaging [26]. However, it has recently been shown that the true plane of minimal hiatal dimensions is non-Euclidean, that is, warped rather than flat. The plane of minimal dimensions is often more caudal in its lateral aspects and more cranial in its ventral and dorsal aspects [28], which implies that determination of hiatal dimensions in a rendered volume may be more appropriate [29]. Figure 4 shows a comparison of the two methods.

Once the plane of minimal dimensions is obtained, it can be used as a reference plane for assessment of the puborectalis muscle on multislice or tomographic ultrasound (TUI, see Fig. 5) [30]. This is particularly important for the identification of levator trauma. Partial trauma is not uncommon [31] and of much less significance for prolapse and prolapse symptoms [31], and it has to be distinguished from complete trauma which has very different implications in that it is strongly associated with prolapse [15–17] and prolapse recurrence [32, 33]. This means that single-slice diagnosis of levator trauma is inappropriate—the entire puborectalis muscle has to be assessed. Tomographic imaging makes this highly practicable, once the reference plane, the plane of minimal dimensions, is identified. An interslice interval of 2.5 mm enables us to reliably image the entire puborectalis from its most caudal to its most cranial aspects [34], and a false-positive diagnosis seems very unlikely if one requires the three central TUI slices (see Fig. 5) to be abnormal (unpublished own data).

The ability to perform a real-time 3D (or 4D) assessment of pelvic floor structures greatly adds to the utility of sono-

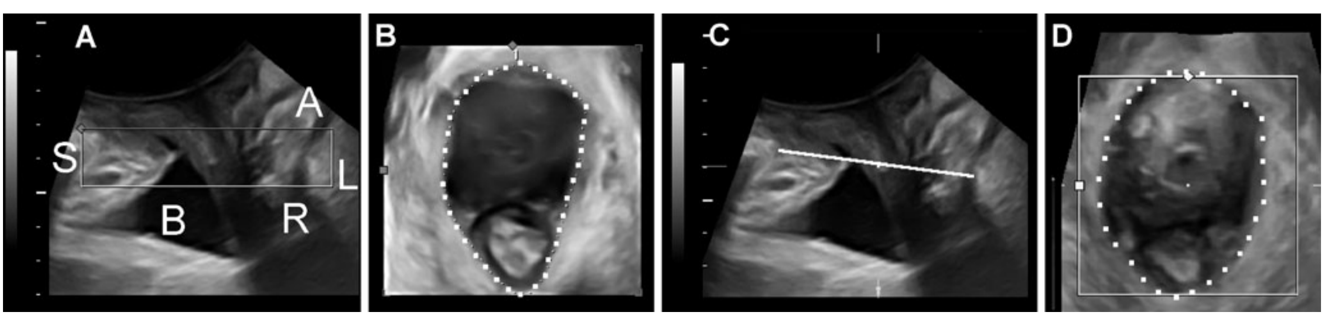

Fig. 4 Determination of the plane of minimal hiatal dimensions on Valsalva. The hiatus can be imaged in a rendered volume placed at the location of the minimal distance between symphysis pubis (*S*) and the levator ani posterior to the anorectal angle (*L*) as shown in image **b** [29]. The original method described for measurement of hiatal dimensions is shown in **c** and **d**, which illustrate the location of the plane of minimal dimensions in the midsagittal plane (**c**) and its representation in the axial plane (**d**) [24]

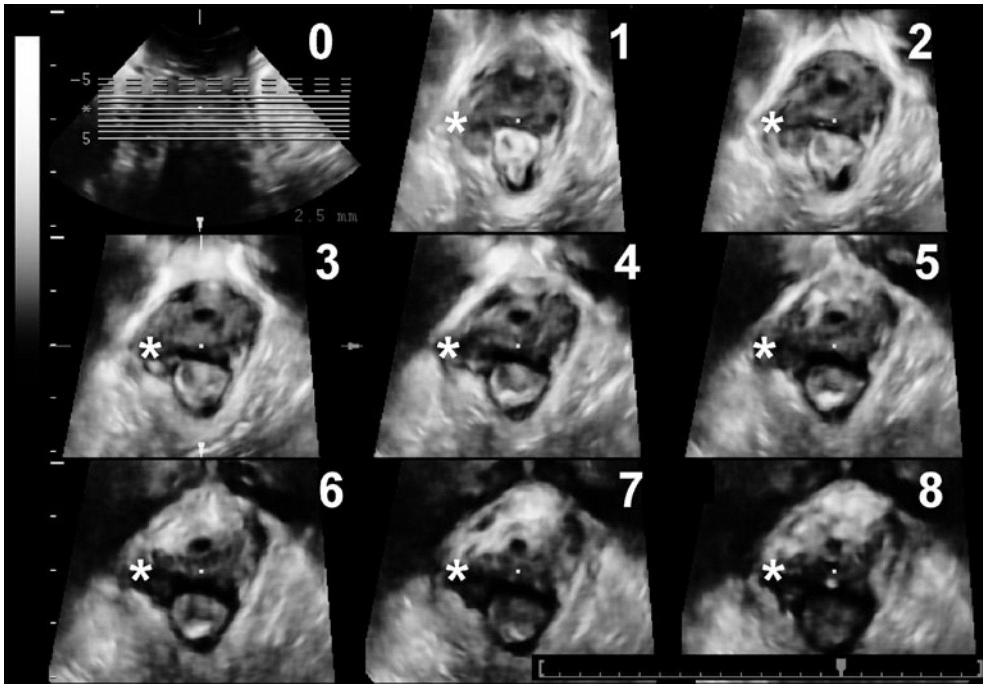

Fig. 5 Tomographic translabial imaging of the puborectalis muscle. This representation is obtained by multislice imaging of a volume on pelvic floor muscle contraction, with slices places at 2.5-mm-slice intervals, from 5 mm below to 12.5 mm above the plane of minimal hiatal dimensions [24]. A complete defect of the puborectalis muscle is evident on the patient's right (the *left side* of any single slice) and marked with an *asterisk*. From [30], with permission

graphic imaging. Prolapse assessment by MR requires ultrafast acquisition [35] which is of limited availability and will not allow optimal resolutions. The physical characteristics of MRI systems make it difficult for the operator to ensure efficient manoeuvres as over 50% of all women will not perform a proper pelvic floor contraction when asked [36], and a Valsalva is often confounded by concomitant levator activation [10]. Without real-time imaging, these confounders are impossible to control for. Therefore, ultrasound has major potential advantages when it comes to describing prolapse, especially when associated with fascial or muscular defects, and in terms of defining functional anatomy.

Finally, although there are no data formatting standards yet for 3D/4D imaging, postprocessing is somewhat simpler and also more powerful than what is currently possible on MR. Offline analysis packages allow distance, area and volume measurements in any user-defined plane (oblique or orthogonal) and in rendered volumes, and postprocessing allows the re-enactment of manoeuvers such as a pelvic floor muscle contraction, a cough or Valsalva.

Functional assessment

The Valsalva manoeuver, i.e. a forced expiration against a closed glottis and contracted diaphragm and abdominal wall, is routinely used to document downwards displacement of pelvic organs (see Fig. 6) and demonstrate distensibility of the levator hiatus. There is downwards movement of the bladder, the uterine cervix and the rectal ampulla, and

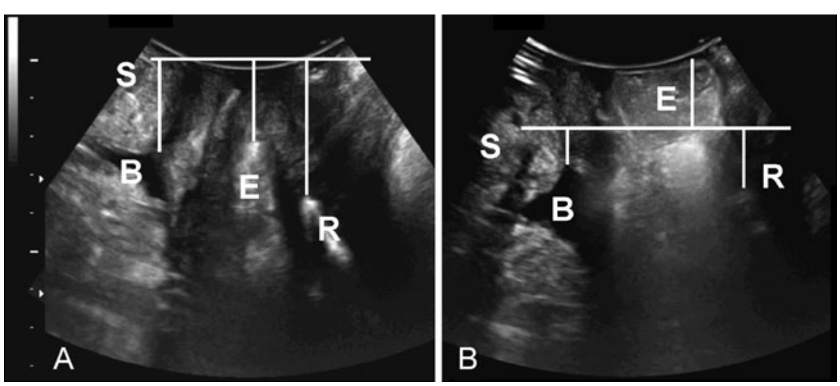

Fig. 6 Prolapse quantification on translabial ultrasound. The *horizontal line* of reference is placed through the inferior margin of the symphysis pubis. *Vertical lines* indicate maximal descent of bladder, enterocele and rectal ampulla relative to the symphysis pubis, at rest (**a**) and on Valsalva (**b**). There is an isolated enterocele; descent of bladder and rectal ampulla is physiological. *S* symphysis pubis, *B* bladder, *E* enterocele, *R* rectal ampulla. Modified from [78], with permission

frequently the development of a rectocele, i.e. a sacculation of the anterior wall of the rectal ampulla, towards the vaginal introitus or beyond (see below). 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 which would prevent full development of a prolapse. Other standard confounders are bladder [8] and rectal filling and levator co-activation [10], all of which tend to reduce pelvic organ descent. As on clinical examination, it is important to reduce such confounders as much as possible. This is easier on real-time imaging which allows one to correct suboptimal effort and recognise organ filling and levator activation. It seems that a Valsalva has to last at least 5 s to result in 80% of maximal organ descent or better. Valsalva pressure seems to be less important since the vast majority of patients can reach sufficient pressures to effect near- maximal organ displacement (own unpublished data). If the patient reports symptoms of prolapse but despite best efforts findings on imaging are negative, or if she is simply unable to perform a proper Valsalva manoeuver, it is advisable to repeat imaging in the standing position.

Pelvic floor muscle contraction

There are several good reasons to document a pelvic floor contraction at the time of prolapse assessment, not the least because this provides an opportunity for visual biofeedback teaching [37]. A levator contraction results in a cranioventral shift of pelvic organs, most notably at the level of the bladder neck, and reduces the dimensions of the levator hiatus, especially in the midsagittal plane. Most importantly, a levator contraction allows optimal imaging of the puborectalis muscle and the external anal sphincter and facilitates the documentation of morphological abnormalities on tomographic ultrasound (Fig. 5).

Clinical uses

Anterior compartment prolapse

Clinical examination is limited to grading anterior compartment prolapse, which we call ‘cystocele’. In fact, imaging can identify a number of entities that are difficult to distinguish clinically. Pelvic floor ultrasound enables us to identify two types of cystocele with very different functional implications [38]. A cystocele with intact retrovesical angle (first described on X-ray cystourethrography as Green type III in the 1960s [39]) is generally associated with voiding dysfunction, a lower likelihood of stress incontinence, and major trauma to the levator ani, while a cystourethrocele (Green type II), especially with funnelling of the bladder neck, is associated with above average flow rates and urodynamic stress incontinence [38]. While it is possible to distinguish the two types clinically [40], on clinical examination these two very different entities are grouped together, which may well be why studies of voiding dysfunction and prolapse have yielded such varying results. In addition, occasionally a cystocele will turn out to be due to a urethral diverticulum, 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. The literature seems to largely ignore this fact, as it is commonly assumed that MR is the diagnostic method of choice [41].

Another major argument in favour of pelvic floor ultrasound imaging is the popularity of synthetic mesh implants used in incontinence and prolapse surgery. Suburethral sling implants are covered in [42] and will not be discussed in this review. Just as such slings, synthetic implants used in prolapse surgery are not visible on X-ray, CT or MR but are easily seen on ultrasound (see Fig. 7). The most cranial aspects of such mesh implants are sometimes difficult to image, especially if they are

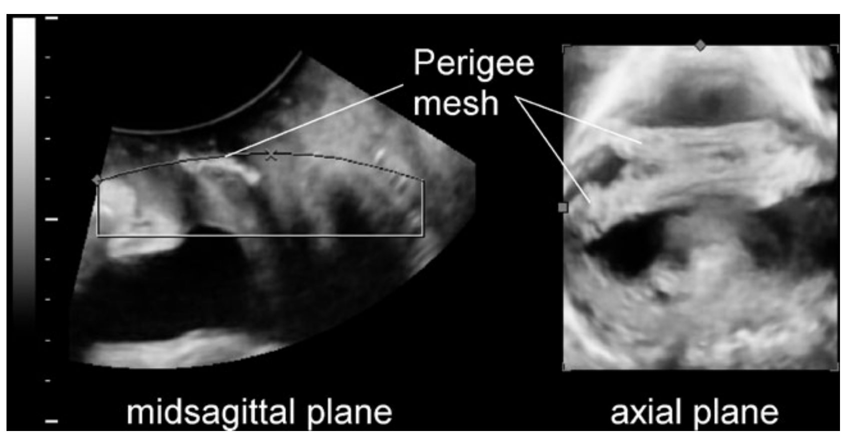

Fig. 7 Translabial imaging of a transobturator anterior compartment mesh. The mesh is seen posterior to proximal urethra and bladder neck in the midsagittal plane on the *left*, and in a rendered volume in an oblique axial plane on the *right*. From [81], with permission

suspended to the sacrospinous ligaments. However, failure of mesh suspension, or a detachment of organs from a well-suspended mesh, is easily apparent on Valsalva, and transvaginal imaging can be added if superior mesh aspects need to be assessed. Biological materials, on the other hand, are usually not that echogenic, and some of them seem to simply disappear over time.

In clinical audit series on several hundreds of anterior and posterior compartment meshes, we have observed a number of different forms of prolapse recurrence due to suspension failure. Some authors seem to deny that mesh failure is a significant problem, and in general the focus in women after mesh implantation has been on erosion/mesh exposure and chronic pain syndromes [43]. Others blame supposed mesh contraction [44], a phenomenon that probably does not exist beyond the period of physiological wound healing [45, 46]. We have found no evidence of mesh shrinkage or contraction in an observation period of almost 60 woman-years [46] after Perigee implantation. To date, there is no information in the literature on the prevalence of suspension failure, and no advice on how to deal with such cases. Rather than focus on how to deal with complications and failures of procedures that have become widely accepted, we are prompted by 'industry to start using newly developed devices and procedures for which there is little or no independent outcome data.

The best information we currently have is on success and failure of transobturator meshes, of which the Perigee™ is the prototype, invented by Rane and Fraser in 2004, with the Anterior Prolift™ largely comparable from a functional anatomy point of view [47]. It is very likely that such meshes reduce anterior compartment recurrence rates [48], and this effect seems to be most marked in women with avulsion of the puborectalis muscle [48]. However, there still is a substantial recurrence risk, especially in those with abnormal levator anatomy and/or function. Dislodgment of all four arms seems uncommon, at no more than 5% of all cases. More common is dislodgment of the superior (cranial) anchoring arms, first described in 2006 [49], see Fig. 8. It is not surprising that the superior arms should be more vulnerable, if one considers that the anterior vaginal wall may be considered a lever arm, anchored to the fulcrum of the symphysis pubis. The further from the fulcrum any support structure is placed, the greater the moment exerted on this structure by forces generated by increases in intra-abdominal pressure. Patients with excessive hiatal distensibility of over 25 cm^2 on maximal Valsalva (‘ballooning’) [22] or levator avulsion seem to be at an increased risk of support failure, which may be explained by a longer effective lever arm, and higher moment (force × distance).

Dislodgment of the superior arms seems to occur in about 20% of transobturator meshes, resulting in the appearance of a ‘high cystocele’ (see Fig. 8), similar to what is sometimes observed after an otherwise successful Burch colposuspension. There currently is no advice on how to deal with such a situation if symptomatic, but apical suspension, by whatever route, may well be necessary. Anterior compartment meshes that provide apical anchoring to the sacrospinous ligaments may not be subject to this type of suspension failure.

Dislodgment of all arms will require resuspension of the entire anterior compartment, e.g. by a second mesh placed deep to the first, possibly after removal of some or all of the failed mesh (personal communication, A. Rane). We have begun to suture anchoring arms to the inferior pubic ramus, but in high-risk patients there clearly is some need for more reliable apical suspension.

In some instances, such meshes are inadequately secured to the bladder base. This may result in a large sonographic gap between symphysis and mesh, a situation that is associated with postoperative stress urinary incontinence [50]. Occasionally, this gap may become so large that a

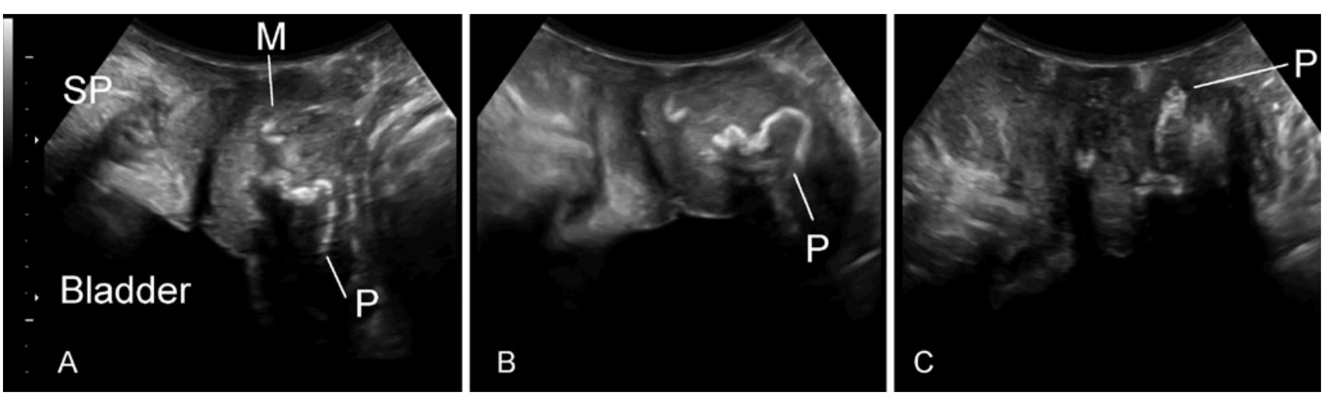

Fig. 8 Translabial imaging of a transobturator anterior compartment mesh. **a** shows the mesh at rest, **b** halfway through a Valsalva and **c** at maximal Valsalva. It is evident that the superior mesh arms have pulled out, resulting in the failure of apical support and a recurrent cystocele, similar in appearances to a high cystocele after Burch colposuspension. *SP* symphysis pubis, *M* monarc sling, *P* perigee mesh (cranial aspect)

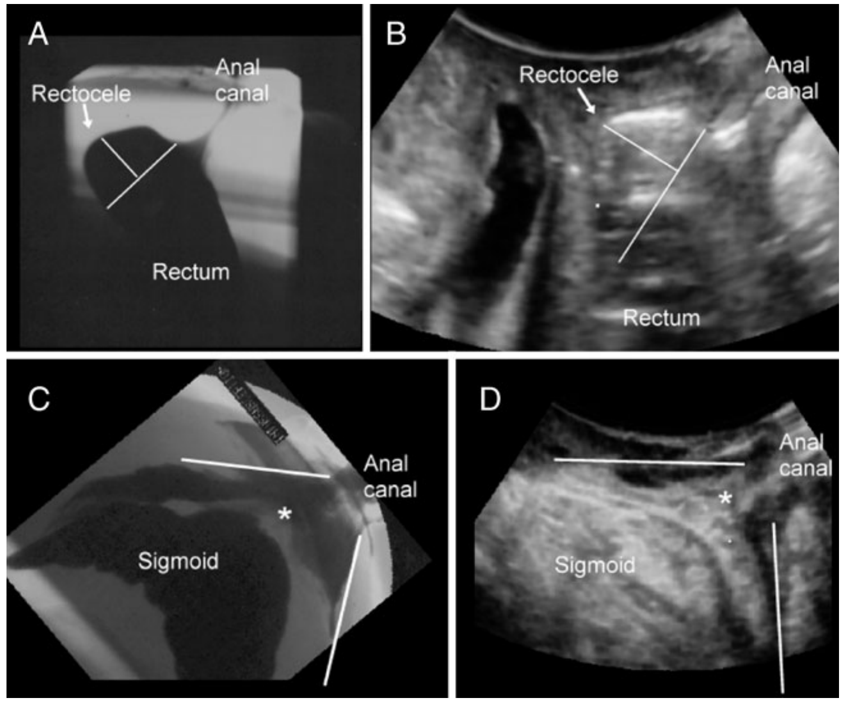

Fig. 9 Comparison of defecation proctography (**a**, **c**) and ultrasound findings (**b**, **d**). The top pair of images shows a typical true rectocele, the bottom pair a rectal intussusception due to a sigmoid enterocele. From [53], with permission

cystourethrocele develops ventral to a well-supported mesh. This situation, if symptomatic, is easy to correct by mobilising the posterior bladder base off the mesh and then reconnecting the mesh to the bladder neck.

Newer meshes that do not utlise transobturator anchoring currently fall into two categories. There are those that rely on anchoring to the sacrospinous ligaments (e.g. Anterior Elevate^{TM}), and then there is the Prosima^{TM}, a technique that assumes mesh fixation to the sidewall after 4 weeks of support with a vaginal splint. In both instances, proof of concept is currently lacking.

Central compartment

The uterus is more difficult to identify than bladder or rectal ampulla since it is iso-echoic, similar to vaginal muscularis. Often however, a Nabothian follicle or a specular echo arising from the leading edge of the cervix, aids in identification. In fact, uterine prolapse can often be more prominent on imaging than on clinical examination. This may be due to the fact that the functional anatomy of the levator hiatus seems to matter most for uterine descent [17]. Hence, one would expect levator co-activation to be particularly likely to result in false-negative findings of normal uterine support. In addition, translabial ultrasound may demonstrate the effect of an anteriorized cervix in women with an enlarged, retroverted uterus, explaining symptoms of voiding dysfunction, and supporting surgical intervention in order to improve voiding in someone with an incarcerated retroverted fibroid uterus. On the other hand, mild descent of an anteverted uterus may result in compression of the anorectum and even a mild degree of

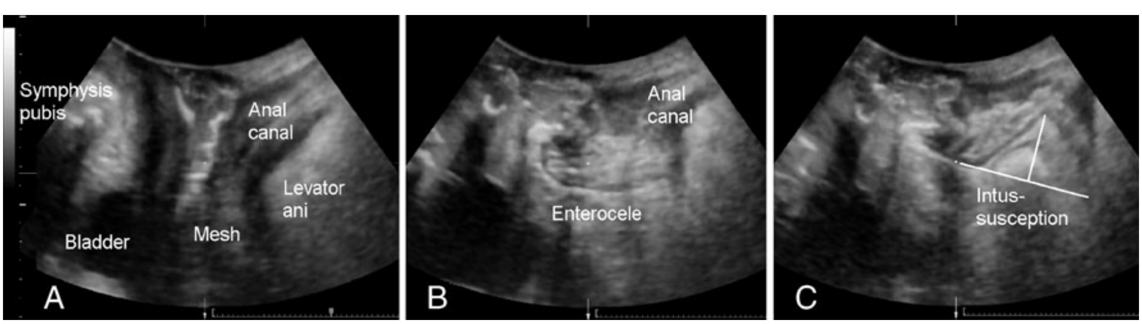

Fig. 10 Occasionally, successful correction of a vaginal prolapse, especially in women with severe ballooning, may result in rectal intussusception/prolapse. This figure shows appearances in the midsagittal plane at rest (**a**) after posterior compartment mesh for a vault prolapse, on submaximal (**b**) and maximal (**c**) Valsalva. On **b** an enterocele is seen dorsal to the mesh, and on **c** this enterocele is inverting the rectal ampulla, resulting in a rectal intussusception. The two lines in (**c**) illustrate the width and depth of the intussuscipiens

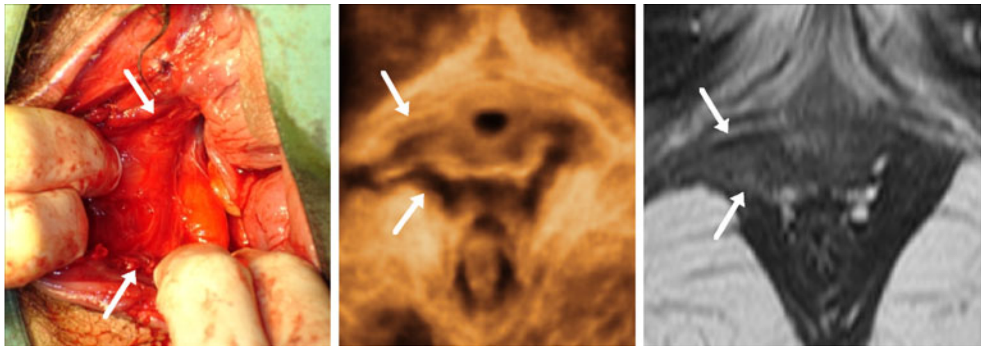

Fig. 11 Typical right-sided levator avulsion injury (*arrows*) as diagnosed in Delivery Suite after a normal vaginal delivery at term, on 3D ultrasound (*centre*) and on magnetic resonance imaging (*right*) 3 months postpartum. At that time, the patient was asymptomatic apart from deep dyspareunia

rectal intussusception, explaining symptoms of obstructed defecation—a situation that is termed a 'colpocele' by radiologists and is virtually unknown in gynaecology. And, as will be discussed in more detail below, marked levator ballooning on Valsalva, or major childbirth-related trauma to the levator ani, may affect surgical decisions in women with uterine prolapse.

Posterior compartment

As regards the posterior compartment, clinically we diagnose 'rectocele' without being able to distinguish the several different conditions leading to downwards displacement of the posterior vaginal wall [51]. A second-degree 'rectocele' could be due to a true rectocele (Fig. 9), i.e. a defect of the rectovaginal septum (most common, and associated with symptoms of prolapse and obstructed defecation) [52], or it could be due to an abnormally distensible, intact rectovaginal septum (common, and associated only with prolapse symptoms), a combined recto-enterocele (less common), an isolated enterocele (uncommon, see Fig. 6), a deficient perineum giving the impression of a 'bulge', or even a rectal intussusception (Figs. 9 and 10), a condition that is not uncommon in urogynecological patients [53], and almost universally overlooked. Translabial ultrasound is a suitable screening tool for all those conditions, with results largely comparable to defecation proctography [54–56], that is increasingly being used not just by gynaecologists, but also by colorectal surgeons and gastroenterologists (see [57] for an overview). Rather unsurprisingly, ultrasound is much better tolerated, and it is cheaper and more generally available. In addition, the real-time nature of the examination allows for immediate therapy in the sense of visual biofeedback, in order to effect behavioural modification. If we can show a patient that straining at stool is obviously counterproductive (whether due to rectocele, colpocele or rectal intussusception), she will hopefully be more likely to modify her behaviour. In some, this is all that is needed to break the vicious cycle of obstructed defecation.

Ultrasound can also demonstrate posterior compartment meshes (see Fig. 10). Compared to the anterior compartment, there is even less evidence on the utility of mesh for rectocele/recto-enterocele, and recurrence may also result in unexpected appearances. Figure 10 shows a rectal intussusception that developed after successful treatment of a recto-enterocele with an Apogee mesh.

The axial plane

Translabial ultrasound has confirmed 60-year-old clinical data [21] and MRI studies [58] showing that major morphological abnormalities of levator structure and function are common in vaginally parous women [16, 59, 60]. It can now be regarded as proven that such abnormalities are due to crowning of the foetal head which is when the puborectalis muscle is subject to the greatest strain [61]. Occasionally, such trauma is visible immediately after delivery, exposed by a large vaginal tear [62], see Fig. 11. Such defects have been confirmed in cadavers [63] and are clearly associated with excessive hiatal distensibility ('ballooning') [64], anterior and central compartment prolapse [15, 17], and with rectal intussusception

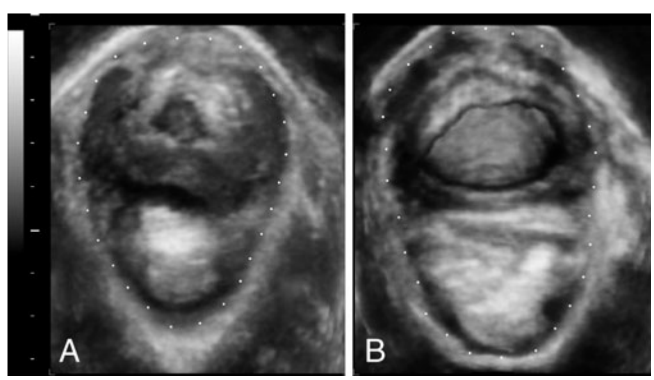

Fig. 12 Altered hiatal dimensions on maximal Valsalva after normal vaginal delivery in a primiparous women, as imaged in the plane of minimal hiatal dimensions. Image A shows the levator hiatus at 36 weeks at 26 cm^2. Image B was obtained 4 months later, with the hiatus measured at 34 cm^2 on maximal Valsalva. Modified from [82], with permission

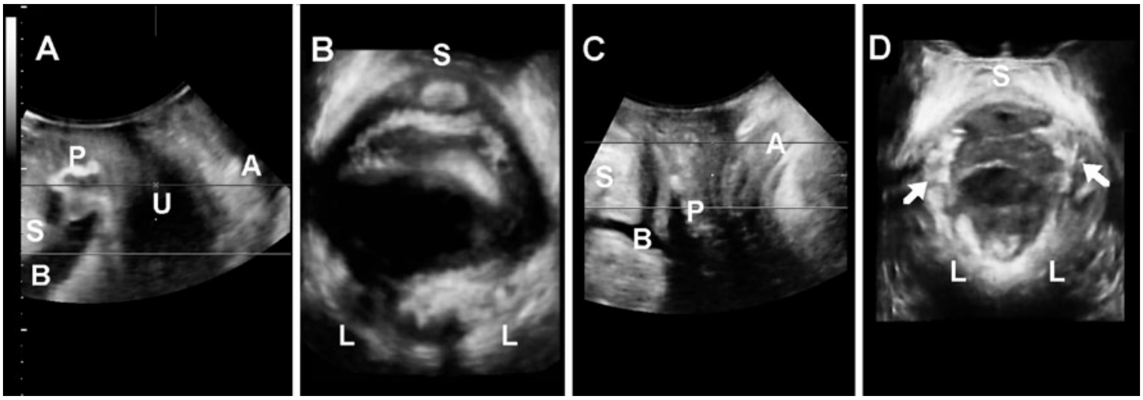

Fig. 13 Marked reduction in hiatal area 3 months after bilateral repair of an avulsion of the puborectalis muscle. Midsagittal (**a**) and axial (**b**) view on Valsalva before abdominal hysterectomy, sacrocolpopexy and bilateral avulsion repair; midsagittal (**c**) and axial (**d**) view on Valsalva 3 months after the procedure. *S* symphysis pubis, *P* perigee mesh, *B* bladder, *U* uterus, *L* levator ani, *A* anal canal. *Arrows* show the location of the avulsion repair

[53]. The larger the defect, the higher is the likelihood of prolapse [30]. Patients frequently notice a deterioration in pelvic floor function after childbirth, and this subjective change is associated with avulsion [65].

While palpation and imaging in rendered volumes can be equally valid [66], diagnosis may be most repeatable when performed using multiplanar or tomographic imaging [30], since single-plane imaging does not distinguish between partial and complete trauma of the puborectalis muscle. Tomographic imaging of the puborectalis muscle can bracket the entire structure, from below its insertion to the inferior aspects of the iliococcygeus muscle [34, 67]; see Fig. 5. This methodology seems robust enough for clinical practice, and the likelihood of false-positive findings appears very low [68].

There are no comparisons of pre- and postnatal data obtained with MR yet, likely due to cost and logistic problems, but such a comparison is available for many hundreds of women seen by 4D translabial ultrasound. While about 10–30% of women will suffer such trauma [13, 59, 60, 69], there is an even greater number that sustain what has been termed 'microtrauma', i.e. irreversible overdistension of the levator hiatus [59], see Fig. 12. The predictors of microtrauma may vary from those that predict levator avulsion [59]. It is not yet clear what the long-term course of such morphological and functional changes is, but neither ongoing deterioration nor 'healing' is likely to be common [70].

Both excessive distensibility of the levator hiatus (ballooning) [22] and levator avulsion seem to be independent risk factors for prolapse [23], and both avulsion [32, 33, 48] and ballooning seem to be risk factors for prolapse recurrence. If so, then we should diagnose such findings preoperatively and adjust our surgical approach accordingly. This may not require imaging. Both avulsion [20] and ballooning (via 'genital hiatus' [gh] and 'perineal body' (pb) measurements included in the ICS POP-Q system) can be diagnosed clinically, and we have determined a cut-off of 7 cm for the sum of gh and pb to define ballooning clinically (unpublished own data).

It is likely that levator avulsion and ballooning can be used to select patients for mesh surgery, especially in the

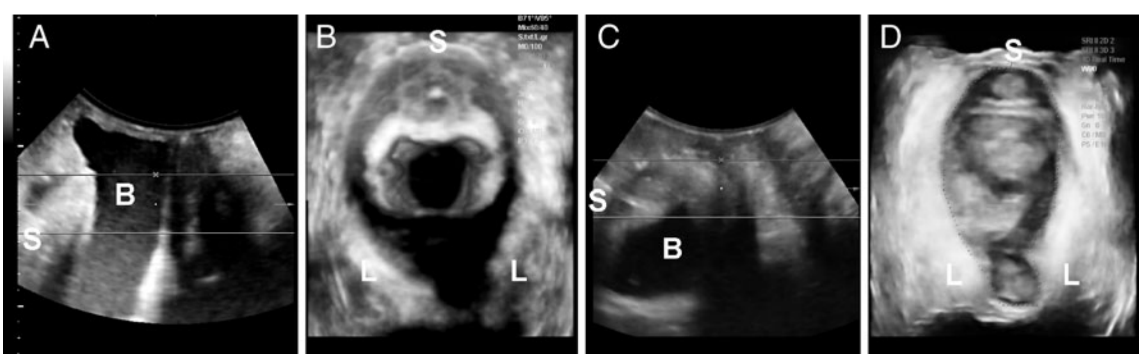

Fig. 14 Hiatal reduction from 35 to 22 cm^2 3 months after insertion of a puborectalis sling. Midsagittal (**a**) and axial (**b**) view on Valsalva before anterior repair, transobturator sling and sacrospinous fixation; midsagittal (**c**) and axial (**d**) view on Valsalva 3 months after the procedure. *S* symphysis pubis, *B* bladder, *L* levator ani

anterior compartment. Any randomised controlled trial of mesh use (such as the PROSPECT trial [71]) that does not allow for a proper diagnostic work-up prior to implantation, or at least an assessment for avulsion at some time point during the trial follow-up, risks wasting large amounts of taxpayer money. Once it is possible to identify patients that are at increased risk of recurrence, such trials need to first be performed in that patient group, and the power of a study of given size would be markedly enhanced by such a policy. It seems very likely that the effect of anterior compartment mesh on recurrence will be much more marked in those with avulsion, i.e. those at high risk of recurrence [48].

In addition, there may be scope for direct repair of levator trauma immediately postpartum [62] or, more likely to be successful, in symptomatic patients [72]. The puborectalis is accessible through a simple distal lateral colpotomy at the level of the hymen and easily dissected off the vagina. From our own modelling and experience in a pilot series of 14 patients to date, it seems unlikely that direct unilateral avulsion repair would result in a major reduction of hiatal dimensions [73, 74], probably because there often is substantial coexisting microtrauma [59]. The effect of reconnecting an avulsed muscle will to a large degree depend on the state of the avulsed muscle. Figure 13 shows a markedly improved hiatus after bilateral avulsion repair in a patient with excellent muscle quality. If the muscle is thin or badly overdistended, which unfortunately is much more common, it may be possible to shorten or splint it prior to re-attachment.

Another approach would be to develop methods to reduce the size of the hiatus more substantially, since the levator hiatus can be regarded as a hernial portal, and since any reduction of the size of a hernial portal should reduce the load or moment exerted on support structures. Neither intravaginal meshes nor the Zacharin levatorplasty [75] seem to be able to effect such permanent change in hiatal dimensions [76]. We have completed a pilot study in 20 women undergoing prolapse repair which shows that, at least in the short term, it is possible to effect a substantial reduction of hiatal dimensions by externally splinting the levator hiatus [77], see Fig. 14. On principle, this would be expected to reduce recurrence rates, but any such hypothesis will have to be tested in randomised controlled trials.

Conclusion

It was evident even in the late 1980s that ultrasound could be of great usefulness to the pelvic reconstructive surgeon. This is more obvious today, considering the increasing prevalence of intravaginal mesh implants which are not visible on X-ray, CT or MR. In addition, there is 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, and this trend is likely to intensify. Within the next 5 years, imaging techniques will very likely help us to further elucidate the aetiology and pathophysiology of pelvic floor dysfunction. Ultrasound in particular will increasingly help to assess the outcomes of conservative and surgical treatment and assist in the development of entirely new therapeutic concepts. Ultrasound outcome measures will become an accepted component of intervention trials and change our appreciation of success and failure. Most importantly, imaging is going to make us much better at examining our patients clinically.

Conflicts of interest The author has received honoraria as a speaker from GE Medical, Astellas and AMS and has in the past acted as consultant for CCS, AMS and Materna Inc. He has also received equipment loans from GE, Toshiba and Bruel and Kjaer.

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