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Ultrasound in the investigation of posterior compartment vaginal prolapse and obstructed defecation

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KEYWORDS: defecography; enterocele; female pelvic organ prolapse; obstructed defecation; rectocele

ABSTRACT

Recent developments in diagnostic imaging have made gynecologists, colorectal surgeons and gastroenterologists realize as never before that they share a common interest in anorectal and pelvic floor dysfunction. While we often may be using different words to describe the same phenomenon (e.g. anismus/vaginismus) or attributing different meanings to the same words (e.g. rectocele), we look after patients with problems that transcend the borders of our respective specialties. Like no other diagnostic modality, imaging helps us understand each other and provides new insights into conditions we all need to learn to investigate better in order to improve clinical management.

In this review we attempt to show what modern ultrasound imaging can contribute to the diagnostic work-up of patients with posterior vaginal wall prolapse, obstructed defecation and rectal intussusception/prolapse. In summary, it is evident that translabial/perineal ultrasound can serve as a first-line diagnostic tool in women with such complaints, replacing defecation proctography and MR proctography in a large proportion of female patients. This is advantageous for the women themselves because ultrasound is much better tolerated, as well as for healthcare systems since sonographic imaging is much less expensive. However, there is a substantial need for education, which currently remains unmet. Copyright © 2012 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

In gynecological and urogynecological populations, rectocele is one of the most common morphological abnormalities seen on clinical examination, and complaints of obstructed defecation are also common[1]. Defecation is a complex learned function involving the coordinated integration of sensory, motor, psychological and mechanical mechanisms. Approximately 20% of adult women report constipation. Between 7% and 10% of these patients report repeated straining at stool and the intermittent need for perineal digitation to assist defecation and to overcome the sensation of blockage or inadequate evacuation[2]. Recognizable morphological pelvic floor and perineal soft-tissue anomalies are relatively common, and, since the symptomatic presentations differ, they are reported differently by gynecologists, coloproctologists and pelvic floor physicians. Over 90% of patients present with a multiplicity of pelvic floor disorders[3]. Some of the mechanisms contributing to obstructed defecation relate to structural pelvic floor abnormalities and include rectocele, enterocele and rectal intussusceptions, each of which may result in outlet obstruction[4].

Even rectal intussusception, while often asymptomatic, is not uncommon in urogynecological patients[5]. However, since these women generally present because of other symptoms that are subjectively more bothersome, e.g. urinary incontinence or uterovaginal prolapse, gynecologists see a different spectrum of anorectal dysfunction compared to that seen by gastroenterologists and colorectal surgeons. Similarly, colorectal surgeons and gastroenterologists seeing patients with rectal intussusception or prolapse will likely encounter many patients with cystocele or uterine prolapse and major childbirth-related pelvic floor trauma. In any event, ultrasound will frequently reveal unexpected abnormalities that technically fall within the realm of other specialties and which require a basic understanding of overall functional pelvic floor anatomy.

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METHODOLOGY OF TRANSLABIAL OR TRANSPERINEAL ULTRASOUND

Two-dimensional imaging

Basic requirements for translabial pelvic floor ultrasound include a B-mode-capable, two-dimensional (2D) ultrasound (US) system with cine-loop function, a 3.5- to 6-MHz curved array transducer and a video printer[6]. Such systems (without the benefit of a video printer) have been in use since the mid-1980s, when transperineal ultrasound (TP-US) was first described[7,8]. A mid-sagittal view is obtained by placing a transducer (usually a curved array with frequencies between 3.5 and 8 MHz) against the perineum (Figure 1) after covering the transducer with a glove, condom or thin plastic wrap. Sterilization, as for intracavitary transducers, is usually considered unnecessary. We use alcoholic wipes to clean the transducer between patients although local regulations may require more extensive cleaning. Powdered or coated gloves should be avoided as they can impair imaging quality due to reverberations. It is worthwhile to test several types of probe covers for their effect on image quality and for ease of application. Imaging is usually performed in the dorsal lithotomy position with the hips flexed and slightly abducted, or in the standing position. Asking the patient to place her heels close to her buttocks and move her hips towards the buttocks will result in an improved pelvic tilt. Bladder filling should also be specified; voiding prior to examination is preferable. A loaded or impacted rectum can impair diagnostic accuracy and a repeat assessment after bowel emptying or a cleansing enema is sometimes required. In the corollary technique of TP-US as described by Beer-Gabel and colleagues[9,10], the rectum is filled with 30–50 mL of acoustic gel, and the vagina with a lesser amount, allowing for high-resolution images of the rectovaginal septal territory and permitting a qualitative assessment of rectal (and rectocele) emptying during contrast evacuation. This technique was initially developed as an alternative to defecography and the need for extended defecographic methods to demonstrate enteroceles; thus, it is an office procedure without the disadvantage of irradiation. Although it is accepted that overdistension of the rectum and vagina might reduce organ descent on Valsalva, the technique has shown equivalent sensitivity for specific pelvic floor diagnoses despite variations in the volumes of acoustic gel in either the rectum or vagina[9,10].

Parting of the labia can improve image quality, which generally is best in pregnant women and poorest in menopausal women with marked atrophy, most likely due to varying hydration and tissue quality. Vaginal scar tissue can also impair visibility, but obesity virtually never seems to be a problem. The transducer can usually be placed firmly on the perineum and the symphysis pubis without causing discomfort, unless there is marked atrophy or local skin changes. The resulting image includes the symphysis pubis anteriorly, the urethra and bladder neck, the vagina, cervix, rectum and anal canal (Figure 1). Posterior to the anorectal junction, a hyperechogenic area indicates the central portion of the levator plate (the puborectalis muscle). The peritoneal cul-de-sac may be seen also, filled with a small amount of fluid, echogenic intraperitoneal fat or small bowel, most obvious when peristalsing and in cases of enterocele.

Three-dimensional/four-dimensional 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 provides 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 aperture and acquisition angles of $\geq 70°$ will include the entire levator hiatus with views of the symphysis pubis, urethra, paravaginal tissues, vagina, anorectum and levator ani muscle from the pelvic sidewall to the posterior aspect of the anorectal junction[11].

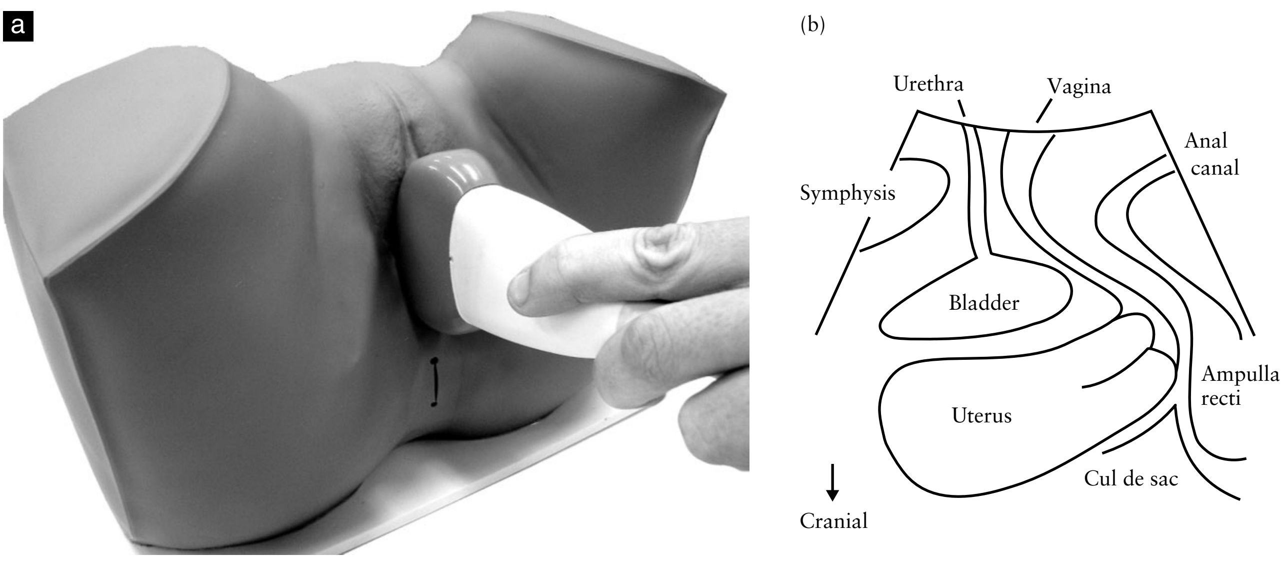

Figure 1 Transducer placement (a) and field of vision (b) for translabial/perineal ultrasound, mid-sagittal plane. (From Dietz[95] with permission.)

Basic requirements for 3D/4D pelvic floor ultrasound include a system that allows acquisition, reconstruction and analysis of volume datasets, and that also has the capability to measure distances and areas within this acquisition volume. This implies motorized or freehand image acquisition with an external position sensor, although the latter is now obsolete. Currently, the most common 3D probes are those that combine an electronic curved array of 3–8 MHz with mechanical sector technology, allowing fast motorized sweeps through a field of vision.

In essence, any system that allows satisfactory 3D imaging using an abdominal obstetric probe will be suitable, provided that the acquisition angle is sufficient to include the entire levator hiatus (i.e. 70–85°). Optimally, one should be able to obtain volumes at an acquisition angle of 80–85° sequentially over a period of 5–10 seconds. Such a cine-loop of volumes is then stored on the system's hard disk for later evaluation.

Display modes

Figure 2 demonstrates the two basic display modes currently in use with 3D ultrasound systems. The multiplanar or orthogonal display mode shows cross-sectional planes through the volume in question. For pelvic floor imaging, this most conveniently utilizes the mid-sagittal (top left), the coronal (top right) and the axial (bottom left) planes. Imaging planes can be varied in a completely arbitrary fashion in order to enhance the visibility of a given anatomical structure, either at the time of acquisition or offline at a later time. The levator ani, for example, usually requires an axial plane that is slightly tilted in a ventrocaudal to dorsocranial direction. The three orthogonal images are complemented by a 'rendered image' (i.e. a semitransparent representation of all voxels in an arbitrarily definable 'box'), the so-called 'region of interest'. Figure 2d shows a standard rendered image of the levator hiatus, with the rendering direction set from caudally to cranially, which is the most appropriate format for imaging the hiatus. The possibilities for postprocessing are restricted only by the software used for this purpose.

Four-dimensional imaging

Four-dimensional imaging implies real-time acquisition of volume ultrasound data, which can be represented in orthogonal planes or rendered volumes. Many systems are now capable of storing cine-loops of dozens of volumes, which is of major importance in pelvic floor imaging as it allows enhanced documentation of functional anatomy. The ability to perform a real-time 3D (or 4D) assessment of pelvic floor structures makes the technology superior to magnetic resonance imaging (MRI), with greater availability and at less cost, as well as allowing the option to assess the effect of position change on pelvic floor anatomy. Prolapse assessment by MRI requires ultrafast acquisition[12], which is of limited availability and will not allow optimal soft-tissue resolution. Alternatively, some systems allow imaging of the seated or erect patient, but again, access to these open-architecture MRI systems is limited for the foreseeable future. The sheer physical characteristics of MRI systems make it much harder for the operator to ensure efficient maneuvers as over

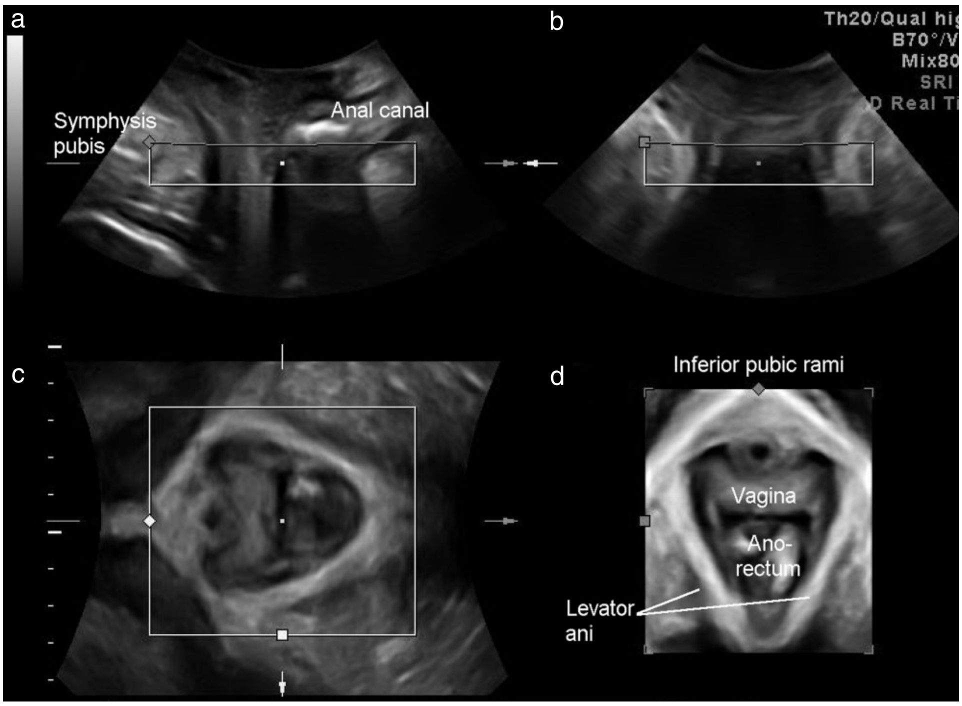

Figure 2 Standard representation of 3D sonography of the pelvic floor. The usual acquisition/evaluation screen on Voluson-type systems shows the three orthogonal planes: sagittal (a), coronal (b) and axial (c) as well as a rendered volume (d), which is a semitransparent representation of all gray-scale data in the rendered volume (i.e. the box visible in (a)–(c)). (From Dietz[94] with permission.)

50% of all women do not perform a proper pelvic floor contraction when asked[13] and a Valsalva maneuver is often confounded by concomitant levator activation[14]. Without real-time imaging, these confounders are difficult to control for. Therefore, ultrasound has major potential advantages for describing prolapse, especially when associated with fascial or muscular defects and for defining functional anatomy. Offline analysis packages allow distance, area and volume measurements in any user-defined plane (oblique or orthogonal), which is far superior to what is currently possible with DICOM (Digital Imaging and Communications in Medicine) viewer software on a standard set of single-plane MR images.

FUNCTIONAL ASSESSMENT

Valsalva maneuver

The Valsalva maneuver, i.e. forced expiration against a closed glottis and contracted diaphragm and abdominal wall, is routinely used to effect downward displacement of pelvic organs, revealing the symptoms and signs of female pelvic organ prolapse and demonstrating distensibility of the levator hiatus. It also serves to mimic anatomical changes during simulated defecation and straining, although it is understood that observations during the Valsalva maneuver cannot be more than an approximation of what actually occurs during normal defecation.

The result of the Valsalva maneuver is a dorsocaudal displacement of pelvic organs that can be quantified against a line placed through the inferoposterior symphyseal margin (see Figure 3 for quantification of hypermobility of the rectal ampulla with and without rectocele). There is caudal movement of the bladder and urethra, the uterine cervix and the rectal ampulla, and frequently the development of a rectocele (i.e. 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. It is important to let the transducer move with the tissues, avoiding undue pressure on the perineum which would prevent full development of a prolapse. In order to achieve maximal or near-maximal organ descent it is necessary to obtain Valsalva pressures of at least 60 cm H_20[15] for at least 5–6 seconds[16]. This is frequently not achieved during clinical examination.

Especially in young, nulliparous women, the Valsalva maneuver is frequently affected by levator activation[14]. Levator coactivation during the Valsalva maneuver is a significant confounding variable during assessment of pelvic floor dysfunction and prolapse. Levator coactivation is visible as a reduction in the anteroposterior

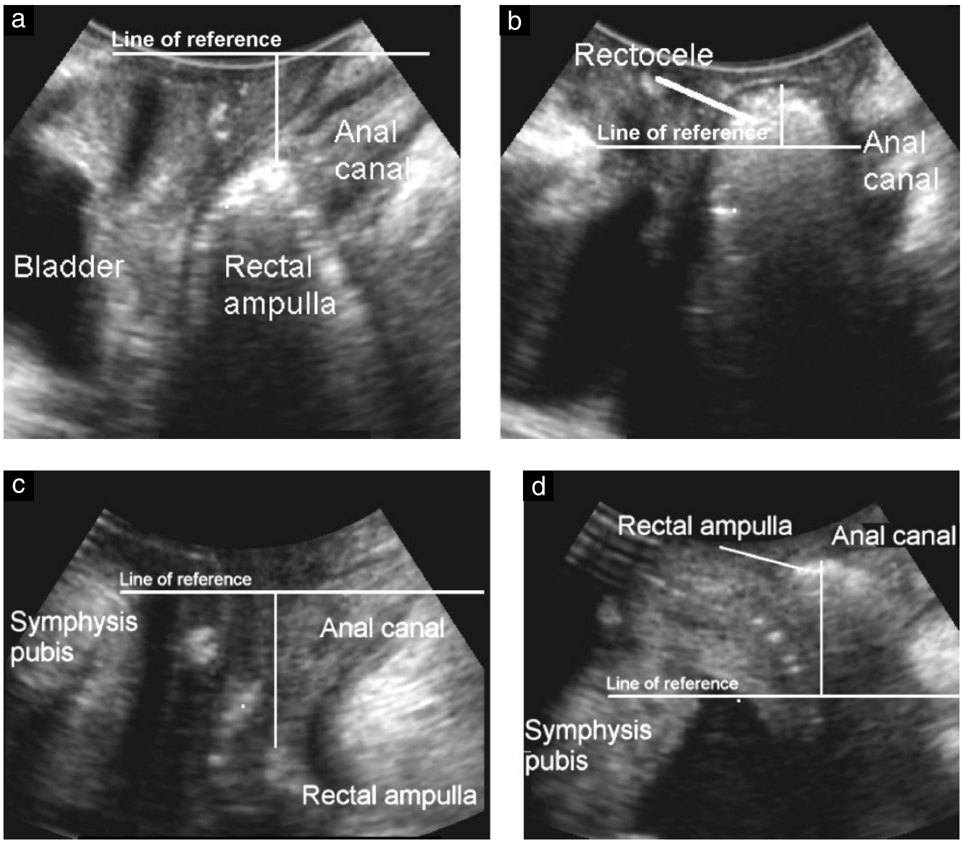

Figure 3 Assessment of organ descent. Descent of pelvic organs on Valsalva is measured against a reference line placed through the inferior margin of the symphysis pubis. Panels (a) and (c) show the situation at rest in two patients with a clinical rectocele stage 2; (b) and (d) illustrate findings on Valsalva. In Case 1, (a) and (b), there is a 'true' rectocele; in Case 2, (c) and (d), no sacculation or diverticulum of the rectal ampulla is visible. The diagnosis is perineal or rectal hypermobility rather than a true rectocele.

diameter of the levator hiatus during Valsalva. Further, any imaging assessment of organ descent requires real-time observation of the effect of the Valsalva maneuver in order to correct suboptimal efforts, especially if leakage from the bladder or bowel is likely or anticipated by the patient. At times, levator coactivation can prevent adequate assessment in the supine position, in particular in women with a strong, intact levator shelf. Occasionally it is necessary to repeat imaging in the standing position, which increases the likelihood of an adequate bearing-down effort during examination. Usually, however, imaging in the supine position is sufficient[17]. In women with symptoms of obstructed defecation, persistent levator coactivation may be a sign of anismus (paradoxical puborectalis contraction). The provision of visual biofeedback may help the patient in learning to relax the levator ani muscle during defecation attempts.

Pelvic floor muscle contraction

Ultrasound is a highly useful tool in the evaluation of pelvic floor musculature, for both purely anatomical (see below) and functional assessment. A levator contraction will reduce the size of the levator hiatus in the sagittal plane and elevate the anorectum, changing the angle between the levator plate and the symphysis pubis. The puborectalis muscle is one of the main determinants of intravaginal as well as anorectal pressure[18]. Shortening of the muscle during a voluntary pelvic floor muscle contraction prior to sphincter repair has been shown to be a good predictor of successful functional outcome[19]. As an indirect effect of the maneuver, other pelvic organs are displaced cranially and there is compression of the urethra, vagina and anorectal junction, suggesting involvement of the levator ani in the pathogenesis of urinary and fecal continence as well as illustrating its importance for sexual function.

CLINICAL APPLICATIONS IN WOMEN WITH OBSTRUCTED DEFECATION

While urogynecologists and urologists use translabial ultrasound mainly in the anterior compartment (i.e. for imaging of the urethra and bladder), pelvic floor ultrasound is particularly useful in the posterior compartment. Gynecologists frequently diagnose rectocele when they really mean a prolapse of the posterior vaginal wall. Prolapse of the posterior vagina detected on vaginal clinical assessment may be due to at least five different conditions[20]:

1. a 'true' rectocele, i.e. a diverticulum of the anterior rectal wall extending into the vagina, due to a defect of the rectovaginal septum (Figures 3–6), which is common and is associated with symptoms of prolapse, incomplete bowel emptying and straining at stool[1];
2. an abnormally distensible, intact rectovaginal septum which is relatively common and associated only with prolapse symptoms and/or perineal hypermobility (Figure 3);
3. a combined recto-enterocele which is less common;
4. an isolated enterocele (Figure 7) which is uncommon;
5. a deficient perineum, giving the impression of a bulge.

On occasion, the clinical appearance of a rectocele is secondary to a rectoanal intussusception (Figure 8). Both a 'true' rectocele and intussusception can be identified by rectal examination during Valsalva, but we are not aware of this as a common practice at present.

Rectocele

An anterior rectocele is evident as a diverticulum of the anterior wall of the rectal ampulla which extends into the vagina on straining, with posterior and lateral rectoceles being relatively uncommon and possibly representing an intussusception variant[21]. Rectoceles usually contain iso- to hyperechoic fecal material with associated bowel gas, resulting in specular echoes and reverberations on transperineal sonography. Occasionally there is no stool in the ampulla that might be propelled into the rectocele and thus it remains smaller and filled only with rectal mucosa. Distension of the rectocele (and hence its appearance on ultrasound) is somewhat dependent on the presence and quality of entrapped stool. It is thought that stool quality may affect symptoms arising from a rectocele of a given size, although we have been unable to confirm such a relationship[22].

The extent of a rectocele can be quantified by measuring its maximal descent relative to the inferior symphyseal margin and by determining the maximal depth of the sacculation on mid-sagittal views (Figures 3 and 4). There seems to be a strong correlation between dynamic TP-US and defecography regarding rectocele depth[9,23]. It has been claimed that a difference in length of the anterior anal canal, measured by either TP-US or 3D endoanal echodefecography in the sagittal plane, may be suggestive of impaired integrity of the perineal body[23,24].

Emptying of a rectocele during straining can be visualized readily during a dynamic transperineal ultrasound examination, although its clinical importance in surgical decision making is controversial[25]. Incomplete emptying may be an intrinsic feature of a larger rectocele which tends to be more symptomatic[1] but may result also from other phenomena such as the effect of prolapse in other compartments, rectal intussusception or coincident anismus, which may be artifactual due to elevated stress levels in a patient who is in close proximity to the examiner during simulated defecation. No correlation is described in the literature between rectocele depth or completeness of emptying and either reported clinical symptoms or functional outcome following surgical repair[26–29].

We assume that a 'true' (radiological) rectocele is due to a defect of the rectovaginal septum or 'Denonvillier's fascia'. However, to date it seems impossible to image the rectovaginal septum directly[30]. The structure can certainly

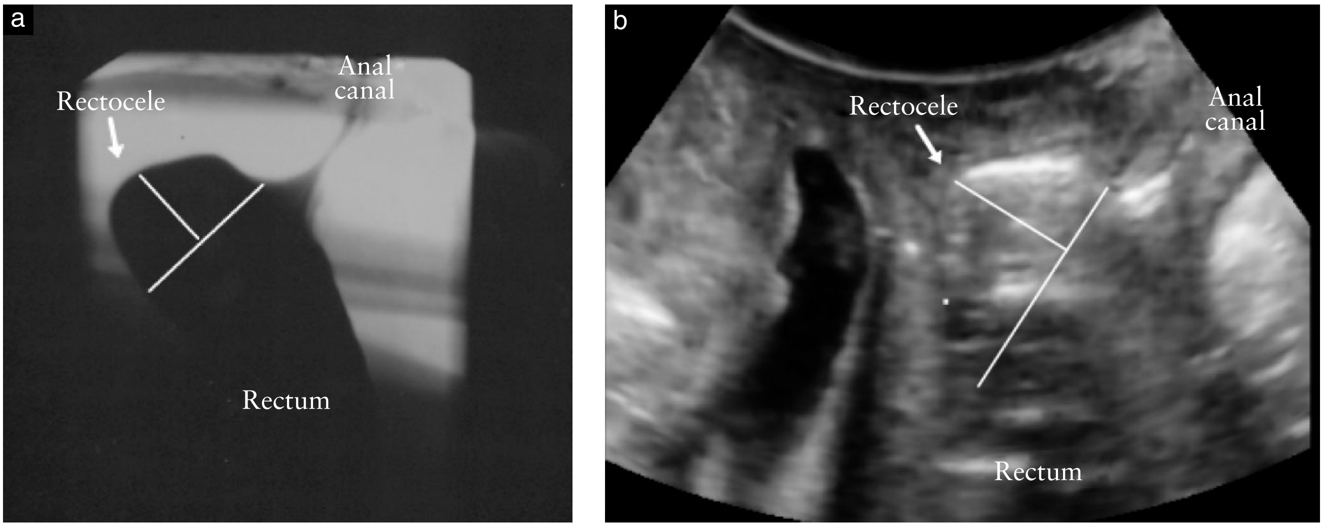

Figure 4 A typical true rectocele as seen on defecation proctogram (a) and on translabial ultrasound (b). Whether such a rectocele is symptomatic will to a large extent depend on stool quality, and many are asymptomatic. (From Perniola *et al.*[38] with permission.)

Figure 5 True rectocele (defect of the rectovaginal septum) seen intraoperatively. The superior margin of the rectovaginal septum, i.e. the inferior margin of the defect that allows a rectocele to herniate into the vagina, is indicated by arrows.

be visualized after posterior colpotomy (Figure 5), provided care is taken to separate the vaginal muscularis from the rectovaginal septum. Hydrodissection is very useful in this regard. Defects in the rectovaginal septum are generally transverse and can be closed with a horizontal row of sutures, approximating the rectovaginal septum to the vaginal vault and the uterosacral ligaments. This is usually termed a 'defect-specific' repair and was first described by the American gynecologist C. Richardson[31]. Such a procedure can reconstitute normal anatomical appearances in the posterior vaginal compartment entirely and normalize the appearance of the anorectum (Figure 6).

Enterocele

An enterocele is visualized as downward displacement of abdominal contents into the vagina, ventral to the anal canal. The small bowel may be identifiable because of its peristalsis and sometimes a small amount of intraperitoneal fluid outlines the apex of the enterocele. Distal shadowing is much less common than that obtained with a rectocele and often contents have an irregular isoechoic or ground glass-like appearance (Figure 7). The differential diagnosis with rectocele is easy once one has identified the rectal ampulla, usually a wedge-shaped area of high echogenicity with distal acoustic shadowing due to filling with stool (Figure 7a). Peristalsis in the ampulla is of course not as obvious as in the small bowel, but a colonic mass movement will distend the rectal ampulla and propel stool towards the anal canal, a process that is often triggered by the repeated Valsalva maneuvers used for prolapse assessment. The detection of an enterocele by transperineal ultrasound compares favorably with findings detected by defecation proctography[32]. Most enteroceles are not detected on clinical examination[33].

Rectal intussusception/prolapse

Intussusception is seen as a splaying of the normally tubular anal canal with the anterior wall of the rectal ampulla (and sometimes the posterior wall) being inverted and propelled into the opening of the anal canal. Figure 8 shows a comparison of radiological and ultrasound findings in a patient with rectal intussusception. A rectal intussusception may be secondary to an enterocele that develops into the anal canal rather than the vagina. The enterocele consists of small bowel although it may occasionally contain sigmoid colon[34,35], omentum or even the uterus (colpocele). Rectal intussusception is associated with abnormal distensibility of the levator ani and avulsion of the puborectalis muscle[5].

When a rectocele or rectal intussusception is identified on translabial imaging, provision of visual biofeedback for the patient may be useful to demonstrate that straining at stool is counterproductive, since stool is propelled not into the anal canal but into the vagina. This observation may permit behavior modification. Several studies

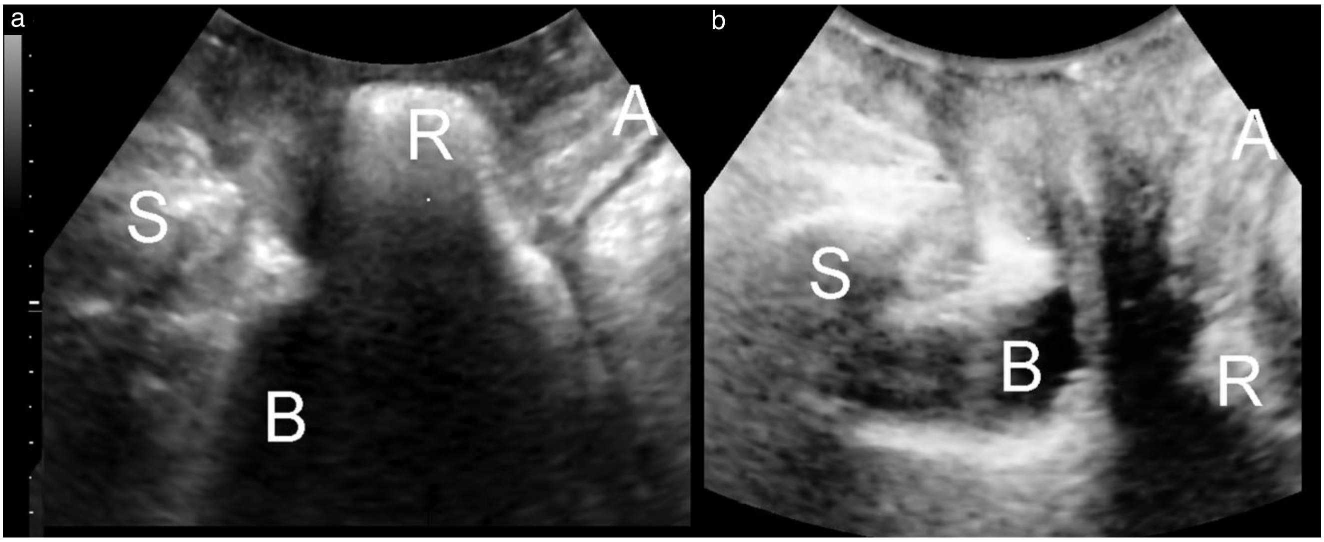

Figure 6 Sonographic appearance on Valsalva, before (a) and 6 months after (b) defect-specific rectocele repair. A, anal canal; B, bladder; R, rectocele/rectal ampulla; S, symphysis pubis.

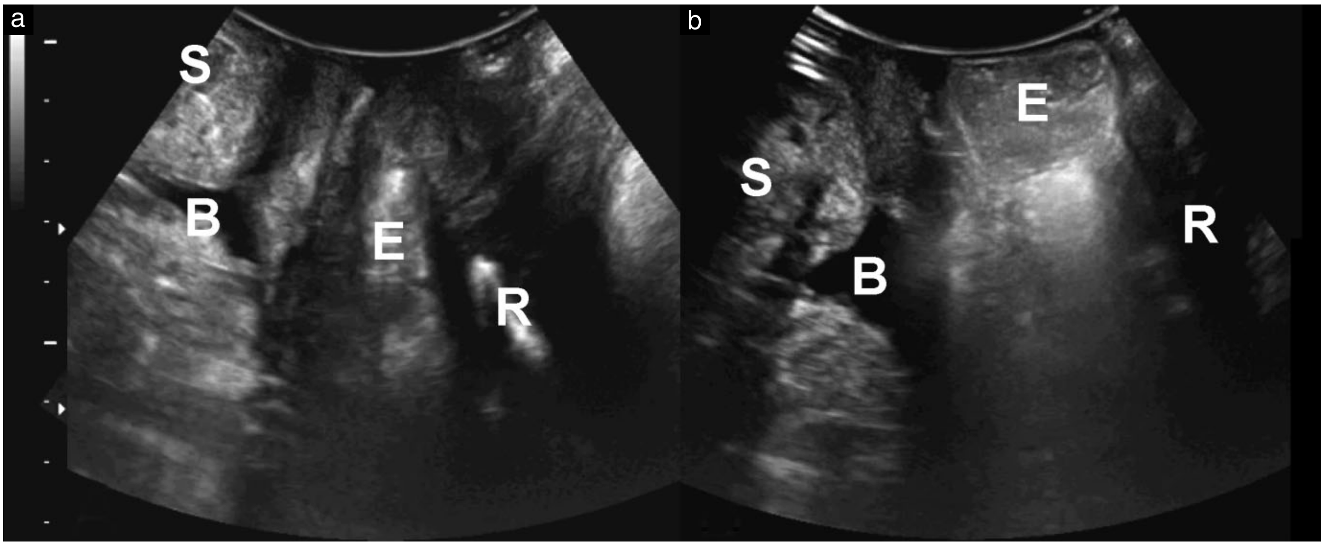

Figure 7 Isolated enterocele in a patient after hysterectomy. There is no significant descent of the rectal ampulla. Panel (a) shows the mid-sagittal plane at rest; the enterocele is evident as a low pouch of Douglas on Valsalva (b). B, bladder; E, enterocele; R, rectum; S, symphysis pubis. (From Dietz[95] with permission.)

have recently shown that ultrasound is better tolerated than defecation proctography[36–39], and it is considerably less expensive. It is thus likely that ultrasound will replace defecography as the initial investigation of choice in women with defecation disorders. If a rectocele or a rectal intussusception/prolapse is discovered by ultrasound, the condition is very likely to be detected also by X-ray imaging. This may be true also for anismus, although it is frequently unclear whether observations made during diagnostic imaging bear any relationship to what occurs during spontaneous defecation[40].

Anal sphincter trauma

Assessment of the anal sphincter will not be discussed in any detail here. The anal sphincter is generally imaged by endoanal ultrasound. This method is firmly established as one of the cornerstones of a colorectal diagnostic work-up for anal incontinence and is beyond the scope of this review. Due to the limited availability of such probes in gynecological practice, obstetricians and gynecologists have taken to using high-frequency curved array or endovaginal probes placed exoanally (i.e. transperineally) in the coronal rather than the mid-sagittal plane[41–44]. Lately, 3D pelvic floor imaging has also been used to demonstrate the anal canal[43–45] and, as in imaging of the levator ani, tomographic or multi-slice ultrasound can be employed to image the entire EAS in 6 to 8 slices at 2–3-mm intervals (Figures 9 and 10).

There are advantages to this approach, not just from the point of view of the patient. Exoanal imaging reduces

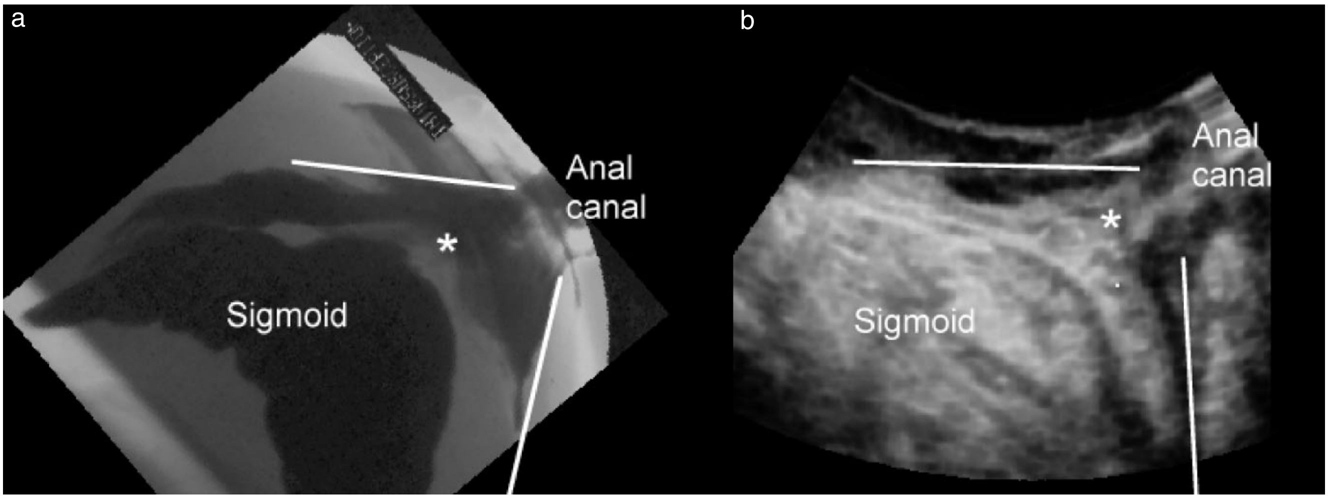

Figure 8 A rectal intussusception due to a sigmoid enterocele as seen on defecation proctogram (a) and translabial ultrasound (b). It is generally not possible to distinguish what part of the small or large bowel propels the intussuscipiens, although the coarse appearance of the intussuscipiens shown in (b) is suggestive of large rather than small bowel. Lines signify the anal canal and stars the apex of the intussuscipiens. (From Perniola *et al.*[38] with permission.)

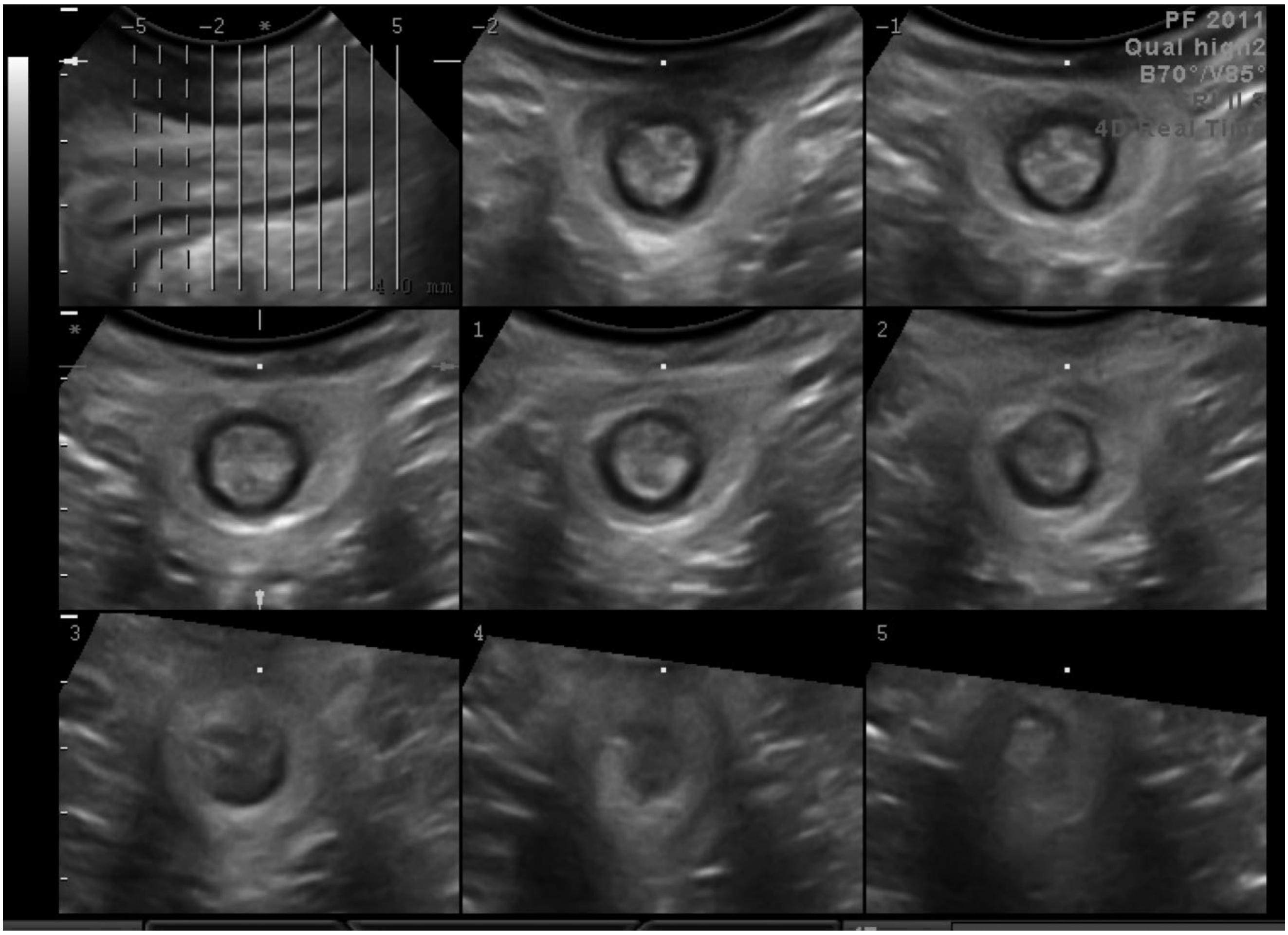

Figure 9 Translabial tomographic ultrasound imaging of the external anal sphincter. The top left image shows the mid-sagittal plane and the remaining eight slices are coronal images of the entire external anal sphincter, the locations of which are shown in the top left hand image

distortion of the anal canal and allows dynamic evaluation of the anal sphincter and mucosa, both at rest and on sphincter contraction, which seems to enhance the definition of muscular defects. Soft-tissue resolution is likely to be inferior to that obtained with endoanal ultrasound[46], but this may not have an impact on detection of clinically relevant defects. Several studies comparing endoanal with exoanal imaging are currently in progress. One has just been published showing moderate agreement between methods, inappropriately

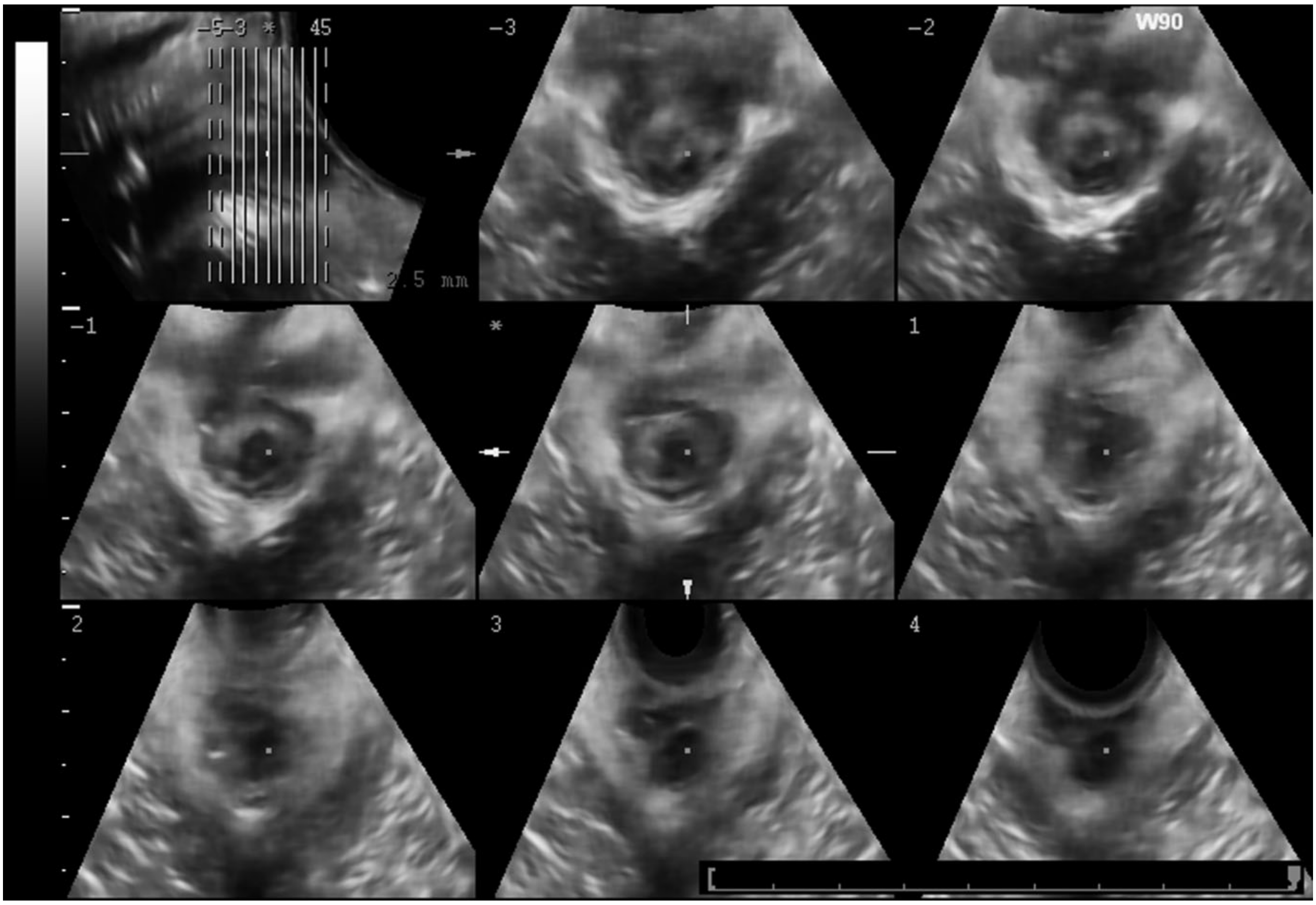

Figure 10 Tomographic representation of a residual sphincter defect after surgical repair of a Grade 3c obstetric anal sphincter tear.

claiming endoanal imaging as the reference standard for anal sphincter tears[47]. Future studies will have to use symptoms or MRI to establish the relative validity of different approaches, and probably should also include an assessment of patient acceptance.

ASSESSMENT OF THE LEVATOR ANI

The state of the levator ani seems to have less bearing on colorectal conditions than on female pelvic organ prolapse which affects the anterior and central compartments. However, rectal intussusception seems to be associated with excessive distensibility of the levator ani ('ballooning') and with major delivery-related trauma to the levator ani[5], which underscores the need for a comprehensive assessment in women with pelvic floor disorders.

Translabial ultrasound examination has confirmed 60-year-old clinical data[48] and MRI studies[49] showing that major morphological abnormalities of levator structure and function are common in vaginally parous women[50]. The archetypal form of trauma is an avulsion, i.e. a tear affecting the insertion of the levator ani on the inferior ramus of the os pubis (Figure 11)[11]. The portion of the levator ani affected by such trauma is variously called the 'pubococcygeus', 'puborectalis' or 'puboviseralis' muscle. Regardless of nomenclature, this is the muscle that forms the levator hiatus, i.e. the narrowest part of the pelvic floor opening. This structure defines the vaginal high-pressure zone[18] and, as such, is very likely the part of the levator ani that is under the most strain during crowning of the baby's head. Required stretch ratios seem to vary enormously from one person to the next[51].

It can be regarded as proven that avulsion is the result of vaginal delivery[52–59]. Such trauma can be documented by 2D ultrasound, with either a side-firing endocavitary probe[60] or parasagittal probe orientation[61]. However, the most convenient and reproducible approach is use of an abdominal 3D probe. Tomographic imaging seems to be the most reproducible technique and can be used to bracket the entire area of interest[62,63]; this method has been shown recently to be equivalent to MRI of such trauma[64].

While there are other etiological factors, probably including microtrauma or altered biomechanics of otherwise intact muscle[58], levator trauma seems to enlarge the hiatus[65] and results in anterior and central compartment prolapse[66]. Patients with avulsion defects are two to three times more likely to have a significant cystocele and four times more likely to have uterine prolapse[66]. Avulsion reduces pelvic floor muscle function by about one-third[67,68] and has a marked effect on hiatal biometry and distensibility[65].

Levator defects seem to be associated with cystocele recurrence after anterior repair[69–71] and may well be a

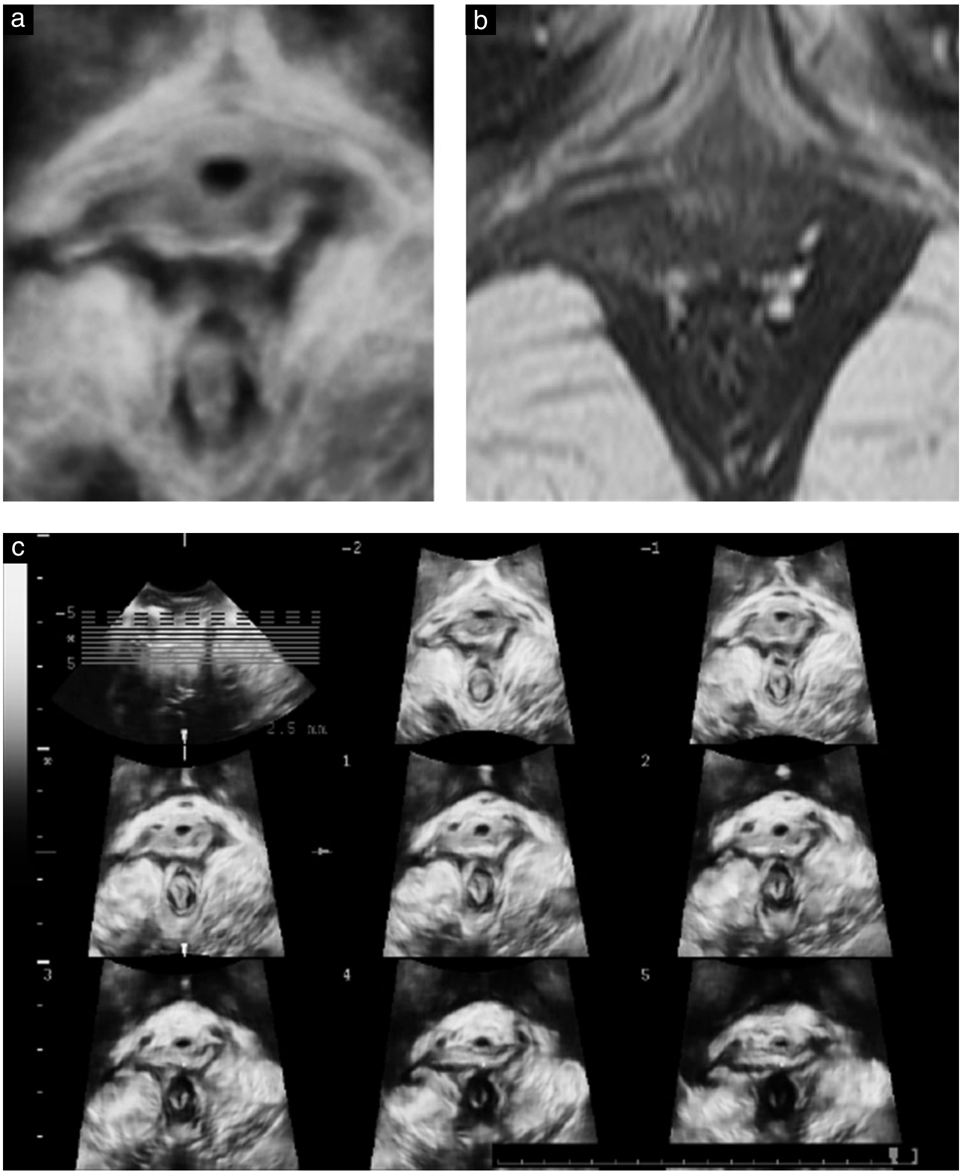

Figure 11 Typical right-sided levator avulsion injury as diagnosed 3 months after a normal vaginal delivery at term, on 3D ultrasound (a), magnetic resonance imaging (b) and tomographic ultrasound imaging (c). This patient was asymptomatic apart from deep dyspareunia.

risk factor for prolapse recurrence following pelvic reconstructive surgery in general[72]. These defects are palpable, but palpation has a significant learning curve[73,74] and is probably less reproducible. Identification of an avulsion injury is aided by determination of the levator–urethra gap which is the measured distance from the center of the urethral lumen to the most medial aspect of the puborectalis muscle[75], analogous to measurement of the levator–symphysis gap on MRI[64,76].

There appears to be a high prevalence of levator defects in women with anal sphincter defects[77,78], which is not really surprising given the overlap in risk factors. Despite this, however, levator defects do not seem to be associated with fecal incontinence[79], although an underactive pelvic floor seems to be a risk factor[80]. Surprisingly, there seems to be no positive association between levator trauma and stress urinary incontinence or urodynamic stress incontinence[81]. This agrees with the finding that there is no association between urethral mobility and levator trauma[82], suggesting that pathophysiological mechanisms vary substantially between female pelvic organ prolapse and stress urinary incontinence.

In some women, childbirth does not result in macroscopically evident muscle tears, but rather in an irreversible overdistension of the levator hiatus. A permanent increase of more than 20% in the hiatal area after childbirth has been defined as microtrauma of the levator ani[58], although a wide hiatus may be congenital rather than acquired, as evident in the wide range of values obtained in nulliparous women[83]. Currently, we have no means of distinguishing acquired overdistensibility or ballooning from an acquired condition, but ballooning is clearly associated with pelvic organ descent[84] and with rectal intussusception[5]. Figure 12 illustrates identification of the plane of minimal hiatal dimensions, which helps in obtaining reproducible qualitative and quantitative findings. After locating the minimal distance between the dorsal aspect of the symphysis pubis and the ventral

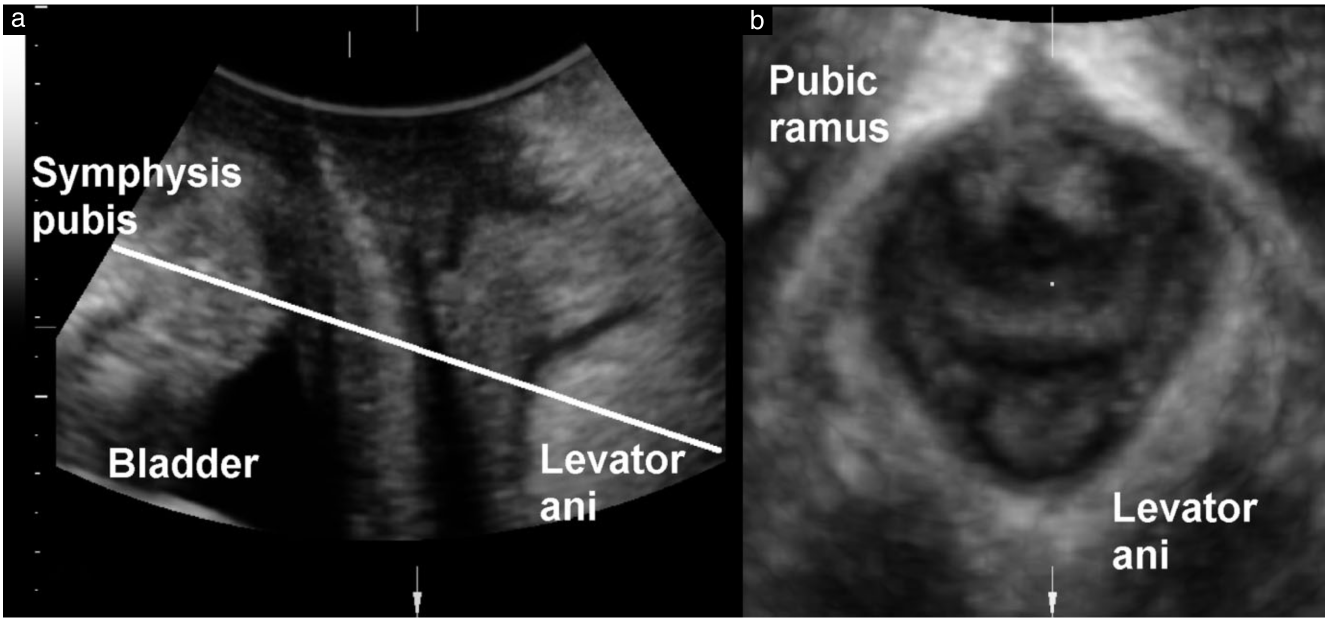

Figure 12 Determination of the plane of minimal hiatal dimensions: the minimal distance between the posterior symphyseal margin and the levator ani immediately posterior to the anorectal angle ((a), mid-sagittal plane) serves to identify the correct axial plane (b).

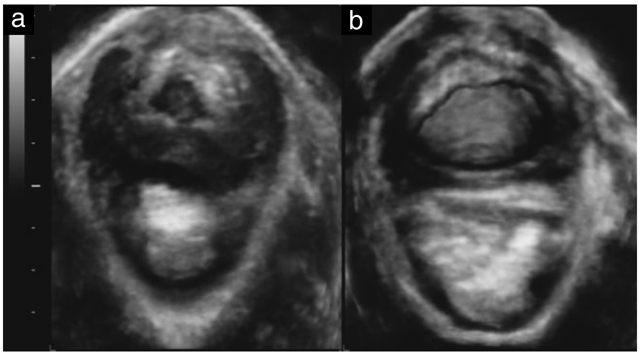

Figure 13 'Ballooning' of the levator hiatus as measured in the plane of minimal dimensions on maximal Valsalva. Image (a) illustrates mild ballooning (28 cm^2) in late pregnancy (36 weeks); image (b) shows moderate ballooning (34 cm^2) 4 months after a normal vaginal delivery. (From Dietz *et al.*[96] with permission.)

aspect of the puborectalis loop, this line is then identified in the axial plane, defining the plane of minimal dimensions. This is a useful approximation, even though it is understood that the true plane of minimal dimensions is non-Euclidean, i.e. distorted. Measures of hiatal dimensions are highly reproducible[83,85–87] and show high correlation with MRI findings[88]. Hiatal enlargement to over 25 cm^2 on Valsalva is defined as ballooning on the basis of receiver–operating characteristics statistics[84] and normative data in young nulliparous women[83]. Ballooning may be either congenital or acquired and may be due to either levator tears or microtrauma (Figure 13). The degree of distension is strongly associated with clinical prolapse and symptoms of prolapse[84,89], rectal intussusception[5] and prolapse recurrence following rectocele repair[90]. In fact, hiatal distension can be determined clinically using the prolapse quantification system of the International Continence Society[91]. Clinical measurements of ballooning correlate strongly with imaging data and with symptoms and signs of prolapse[92]. There have been first attempts at reducing the levator hiatus surgically[93], but the effectiveness of such measures is as yet unclear, in particular as regards anorectal function.

CONCLUSIONS

Ultrasound should be considered the imaging method of choice for women presenting with posterior pelvic floor symptoms. Since pelvic floor structural changes are frequently multicompartmental, a comprehensive investigation of the entire pelvic floor is useful, especially prior to surgical intervention. Dynamic transperineal or translabial ultrasound examinations are office procedures that are highly acceptable to patients. Dynamic transperineal ultrasound can be performed as sonographic defecography, allowing simultaneous investigation of all pelvic floor organs and levator ani, without the disadvantage of using radiation, and with the advantage of low cost. Findings are dependent on the systems used, on the techniques implemented and, of course, on the experience of the operator. Several different modalities are in current use. Each has its limitations, and the choice is often determined by the operator's specialty, for historical reasons and because of equipment availability.

Two-dimensional ultrasound in the mid-sagittal plane allows a basic assessment of functional anatomy and is sufficient for the diagnosis of rectocele, enterocele, rectal intussusception, rectal prolapse and possibly anismus. Three-dimensional ultrasound allows a more systematic approach, easy archiving of imaging data and postprocessing, and it simplifies training. Clinical audit, especially the assessment of surgical outcomes, is greatly enhanced by 3D/4D imaging. Most importantly, 4D imaging gives access to the axial plane and allows dynamic cross-sectional tomographic imaging. We are already beginning to see the translation of diagnostic innovation into new surgical approaches and into new forms of collaboration among the different specialties dealing with women suffering from pelvic floor dysfunction. However, as always, the introduction of a new diagnostic tool requires a substantial and sustained educational effort in order to maximize benefits in training and research, and of course in clinical patient care.

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