

# Pelvic Floor Ultrasound

Atlas and Textbook



Hans Peter Dietz MD PhD

Pelvic Floor Ultrasound- Atlas and Textbook by Hans Peter Dietz MD PhD

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# Chapter 1

## **Introduction: What can Pelvic Floor Ultrasound do for the clinician?**

Ultrasound has been used in the investigation of pelvic floor disorders since the 1980's,[1][2][3][4] not that long after its introduction into other gynaecological subspecialties such as Reproductive Endocrinology and Gyn. Oncology. Progress in our field however has been much slower, and this deserves comment.

Delays in the uptake of the new modality were partly due to the relative immaturity of urogynecology as a subspecialty, partly due to the fundamentally different way in which ultrasound was utilised in clinical practice. In the Anglo-saxon world, where the development of urogynaecology was focussed until the late 1990s, radiologists managed to retain ownership of the new modality of ultrasound much longer than in continental Europe, and this retarded progress. To a lesser degree this was also true for female urology.

In addition, both subspecialties of their respective parent specialties Gynecology and Urology were primarily surgical from the very beginning, with diagnostic aspects almost entirely limited to urodynamic testing. If one needed any proof for this near- absence of diagnostics it would suffice to remember that a standardised prolapse quantification methodology (ICS POP-Q)[5] still is not universally accepted 20 years after its introduction. That may even be for the better, since this basic system for assessing female pelvic prolapse, the commonest condition in pelvic floor medicine, was never properly validated until very recently. We don't know what's normal and what's not- surely the most basic precondition to the practice of medicine.

There are several other factors that have tended to inhibit progress in this field. The attitude of opinion leaders who are primarily surgeons rather than diagnosticians and commonly unable to transcend their own narrow field of vision, and the absence of financial incentives certainly have played a role. However, every year there are more abstracts presented at our conferences, more papers published in our journals that utilise imaging. 3D/ 4D ultrasound systems are now almost universally available, and not just in the developed world.

Over the last 20 years, imaging has contributed substantially to our understanding of stress urinary incontinence, obstructed defecation, fecal

incontinence and pelvic organ prolapse. In some instances it is helping to settle arguments that are decades old. Imaging has helped revive the idea that the pubourethral ligaments do indeed exist (rather than an ill-defined 'suburethral hammock'), and that they contribute substantially to urinary continence in women. We now understand that Cullen Richardson [6] was right when he tried to teach us the role of the rectovaginal septum in posterior compartment support. We may even accept that older explanations of rectal intussusception are superior to more recent versions.

Most importantly, pelvic floor imaging has led to the rediscovery of major levator trauma. While there clearly was some awareness of levator tears in the 30s[7] and 40s[8], this knowledge seems to have been lost until the early years of the new century. If we needed any confirmation for the claim that imaging will entirely remake urogynaecology and female urology, then surely this is it: for 60 years clinicians all over the world had forgotten this most fundamental etiological factor of pelvic floor dysfunction, a form of musculoskeletal trauma that is so major that every affected woman can palpate it herself, and that many women (and their partners!) notice its effect once they resume sexual relations after a first vaginal birth. And now, over the last few years, we have learnt how to assess anal sphincter trauma as well, producing images that are superior to endo-anal ultrasound and obtained within very few minutes. This is possible during a routine assessment for urinary incontinence, obstructed defecation or prolapse, all using the same imaging systems and transducers, in a non-invasive fashion, with minimal inconvenience to the patient.

As a result of these developments we have now reached the stage where we attain competence not just as regards diagnosis and treatment, but also regarding prevention. And since vaginal childbirth is by far the most substantial modifiable etiological factor in the pathogenesis of pelvic floor dysfunction, this means that we are now in a position to advise obstetricians. This will not be easy, since Obstetrics is a rather conservative part of medicine. Little has changed in decades- in fact, one sometimes gains the impression that there has been regression rather than progress. The field is subject to the influence of a group of practitioners outside the medical paradigm, midwives, who have a centuries-old history of turf battles with medical practitioners.

Together with the influence of natural childbirth advocates this has resulted in a body of opinion and influence which is deeply irrational and remote to fundamental scientific principles. Hence, research in clinical obstetrics is difficult to perform and very much under a highly critical, ideologically motivated spotlight. It will be difficult enough to convince our obstetric colleagues that maternal birth trauma should be diagnosed, treated and prevented, that it should become a key performance indicator of obstetric

services[9]. Even more difficult, if not impossible, will it be to convince natural childbirth advocates of the often harmful, and sometimes disastrous, consequences of ‘natural’ birth for the integrity of pelvic floor structures.

Hence this book is as much an attempt to discharge a moral responsibility as it is a manual, an attempt to demonstrate what you, as imaging practitioner, as a user of diagnostic ultrasound, can gain from this diagnostic method, both for research and clinical practice.

HP Dietz

Sydney, January 2016

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# Chapter 2

## **Basic physics, instrumentation and exam technique**

Diagnostic ultrasound produces images by way of registration of acoustic echoes arising in insonated tissues. The ultrasound signal, of a frequency between 2 and 20 MHz, i.e., above the audible range by a factor of 100-1000, is produced by piezoelectric crystals that can act as both transmitters and receivers. The elements have to go through at least 15 cycles of sending and listening per second in order to produce a flicker-free image; B mode frame rates are usually set at half the AC power supply frequency, i.e., between 25 and 30 frames per second. The sending phase is much shorter, e.g. 1 ms, followed by e.g. 39 ms of listening. The timing of arrival of any returning echoes defines the depth at which the reflection has occurred. Once the crystal has converted a returning ultrasound signal to a voltage, this voltage can be displayed on a cathode ray tube, or processed electronically [1].

Decades of technological development stand between this basic concept and the reality of current diagnostic imaging systems. Multiple elements are integrated to form arrays, and steering of outgoing beams allows focussing. Frequency shifts resulting from wavefronts being reflected from moving reflectors such as red blood cells (the ‘Doppler effect’) allow the representation of blood (or urine) flow with colour Doppler, Power/ energy Doppler and other techniques. Speckle reduction algorithms (such as SRI and CRI) help to distinguish true echoes from random noise, and harmonic imaging techniques utilize the fact that echoes are not exclusively returned in the original frequency (e.g. 4Mhz) but at many other ‘harmonic’ frequencies.

Most recently, fast mechanical oscillation of a transducer array has been used to produce volume datasets that allow reconstruction of imaging data in any potential plane, and ‘matrix arrays’ have moved from strips of elements to blocks of thousands of increasingly miniaturized piezoelectric transmitters. Systems currently in use rely heavily on modern computer technology familiar from consumer electronics, and many modern machines use Windows-type user interfaces. Data volumes generated with latest-generation 4D capable systems may reach over 130 MB with one acquisition, and over 1 GB per patient. A DVD burner and a large-capacity

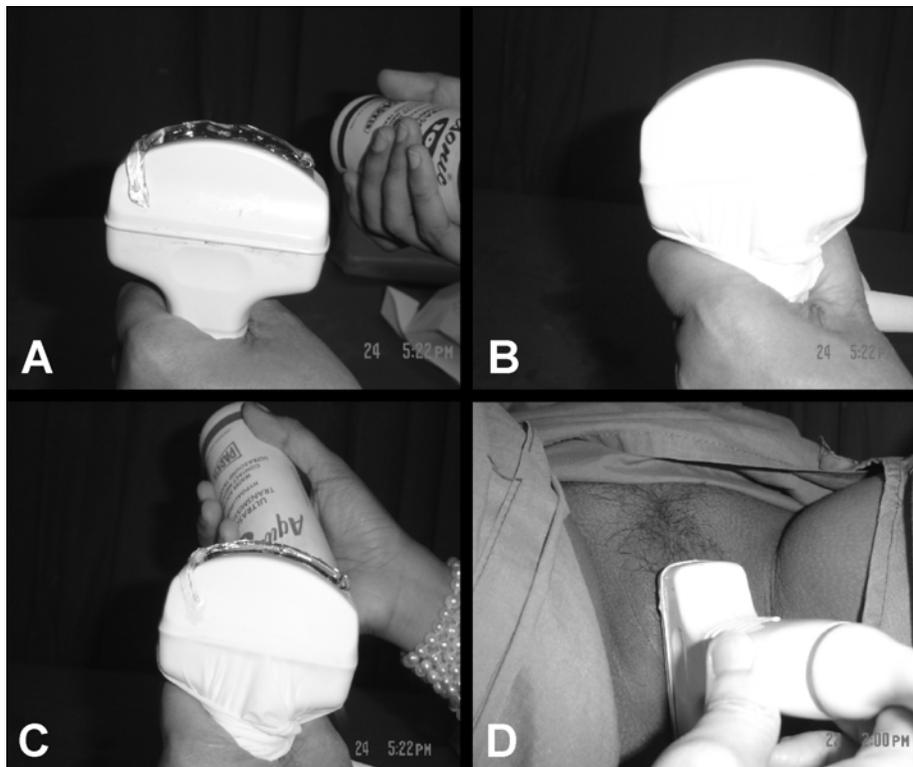
Hard Disk (preferably over 1 TB) have become indispensable. The miniaturisation of hardware has allowed systems that are not much larger and heavier than laptop computers and almost reach the capabilities and image quality of stationary flagship systems, generally at a much lower price. Reliability may at times be an issue however.

Clearly, the technical side of ultrasound imaging is well beyond the scope of this manual. The interested reader is referred to technical literature on the subject [1] since I will limit myself to practical applications.

The use of transabdominal ultrasound in the evaluation of lower urinary tract and pelvic floor dysfunction was first documented in the early 80's[2], with translabial [3,4] [transrectal [5] and transvaginal 6] techniques developed somewhat later. In this volume we intend to limit ourselves to translabial (transperineal, introital) imaging as first described in 1986 [3,4]. This modality is the most widespread due to the wide availability of suitable equipment and its non-invasive nature, and has the advantage of reducing tissue distortion compared to transvaginal techniques [7]. Abdominal curved array transducers are particularly well suited to translabial imaging due to their convenient footprint that tends to encompass the entire pelvic floor.

For translabial pelvic floor imaging, the most basic requirement is a small, portable real time B mode capable system. This implies that the monitor is able to display a 2D grayscale image in real time. For documentation a videoprinter is the most convenient solution. The standard transducers used for abdominal or obstetric imaging (e.g. a 3.5 – 5 MHz curved array transducer) are virtually perfect for pelvic floor diagnosis, allowing visualization of all three compartments. A cine loop function is useful for capturing the effect of manoeuvres such as a pelvic floor muscle contraction or a Valsalva maneuver, but not essential. The same holds true for the option of splitting the screen into two adjacent images, and image inversion (top-bottom, left- right). On- screen callipers have been standard since the early 80's. In essence, any older, surplus-to-requirement US system used for abdominal imaging you may locate in a regional hospital anywhere in the developed world is going to be suitable. Used equipment including a printer and abdominal/ obstetric type transducer should not require an investment of more than the equivalent of USD 10000/ Eur 8000, but could certainly be obtained significantly cheaper. The main concern regarding used systems is the state of the transducer, with the commonest fault being drop-out lines due to defective piezoelectric elements.

In order to image a midsagittal view of the pelvic floor, the transducer (ideally a curved array of a footprint of 5-8 cm) is placed on the perineum, after covering the transducer with a glove or condom or thin plastic wrap for hygienic reasons (see Fig. 2.1a-d). Some types of gloves, especially powdered gloves, can markedly impair image quality due to reverberations and should be avoided. Imaging can be performed in dorsal lithotomy, with the hips flexed and slightly abducted, or in the standing position. The latter is sometimes necessary in women who find it difficult to perform an effective Valsalva manoeuvre.

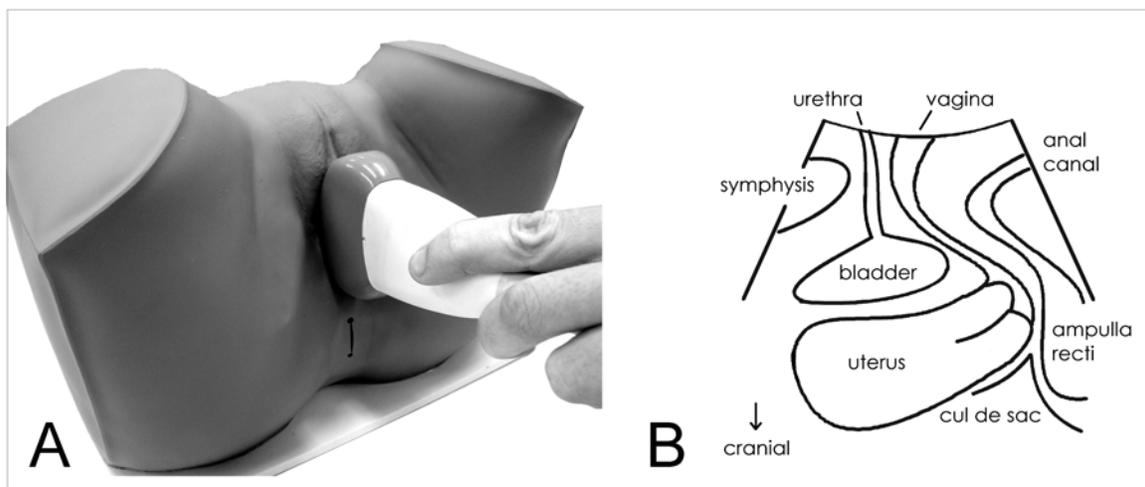


*Figure 2.1: Preparation of a curved array transducer for translabial ultrasound. After covering the transducer with gel (A), it is covered with a powder-free glove (B). More gel is applied (C), and the transducer is placed on the perineum, between the labia maiora (D). Image courtesy of Dr N Pangilinan, Manila.*

Bladder filling should be specified; for some applications prior voiding is preferable. The presence of a full rectum may impair diagnostic accuracy and sometimes necessitates a repeat assessment after bowel emptying.

Tissue discrimination is best in pregnancy and poorest in menopausal women with marked atrophy, most likely due to varying hydration of tissues. The symphysis pubis should appear <1cm from the transducer surface which signifies that the labia have been displaced laterally by the transducer, improving imaging conditions. Manual parting of the labia before transducer placement may be necessary, especially if they are hypertrophic or particularly hirsute.

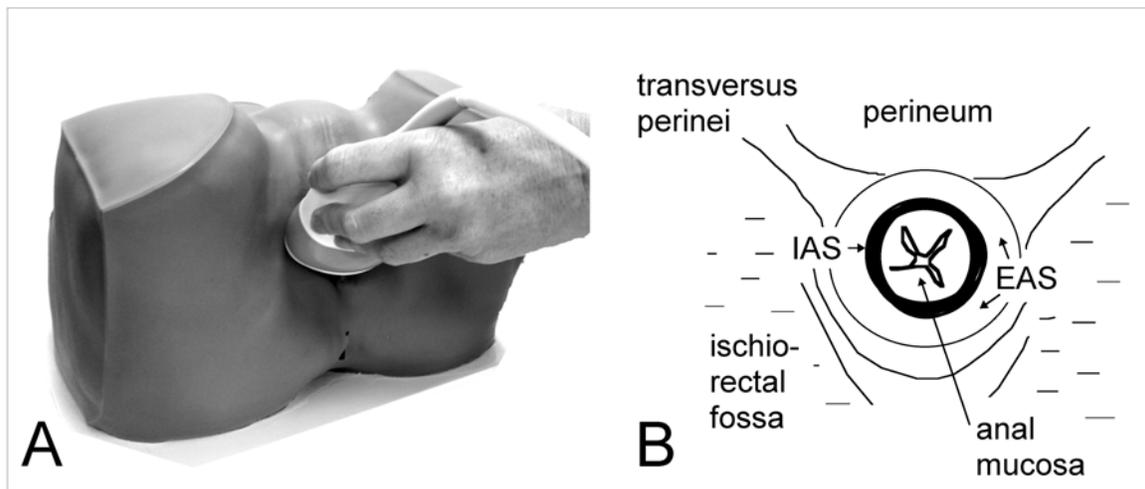
The transducer can generally be placed quite firmly against the symphysis pubis and the perineum without causing significant discomfort, unless there is marked atrophy. Obesity is much less of an issue than with abdominal ultrasound, but large buttocks may at times make it difficult to reach the perineum. Once a satisfactory field of view is obtained one will adjust gain and focal zones to the region of interest (at a depth of 2-5 cm), and harmonic imaging at system- specific settings or software options such as speckle reduction algorithms can be used to optimize image quality.



*Figure 2.2: Transducer placement and field of view in the midsagittal plane when using a curved array transducer designed for abdominal or obstetric applications. From [25], with permission.*

The standard midsagittal field of vision includes the symphysis pubis anteriorly, the urethra and bladder neck, the vagina, cervix, rectum and anal

canal (see Fig. 2.2). Posterior to the anorectal junction a hyperechogenic area indicates the central portion of the levator plate, i.e., the puborectalis/pubococcygeus or pubovisceral muscle. The cul de sac may also be seen, filled with a small amount of fluid, echogenic fat or peristalsing small bowel. Larger amounts of free fluid in the Pouch of Douglas will of course require further investigation unless the cause is known. Parasagittal views may yield additional information, e.g. enabling assessment of the puborectalis muscle and its insertion on the arcus tendineus of the levator ani, and for imaging of transobturator implants. For anal sphincter imaging the transducer is rotated by 90 degrees in a clockwise direction (Fig. 2.3). This technique is even more of a near-field application than imaging of the levator or urethra, hence we use only one focal zone at 1-2 cm depth, and high harmonics. Care should be taken to not compress the anal sphincter, which is readily apparent as a flattening of the bull's eye pattern of the external and internal anal sphincters, and an additional application of gel over the introitus may be required to achieve an optimal distance between ventral aspects of the EAS, the commonest site of abnormalities, and the transducer.

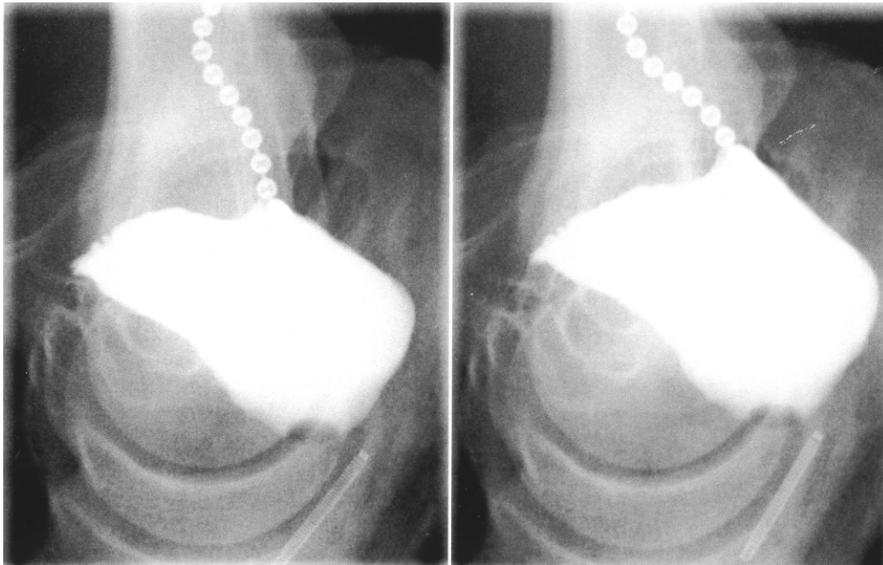


*Figure 2.3: Transducer placement and field of view in the coronal or transverse plane when imaging the external and internal anal sphincters. From [26]. with permission.*

A basic fact to remember is that the echogenicity of a given tissue depends largely on the presence of interfaces between areas of different acoustic impedance, and on the angle between the incident beam and the interfaces in

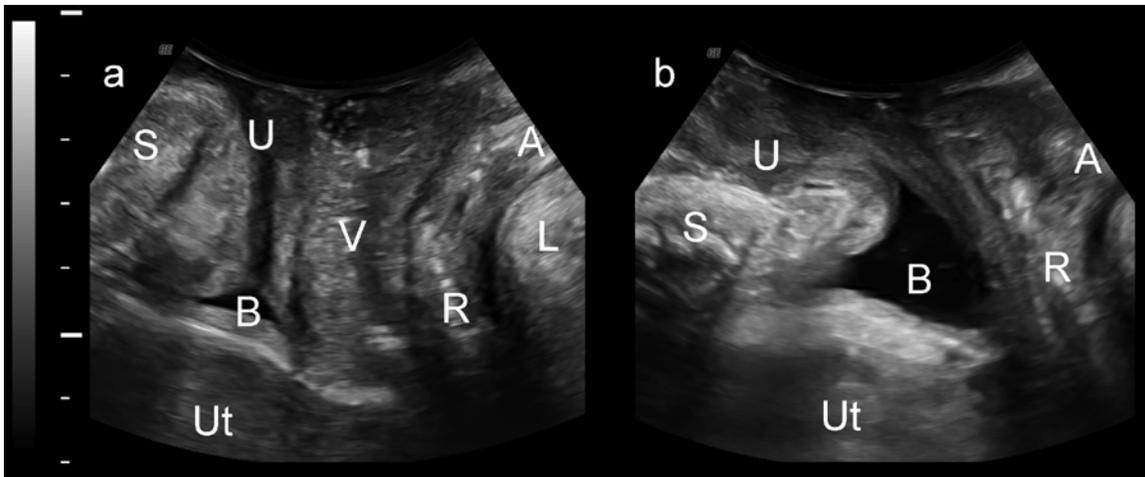
question. This implies that striated muscle or tubular structures such as the urethra may appear hypo- or iso/ hyperechoic depending on transducer orientation[8]. In practice, this is most relevant as regards the urethral rhabdosphincter which appears hyperechoic on translabial ultrasound and partly hypoechoic on transvaginal scanning. In fact, the urethral rhabdosphincter may appear hypoechoic AND hyperechoic in the same plane or image obtained by transvaginal ultrasound, giving rise to misunderstandings regarding its shape and extent[9,10]. The same is true for the anal sphincter, the lateral aspects of which will generally appear less echogenic than ventral and dorsal aspects.

There has been some disagreement regarding image orientation in the midsagittal plane. Some prefer orientation as in the standing patient facing right[11,12] which requires image inversion on the ultrasound system, a facility that is not universally available. Others (including the author) prefer an orientation as on conventional transvaginal ultrasound (cranioventral aspects to the left, dorsocaudal to the right) [13]. This orientation was used in the first publications on pelvic floor ultrasound in 1986 [3,4], and it is usually more convenient when using 3D/ 4D systems. However, since any image reproduced in one of the above orientations can be converted to the other by rotation through 180°, formal standardization may be unnecessary.



*Figure 2.4: Lateral bead- chain urethrocytography, at rest (left) and on Valsalva (right), rotated and combined to allow for easier comparison with translabial ultrasound images. From [13], with permission.*

Translabial ultrasound of the lower urinary tract, even if limited to B Mode imaging in the midsagittal plane, yields information equivalent or superior to the lateral urethrocytogram (shown in Fig. 2.4, rotated by 180 degrees for comparison) or fluoroscopic imaging. Comparative studies have mostly shown good correlation between radiological and ultrasound data[5,14-19]. Magnetic resonance imaging is not particularly useful in the assessment of incontinence and proptase, mainly due to poor tissue discrimination within the levator hiatus, poor temporal resolution and due to cost and access issues. Figure 2.5 shows ultrasound appearances on standard midsagittal view, the left image taken at rest, the right one on maximal Valsalva. Such an orientation is very difficult to obtain on MR due to the fact that the midsagittal plane is likely to shift during a Valsalva and since it is impossible to follow movement in real time. In addition, it is impossible to obtain tissue discrimination such as the one shown in Figure 2.5 on MR imaging.



*Figure 2.5: Translabial midsagittal view demonstrating the symphysis pubis (S), urethra and bladder neck at rest (left) and maximal Valsalva (right). U= urethra, Ut= uterus, B= bladder, V= vagina, R= rectal ampulla, A= anal canal, L= levator ani muscle. From [27], with permission.*

The one remaining advantage of Xray fluoroscopy may be the ease with which the voiding phase can be observed although some investigators have used specially- constructed equipment to document voiding with ultrasound[20]. It even seems possible, at least in principle, to observe voiding while using handheld B Mode transducers, with the patient seated on a commode[21]. Due to psychological factors however, it seems unlikely

that any imaging method requiring the presence of staff (or even just a significant amount of unfamiliar machinery) could reproducibly document normal voiding, especially in females.

For colorectal imaging, contrast medium has been used in an attempt to replicate defecation proctography (DP), with good agreement found between ultrasound and fluoroscopy[22,23]. As anismus, rectocele, enterocele, rectal intususception, rectal prolapse and other rarer causes of obstructed defecation can be imaged during a Valsalva manoeuvre and without resorting to invasive manipulation or contrast[24], one wonders whether there is any need to try and reproduce the exact process of an investigation such as DP, which is quite unlikely to bear much resemblance to normal defecation. This issue will be discussed in more detail in Chapter 5.

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# Chapter 3

## **3D/ 4D imaging: Technical overview and basic methodology**

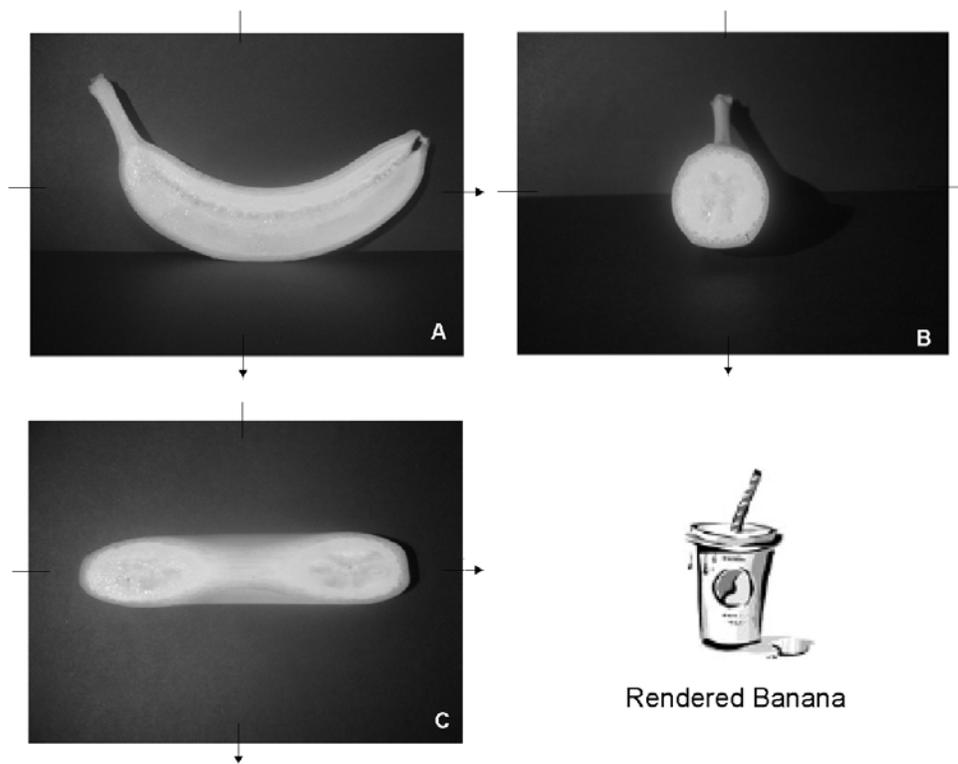
### **Technical overview**

Three main engineering solutions have been developed to allow integration of 2D sectional images obtained by a strip or ‘array’ of piezoelectric elements into 3D volume data. On principle, an external position sensor may allow handheld acquisition of multiple 2D slices which are then integrated to form a volume. This technique has never reached commercial applications. The second is mechanical oscillation of an array, combining the technology used in early ‘wobbler’ mechanical sector transducers with that of solid state linear or curved arrays. This technology was the first to see clinical application in the late 80s and early 90s in the form of ‘Voluson’ systems built by a small Austrian company, Kretz Medizintechnik in Zipf, and it forms the basis of most currently used 3D ultrasound systems.

For the last ten years, a third technology has promised superior imaging characteristics, even though this promise has not been realised to the degree originally expected. Matrix probes are made up of large numbers of heavily miniaturised piezoelectric elements arranged not in a strip of 100 or so elements but rather in blocks of thousands. Most major manufacturers now offer Matrix probes, but due to the complexity of ensuring flawless operation of such a large number of single components they are still rather expensive. There are fundamental theoretical advantages to Matrix arrays, especially as regards temporal resolution of 3D images (which is highly useful in echocardiography, but of little importance in pelvic floor medicine) and beam steering/ focussing.

Hence, probes that use motorised acquisition are still the mainstay of 3D/ 4D imaging in our field. This technology may take the shape of automatic withdrawal of an endocavitary probe or motor action within the transducer itself, which allows handling of the probe just as one would handle a standard 2D transducer. The first motorized probe for abdominal imaging was developed in 1974, and by 1987 transducers for clinical use were introduced that allowed motorized acquisition of imaging data[1] The first commercially available system platform, the Kretz Voluson, was developed around such a ‘fan scan’ probe, using mechanical sector technology that was

generally regarded as obsolete at that time, and combining it with a curved array. The result have been the abdominal and endovaginal probes used in systems such as the GE Kretz Voluson 730 series. The widespread acceptance of 3D ultrasound in Obstetrics and Gynaecology was helped considerably by this development since these transducers do not require any movement relative to the investigated tissue during acquisition. All major suppliers of Ultrasound equipment have developed such transducers between 2005 and 2015, although the resulting image quality still varies substantially, especially for reconstructed planes and rendering.



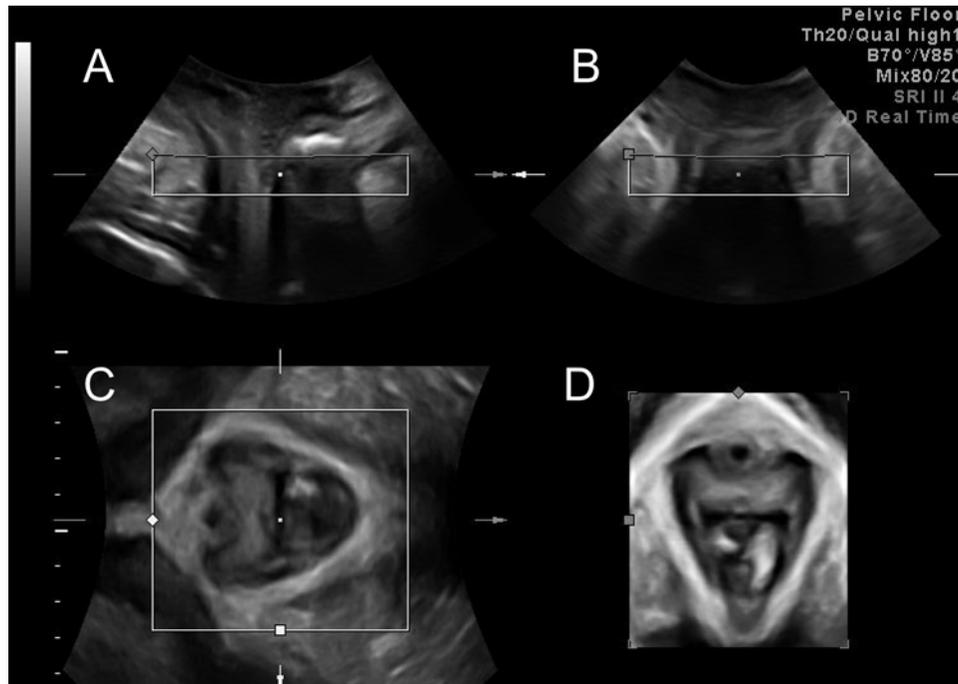
*Figure 3.1: The three orthogonal planes used to represent volume data information on translabial ultrasound, illustrated by transection of a popular fruit. The A plane (top left) represents the midsagittal plane, B (top right) the coronal and C (bottom left) the axial or transverse plane. By convention the bottom right field is generally used to show semitransparent, 'rendered' representations of volume data (images courtesy of Dr Shawn Choong, Melbourne).*

With current mechanical 3D transducers, automatic image acquisition is achieved by rapid oscillation of a group of elements within the transducer, with the mechanics contained in an oil bath. The transducer surface is formed either by a soft membrane or a shell. Breaching of this containment usually requires transducer replacement.

Oscillation of a curved array within this oil bath allows the registration of multiple sectional planes that can be integrated into a volume, since the location of a given pixel (or, to use the correct term for a pixel that has a defined location in space, a 'voxel') is determined by transducer and insonation characteristics. For the user, orientation within the volume is achieved by providing 2D image data in the three main axes of the volume, the 'orthogonal planes' A (usually the midsagittal plane), B (usually coronal) and C (usually axial or transverse), see Figure 3.1.

Fortuitously, transducer characteristics on currently available systems for transabdominal use have been highly suitable for pelvic floor imaging. Acquisition for the assessment of pelvic organ descent and levator biometry is most conveniently performed with the main axis of the transducer in the midsagittal plane, as the urethra and bladder neck provide points of reference, ensuring symmetry. Provided this plane shows both the inferoposterior margin of the symphysis pubis and the pubovisceral muscle posterior to the anorectal junction, a single volume obtained at rest with an acquisition angle of 70 degrees or higher will comprise the entire levator hiatus as our area of interest.

The volume dataset will include part of the symphysis pubis, the inferior pubic rami, urethra, paravaginal tissues, the vagina, the cervix if present, the anorectum and the pubovisceral (puborectalis/ pubococcygeus part of the levator ani) muscle from the pelvic sidewall in the area of the arcus tendineus of the levator ani (ATLA) to the posterior aspect of the anorectal junction (see Figure 3.2 and following). Depending on the anteroposterior dimensions of the pubovisceral muscle, it may also include the anal canal and even the external sphincter. This also holds true for volumes acquired on levator contraction since this shortens the hiatus. A Valsalva manoeuvre however may result in lateral or posterior parts of the puborectalis being displaced outside the field of vision, especially in women with significant prolapse (see Chapter 7).



*Figure 3.2: The three orthogonal planes: midsagittal (A, top left), coronal (B, top right), and axial (C, bottom left) as well as a semitransparent rendering of all voxels in the region of interest (the boxed area evident in the A and B planes) at the bottom right.*

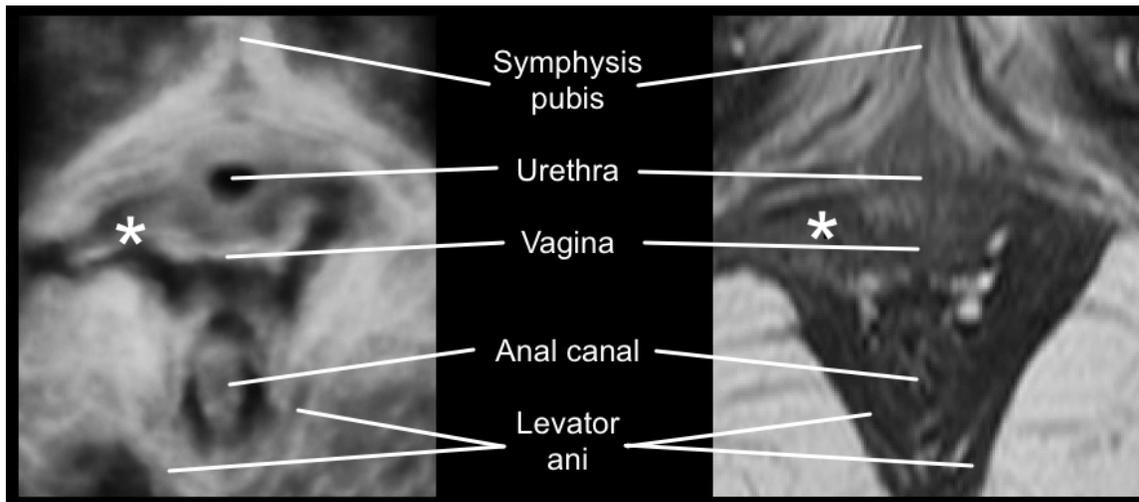
The currently offered abdominal 2-6 and 8-4 MHz volume transducers for Voluson systems allow acquisition angles of up to 85 degrees, ensuring that the levator hiatus can be imaged in its entirety even in women with significant enlargement (‘ballooning’) of the hiatus on Valsalva. Higher acquisition angles come at a price: one will have to accept lower spatial or temporal resolutions. Gain, focussing, harmonic imaging, speckle reduction techniques and volume contrast imaging may be used as for B mode imaging: as a rule, one should optimise image quality in the midsagittal plane before progressing to volume acquisition. Recent systems provide superior harmonic imaging. As most applications in pelvic floor medicine involve the near field (a depth of  $\leq 7$  cm for pelvic organ descent, and of  $\leq 5$  cm for the levator ani and the anal sphincter), harmonics can usually be set to high. For pelvic floor and prolapse imaging we use two focal zones at approx. 2 and 5 cm, for sphincter imaging one focal zone at 1-2 cm may be optimal.

For the latter application, optimal resolution and tissue discrimination is required in the coronal plane, which means that the A plane is coronal, the B plane midsagittal and the C plane axial. Aperture and acquisition (volume) angles are less crucial as an aperture of 60 degrees and a volume angle of 70 degrees are usually sufficient.

## **Display modes**

Figure 3.2 demonstrates the two basic display modes in use on 3D ultrasound systems. The multiplanar or orthogonal display mode shows cross-sectional planes through the volume in question. For pelvic floor imaging, this most conveniently means the midsagittal (top left), the coronal (top right) and the axial plane (bottom left). On assessing the anal sphincter, this is changed to coronal (top left), midsagittal (top right) and axial (bottom left).

One of the main advantages of volume ultrasound for pelvic floor imaging is that the method gives access to the axial plane. Until the introduction of 3D/4D imaging, translabial pelvic floor ultrasound was limited to the midsagittal plane[2][3][4]. Parasagittal and coronal plane imaging have not been widely used, which may be due to the fact that there are no obvious points of reference, as opposed to the convenient reference point of the symphysis pubis on midsagittal views. The axial plane was accessible on MRI[5][6][7]. Despite the obvious disadvantages (distortion of structures, no opportunity for imaging on Valsalva), some investigators have used intracavitary probes for levator imaging[8]. Pelvic floor MRI is an established investigational method, at least for research applications, with a multitude of papers published over the last 20 years. However, recently most imaging studies seem to use ultrasound rather than MR due to the much reduced cost, and case numbers often are one magnitude higher in sonographic studies. Figure 3.3 shows a comparison of axial views of the levator hiatus on 3D ultrasound (left) and MRI (right) in a parous patient with avulsion injury (\*). While spatial resolutions may be higher on MRI, tissue discrimination between vaginal muscularis and puborectalis muscle, a crucial issue in the assessment of trauma, is lower, as is temporal resolution. There have been several studies comparing MR with translabial ultrasound for imaging of the levator ani muscle, all showing that sonographic imaging is at least as suitable as MR[9][10][11].



*Figure 3.3: A comparison of magnetic resonance and 3D pelvic floor ultrasound imaging of the pubovisceral muscle in a patient 3 months after a right-sided avulsion injury (\*). All axial plane images of the levator are oriented as seen from caudad.*

Imaging planes on 3D ultrasound 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. This is another factor contributing to the superiority of sonographic over MR imaging in pelvic floor medicine as MR produces a pre-determined set of slices that usually can not be altered. Hence, it is easy to locate the true plane of minimal hiatal dimensions by rotating the midsagittal (A) plane until the axial plane (C) represents the narrowest part of the levator hiatus. This is usually impossible on MR without re-acquisition of imaging data, although some systems now allow extrapolation of secondary planes..

The three orthogonal images are usually complemented by a ‘rendered image’, i.e., a semitransparent representation of all voxels in an arbitrarily definable ‘box’. Rendering was originally developed to visualise fetal surface structures, such as the face, hands or feet, or the fetal skeleton. In pelvic floor medicine, rendering techniques are particularly useful for the identification of synthetic implants such as slings and meshes, which are commonly highly echogenic, and for the levator ani muscle, which is hyperechoic relative to the vaginal mucosa and muscularis layers.

The bottom right hand image in Figure 3.2 shows a rendered image of the levator hiatus, with the rendering direction set from caudally to cranially, which is the most convenient setting for pelvic floor imaging. The conventional orientation, as in MR imaging, requires that the C plane be rotated so that the ventral aspect (the symphysis pubis) appears at the top of the image, and the patient's right on the left hand side. This orientation is the most intuitive for those used to clinical pelvic floor assessment, and is easily obtained as the default with 2D image orientation as suggested by the author, i.e., with the symphysis pubis in the top left hand corner of the B Mode midsagittal plane.

The possibilities for postprocessing are restricted only by the software used for this purpose; programmes such as GE Kretz 4D View (Kretztechnik GmbH, Zipf, Austria), at the time of writing in its fourteenth version, allow extensive manipulation of image characteristics and output of stills, cine loops and rotational volumes in bitmap and AVI format. Another interesting option is format conversions which are useful for more sophisticated forms of software analysis and modelling, and de-identification of volume data, sometimes required for research applications.

Systems usually allow the use of a number of different rendering algorithms. For pelvic floor imaging, surface rendering seems most useful, although users may want to experiment with different degrees of transparency. The most convenient setting for pelvic floor imaging on Voluson systems seems to be a mix of 80% Surface mode and 20% Minimum mode which gives a very clear representation of the pubovisceral muscle. Other modes such as xray mode (used e.g. to examine the fetal skeleton), pure minimum mode and inversion mode, seem less useful. Modern systems also provide different colour maps, overcoming a limitation of the human eye which is unable to distinguish the 256 shades of Gray that are produced by the system. For this reason, rendering in sepia is often preferred.

## **4D imaging**

4D imaging implies the real-time acquisition of volume ultrasound data, which can then be represented in orthogonal planes or rendered volumes. In 1998, Kretztechnik AG in Austria developed the first 4D capable system, and by 2002 such volumes could be stored for later processing. While the

company is now a wholly owned subsidiary of General Electric, it has preserved an unusual degree of autonomy, which is evident as substantial continuity in machine design and user interfaces. The processing of cine loops of volumes, i.e., 4D scanning, 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. Avulsion of the pubovisceral muscle from the ATLA is often more evident on levator contraction, due to enhanced tissue discrimination between levator muscle and vagina, and due to muscle thickening. Most significant pelvic organ prolapse is not visible at rest in the supine position, unless severe. Fascial defects such as those defining a true rectocele (see Chapter 5) frequently only become visible on Valsalva.

The ability to perform a real-time 3D (or 4D) assessment of pelvic floor structures contributes to the superiority of this technology over MR imaging. Prolapse assessment by MRI requires ultrafast acquisition[12] which is of limited availability and will not allow optimal resolutions. Alternatively, some systems provide for imaging of the sitting or erect patient[13] but again accessibility will be 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 50% of all women will not perform a proper pelvic floor contraction when asked<sup>20</sup>, and a Valsalva maneuver is often confounded by concomitant levator activation (see Chapter 4). 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.

Offline analysis packages such as GE Kretztechnik 4D View allow distance, area and volume measurements in any user- defined plane (oblique or orthogonal) which is much superior to what is possible with DICOM viewer software on a standard set of single plane MR images. Other software tools may not allow measurements in rendered volumes, since strictly speaking this is impermissible under the rules of Euclidean geometry[14].

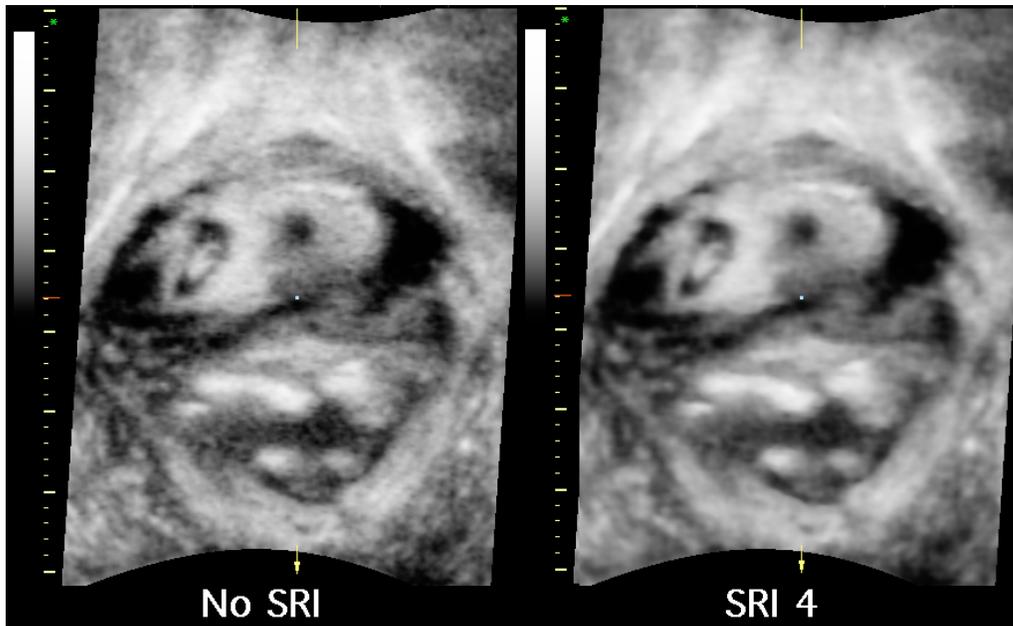
## Techniques used to enhance resolution

**Volume Contrast Imaging** employs rendering algorithms as a means of improving resolutions in the coronal plane. As a result, speckle artefact is markedly reduced[15]. So far, measuring in the axial or C plane has been limited to raw data without significant post-processing. Consequently, resolutions were much poorer than in the sagittal plane, reducing accuracy of measurements and our ability to identify structural changes. The latter were best detected on standard rendered volumes, which requires a render thickness of 1-2 cm.

In contrast to most other 3D/4D ultrasound systems, Voluson systems conveniently allow circumference and area measurements in such rendered volumes, which improves the contour of the levator hiatus and simplifies the diagnosis of hiatal ballooning[16]. By using VCI on slices of a thickness of 1-3 mm, resolutions of about 1 mm can be reached on axial or oblique axial slices. If resolutions appear inferior on the particular system used, VCI seems to be particularly useful for anal sphincter imaging (see Chapter 6).

A further development in the use of rendering techniques for the improvement of spatial resolution is '**speckle reduction imaging**' which can be used in the post-processing of standard volume datasets analysed by 4D View software, although volumes obtained with a system that has this option integrated seem to be superior. SRI can be applied in any of the three orthogonal planes and rendered volumes.

Figure 3.4 shows an axial plane view of a right sided levator injury in a rendered volume, the left image without processing, the right after SRI post-processing using 4D View. One major advantage of those software options is that they have been implemented both on the ultrasound system and on the software used for post-processing, allowing significantly enhanced analysis of previously acquired volume data.



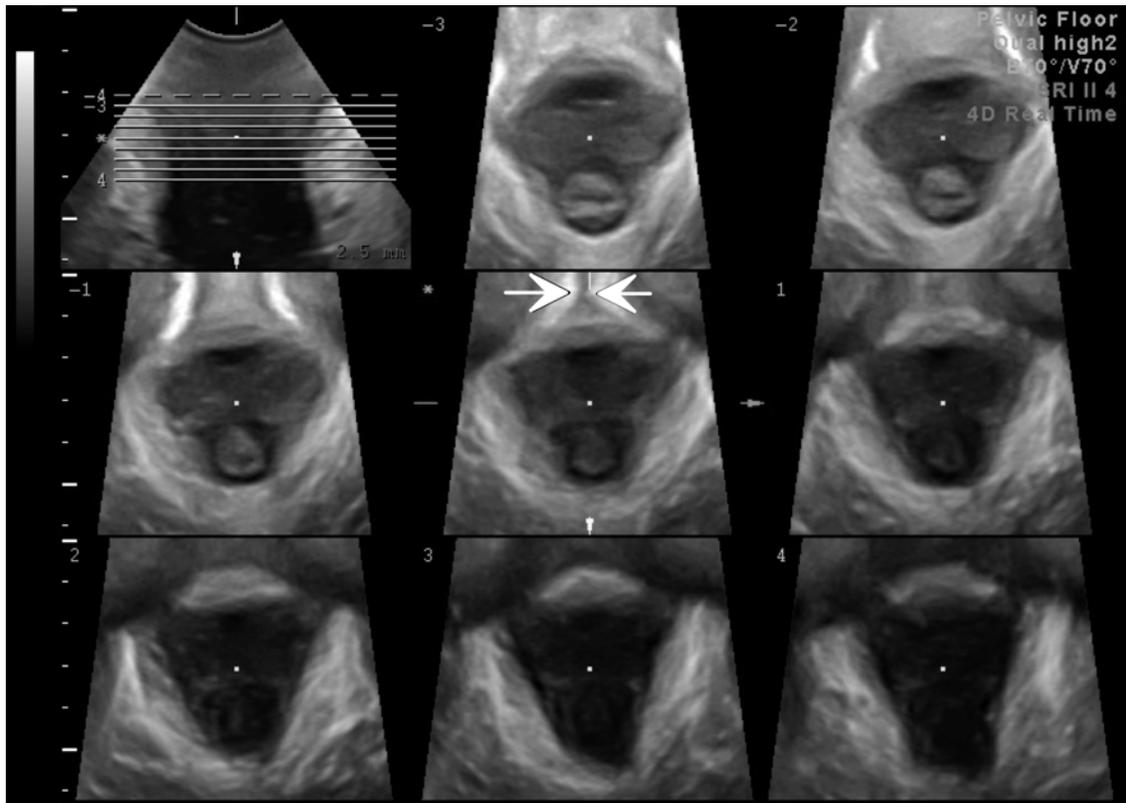
*Figure 3.4: The effect of speckle reduction algorithms on axial plane rendered volumes in a patient with right- sided avulsion injury.*

### **Tomographic Imaging (TUI)**

From about 2005 onwards it became possible to process imaging information into slices of predetermined number and spacing, reminiscent of computer tomography or nuclear magnetic resonance imaging. This technique has been termed ‘multislice imaging’ or Tomographic Ultrasound Imaging (TUI) by manufacturers. As opposed to CT or MRI, the location, number, depth and tilt of slices can be adjusted at will after volume acquisition. The combination of true 4D capability and TUI or multislice imaging allows simultaneous observation of the effect of manoeuvres at multiple different levels.

The pelvic floor easily lends itself to such techniques, and the author suggests using the plane of minimal dimensions (see chapter 7) as plane of reference, with 2.5 mm steps recorded from 5 mm below this plane to 15 mm above[17][18], which has now become a de facto standard used by many units working in this field. The exact location of slices can be adjusted by using the appearance of the symphysis and the inferior pubic rami as reference: the central left slice should show an open symphysis, the central slice should see it just closed, and in the central right slice the bony structures of the symphysis should be absent, replaced by acoustic shadowing (see Figure 3.5). The reference plane in the top left hand corner

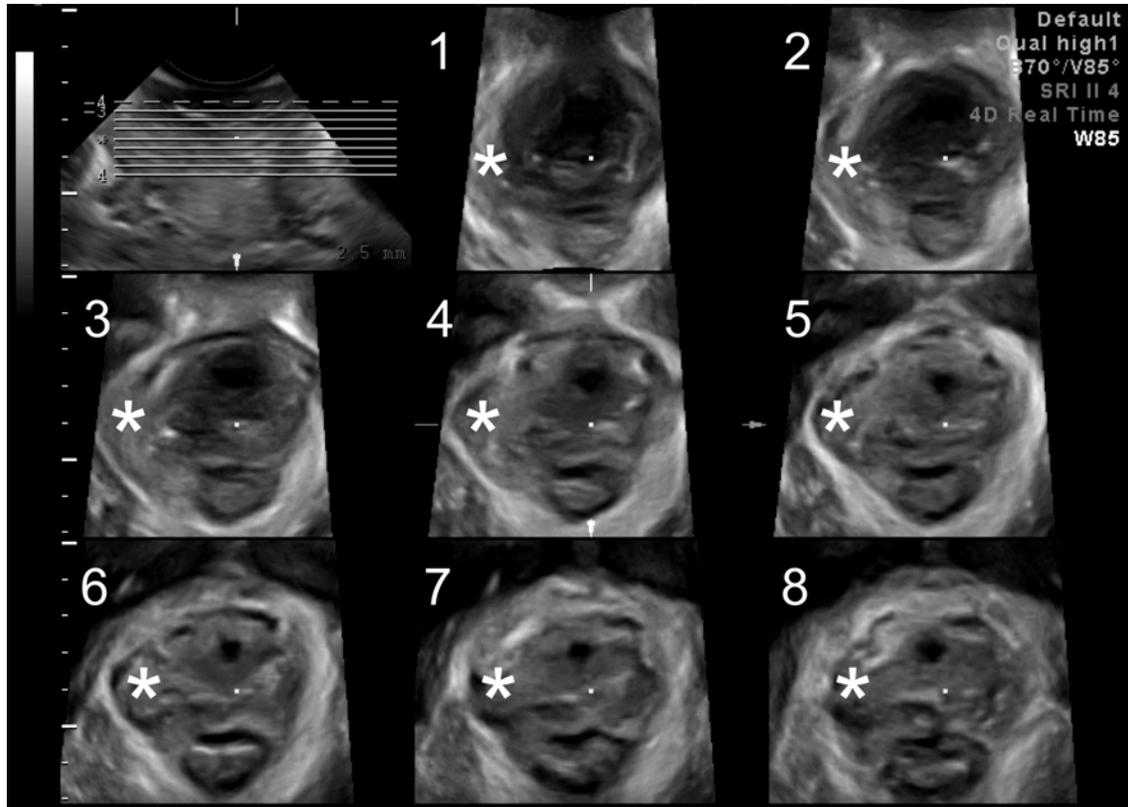
of a TUI set containing 8 axial slices represents the coronal plane, which can provide for a graphic overview of the levator plate.



*Figure 3.5: Normal pelvic floor showing 8 axial plane slices set at 2.5 mm interslice interval, with the central slice at the level of the plane of minimal hiatal dimensions, showing the closure of the symphysis pubis (arrow). The slice immediately to the left is set 2.5 mm caudad, showing the symphysis pubis open, the one to the right 2.5 mm cranial, with the hyperechogenic pubic rami replaced by acoustic shadowing.*

Figure 3.5 shows the standard TUI format currently most appropriate to pelvic floor imaging, with the coronal plane for reference, and eight axial plane slices at a distance of 2.5 mm each, in a nulliparous patient with normal pelvic floor function and anatomy. Figure 3.6, on the other hand, demonstrates TUI findings in a patient with major unilateral avulsion injury of the pubovesical muscle after rotational Forceps delivery. The presence and extent of injuries is evident at a glance from one printout or film, without requiring any further manipulation of data, just as it is familiar to all of us from radiological cross-sectional techniques. This technique has

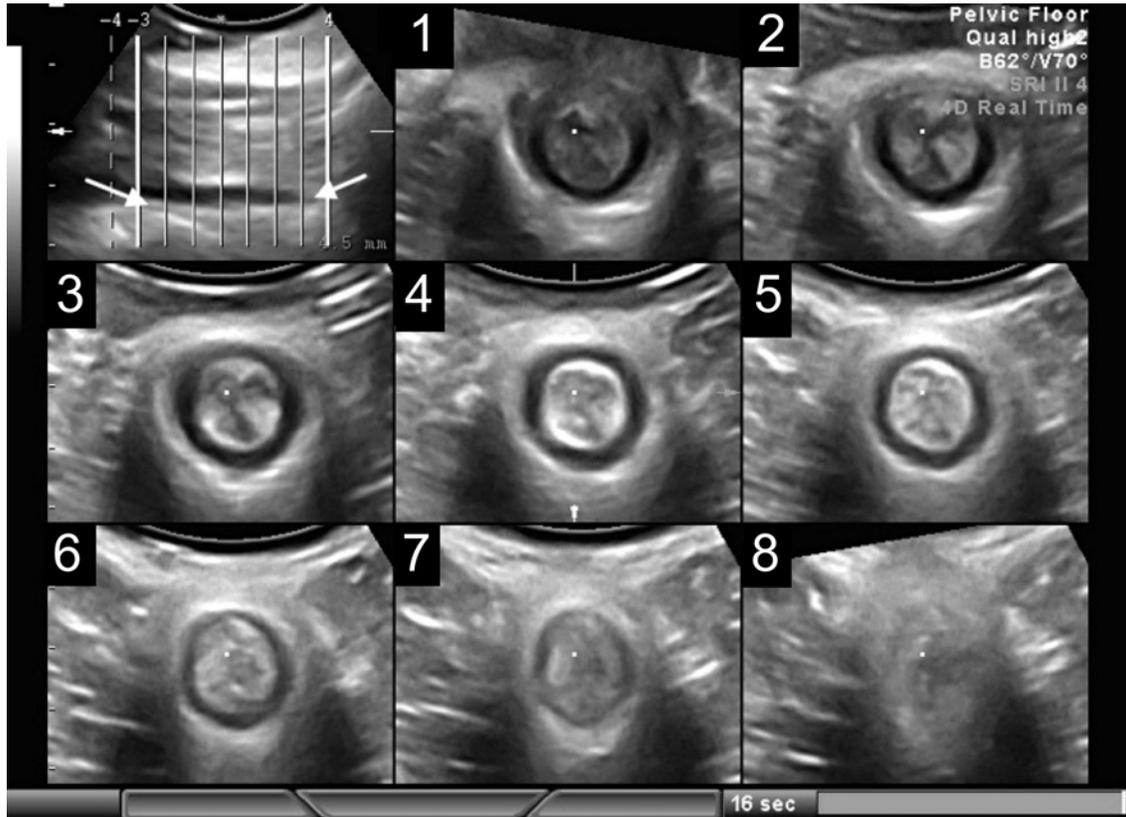
greatly assisted in the standardisation of assessment for levator trauma, as evident in the recent literature.



*Figure 3.6: Unilateral major right-sided levator avulsion (marked by \*) on tomographic ultrasound imaging. The defect is visible on the left hand side of the image in all slices. There also is minor left-sided trauma in slices 4,5 and 8.*

Figure 3.7 illustrates the use of TUI for imaging of the anal sphincter[19][20]. For this application one is able to identify standard landmarks that directly refer to the external and internal muscles, allowing individualisation of interslice intervals, something that is impossible for the levator. We identify the cranial margin of the EAS at its dorsal aspect with the help of the fascial plane between EAS and levator ani, since obstetric trauma is extremely unlikely to affect this location. The caudad termination of the Internal anal sphincter is even easier to identify. One slice is placed above the EAS, another below the IAS (see Figure 3.7) allowing for six slices at an interslice interval of between 1.5 and 4 mm to cover by far the greatest part of the EAS in a highly reproducible manner[19][20][21].

As is the case for SRI and VCI, these software based developments are available both in real-time on systems of the Voluson series and offline as part of the latest versions of 4D View, allowing re-analysis of existing older volume data.



*Figure 3.7: Tomographic imaging for anal sphincter assessment in an asymptomatic nulliparous patient. As there are two well defined planes of reference (the caudad termination of the Internal anal sphincter [right arrow] and the dorsocranial termination of the external anal sphincter [left arrow], interslice interval can be individualised - in this case of a very large EAS to 4.5 mm. The EAS is represented by slices 2-7, with slice 8 showing the subcutaneous part of the EAS which often is difficult to interpret due to artefact.*

## Practical considerations

Pelvic floor ultrasound is highly operator- dependent, as is true for all real-time imaging. 3D systems have the potential to reduce this operator dependence since volume acquisition is easily taught and should be within the capabilities of every sonographer or sonologist after a day's training. While the method does require postprocessing (and the skills involved in this are more significant), static volume data typically of 1-6 MB in size can be de-identified and transmitted electronically so that evaluation may be obtained by email, and this opens up entirely new possibilities for local and international cooperation. Unfortunately, the de-facto software standard of 3D image files provided by licensing of the original technology has been lost. Currently there are numerous proprietary standards developed by the different manufacturers, which impairs opportunities for collaboration between different centres unless they use systems produced by the same manufacturer. Due to the market dominance of Voluson systems, this is a relatively minor issue.

An initially underestimated advantage of 3D/ 4D ultrasound is the fact that all data can be stored electronically and may at any time be retrieved for post-processing, reanalysis or comparison with later findings. These benefits are clearly evident in the research setting, but also apply to the pelvic reconstructive surgeon, especially in the context of surgical audit.

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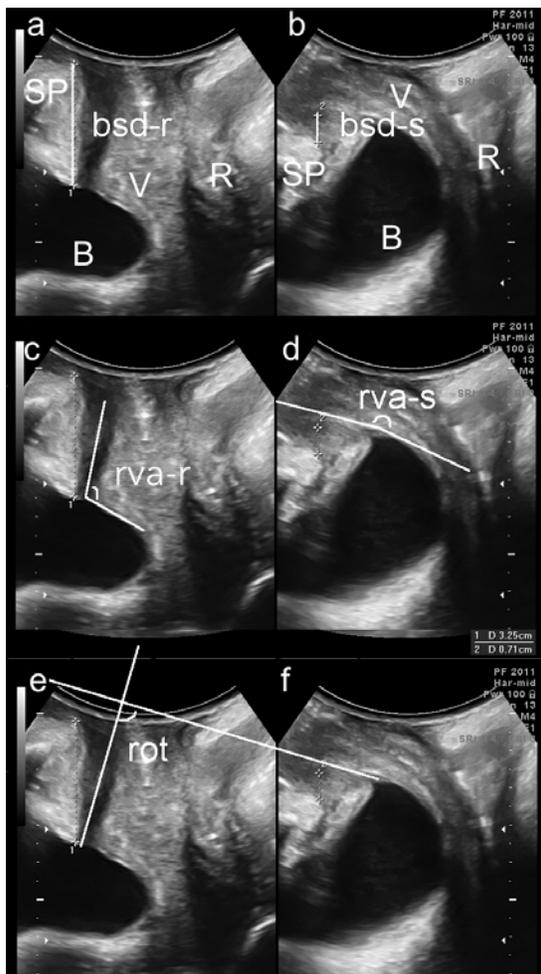


# Chapter 4

## The Anterior Compartment

### Bladder neck position and mobility

One of the earliest parameters to be examined by translabial ultrasound was bladder neck mobility. This is due to the perception that a hypermobile bladder neck is an important factor in the etiology of female stress urinary incontinence. While this is undoubtedly true to a degree, there are several other factors influencing continence, and the importance of this particular parameter should not be overestimated. It is in fact mobility of the mid-urethra rather than the bladder neck that is most relevant for continence[1] which supports the concept of mid-urethral tethering of the urethra by ‘para-urethral’ ligaments.



*Figure 4.1: Some of the parameters used to evaluate a translabial scan for anterior compartment assessment.*

*The upper row of images represents ultrasound images obtained at rest (left of each pair) and on maximal Valsalva (right of each pair), explaining the parameters bladder neck descent relative to the infero-posterior margin of the symphysis pubis (top pair), retrovesical angle (middle pair) and urethral rotation (bottom pair).*

*SP= symphysis pubis, B= bladder, V= vagina, R= rectum. ‘bsd-r’ and ‘bsd-s’ signify the distance between bladder neck and symphysis pubis at rest and on Valsalva; ‘rva’= retrovesical angle. ‘rot’= proximal urethral rotation.*

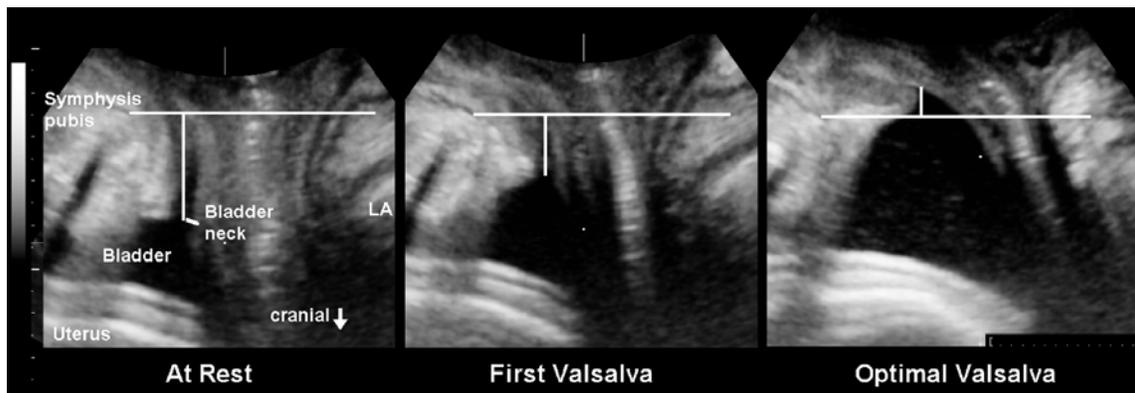
Bladder neck position and mobility can be assessed with a high degree of reliability. Points of reference are the central axis of the symphysis pubis [2], or its inferoposterior margin[3], see Fig. 4.1. The former may potentially be more accurate as measurements are independent of transducer position or movement; however, due to calcification of the interpubic disc the central axis is often difficult to obtain in older women, reducing reliability. This method is also considerably more time- consuming than use of the inferoposterior symphyseal margin as a point of reference. The inferoposterior margin can also be used to determine segmental urethral mobility[1].

Imaging can be undertaken supine or erect, with the bladder full or empty. The full bladder is less mobile[4] and may prevent complete development of pelvic organ prolapse. In the standing position, the bladder is situated lower at rest but descends about as far as in the supine patient on Valsalva[5]. Pelvic organ descent measurements are usually higher, and the levator hiatus is wider (unpublished own data). It is essential not to exert undue pressure on the perineum so as to allow full development of pelvic organ descent, although this may be difficult in women with severe prolapse such as vaginal eversion or procidentia. In such cases there will be loss of contact with the perineum at some stage, and assessment of organ descent and hiatal area has to be carried out in images or volumes acquired before maximal organ descent. In practice this is rarely an issue as it does not matter whether a cystocele or uterine prolapse descends to 5 or 6 cm below the symphysis. Occasionally, a large rectocele, on the other hand, can seriously impair the assessment as bowel gas in the rectocele may result in acoustic shadowing affecting a large part of the field of vision.

Measurements of bladder neck position relative to the symphysis pubis are generally performed at rest and on maximal Valsalva manoeuvre. The difference yields a numerical value for bladder neck descent. On Valsalva, the proximal urethra may be seen to rotate in a postero-inferior direction. The extent of rotation can be measured by comparing the angle of inclination between the proximal urethra and any other fixed axis (see Fig. 4.1). Some investigators measure the retrovesical (RVA or posterior urethrovesical PUV) angle between proximal urethra and trigone or rotation of the proximal urethra (see Fig. 4.1). Bladder neck descent (BND) and

urethral rotation have the strongest association with Urodynamic Stress Incontinence (USI) [6][7]. Repeatability of these measurements is high[8].

While the association between bladder neck descent and stress urinary incontinence is significant, it is rather weak and unsuitable as a diagnostic test. The best cut-off for the definition of normality on the basis of receiver operator characteristics statistics, using Urodynamic Stress Incontinence as an outcome measure, is 25 mm (unpublished own data). In young nulliparous women, the author has obtained bladder neck descent measurements of 1.2- 40.2 mm (mean 17.3 mm) in a group of 106 stress continent nulligravid young women of 18- 23 years of age[9]. Figure 4.1 shows typical findings in a patient with stress urinary incontinence, at rest (left) and on Valsalva (right), with approx. 3.5 cm of bladder neck descent, an open retrovesical angle, funneling and 90 degrees of proximal urethral rotation. Such findings are clearly associated with stress urinary incontinence and urodynamic stress incontinence, although there are many continent women who show similar appearances, and many incontinent patients who don't, with urethral quality being the main confounder[10].



*Figure 4.2: The effect of levator co-activation on bladder neck descent. Midsagittal views at rest (left), on first Valsalva, confounded by levator co-activation (central image) and optimal Valsalva, after biofeedback teaching (right image). The horizontal line signifies the inferior margin of the symphysis pubis. From[11], with permission.*

It can occasionally be quite difficult to obtain an effective Valsalva manoeuvre, especially in nulliparous women, primarily due to levator co-activation which can entirely prevent downwards displacement of pelvic organs, even in women with substantial prolapse[11]. Levator co-activation commonly affects the efficacy of a Valsalva manoeuvre, especially in

nulliparous women, and is evident as a reduction of hiatal diameters in the midsagittal plane (see Figure 4.2). It seems that almost half of nulliparous women will contract the levator when asked to ‘push’ or ‘bear down’[11]. Repeated coughing can be used to detect organ descent in women with strong levator co-activation, but sometimes it is necessary to repeat the assessment in the standing position which tends to allow for a more effective Valsalva maneuver. It is much easier to control for this confounder on real-time ultrasound imaging than on magnetic resonance (MR) imaging, which is one of the main weaknesses of dynamic MR for prolapse assessment.

Attempts at standardizing Valsalva manoeuvres[12] have not found widespread application since this requires intraabdominal pressure measurement, i.e., a rectal balloon catheter. Other methods such as the use of a spirometer are likely to lead to suboptimal Valsalva manoeuvres. However, recent investigations have shown that standardisation of Valsalva pressure is unnecessary as a large proportion of women will reach near- maximal organ descent when coached properly[13]. Duration of Valsalva, a generally ignored factor, seems to be much more important in avoiding false negative assessments, given that a duration of 6 seconds or more is required to achieve near- maximal organ descent[14].

Bladder neck descent seems to be of some importance in the clinical management of patients with stress incontinence. It may be a predictor of success after suburethral slings. An association between preoperative bladder neck mobility and cure has been claimed by Xray[15], Q-tip assessment[16] and ultrasound[17], demonstrating that patients with a fixed urethra are less likely to be stress- dry postoperatively. This association between mobility and cure is explained by the need for dynamic compression of the urethra between tape and symphysis pubis (see also Chapter 8). The less mobility, the more difficult it may be to achieve just the right degree of tension to avoid either excessive obstruction, resulting in voiding dysfunction, or insufficient compression, resulting in recurrent stress leakage[18].

The aetiology of increased bladder neck descent is likely to be multifactorial. The wide range of values obtained in young nulliparous women suggests a congenital component, and a recently published twin study has confirmed a high degree of heritability for anterior vaginal wall mobility[19]. Vaginal childbirth[20][21][22] is probably the most significant environmental factor, with a long second stage of labour and vaginal operative delivery being associated with increased postpartum descent [20].

This association between increased bladder descent and vaginal parity is also evident in older women with symptoms of pelvic floor dysfunction[23]. It is not clear as to why bladder neck mobility should increase with childbirth. Hormonal effects have been postulated, and primigravid women seem to show more descent than nulliparae [24]. However, most of the effect seems to be due to vaginal childbirth [20][21][22], and it has recently been shown that trauma to the levator ani muscle sustained during a vaginal delivery is associated with markedly increased bladder neck mobility[25]. Mobility of the mid- urethra, which is clearly more important for continence, seems to be affected by pregnancy rather than childbirth however, and this (likely hormonal) effect appears to be at least partly irreversible[26].

The pelvic floor is undoubtedly affected by labour and delivery, but the converse also seems to be true. It appears that hiatal distensibility and pelvic organ mobility are associated with the length of the second stage of labour and delivery mode, but such measurements are insufficiently predictive to help with antenatal or intrapartum management[27][28][29].

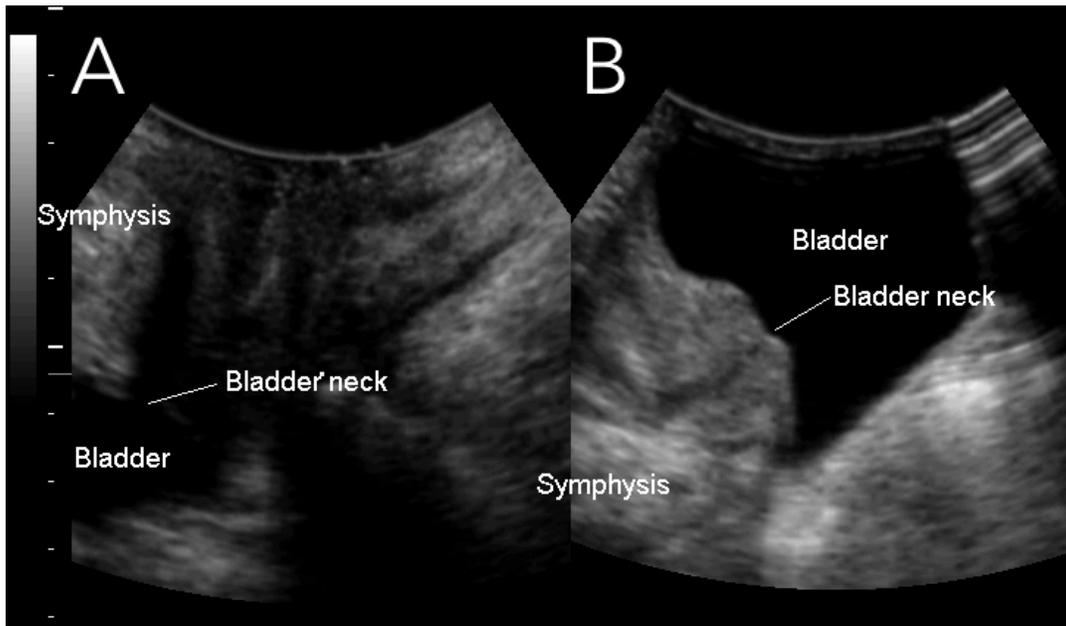
## **Funneling**

In patients with stress incontinence, but also in asymptomatic women[30], funneling of the internal urethral meatus may be observed on Valsalva and sometimes even at rest. Funneling is often associated with leakage. Other indirect signs of urine leakage on B- mode realtime imaging are weak grayscale echoes (‘streaming’) and the appearance of two linear (‘specular’) echoes defining the lumen of a fluid- filled urethra. However, funneling may also be observed in urge incontinence and must not be regarded as proof of urodynamic stress incontinence. Its anatomical basis is unclear. Marked funneling has been shown to be associated with poor urethral closure pressures [31][32].

Classifications developed for the evaluation of radiological imaging[33] can be modified for ultrasound; however, this approach has not come into general use. The commonest finding in cases of bladder neck hypermobility is the so- called rotational descent of the internal meatus, i.e., proximal urethra and trigone rotate around the symphysis pubis, that is, in a dorso-caudal direction. In such cases the retrovesical angle opens to up to 160- 180 degrees from a normal value of 90-120 degrees, and such change in the retrovesical angle is generally associated with funneling, as seen in Figure 4.1. A cystocele with intact retrovesical angle (90- 120 degrees) is frequently

seen in continent prolapse patients (see Fig. 4.3), and this finding is associated with prolapse symptoms and voiding dysfunction rather than stress incontinence[34]; see below.

Marked urethral kinking in patients with cystocele can lead to voiding dysfunction (potentially worsened by straining) and urinary retention. Occult stress incontinence may be unmasked once a successful prolapse repair prevents urethral kinking, an effect that is not surprising if one considers appearances such as those in Figure 4.3.



*Figure 4.3: Marked cystocele with 4 cm of bladder neck descent but intact retrovesical angle and no funnelling, as seen in a continent patient with 3<sup>rd</sup> degree cystocele. The cystocele reaches to over 4 cm below the symphysis pubis. The proximal urethra has rotated by more than 120 degrees and is markedly kinked. Modified from [66], with permission.*

Descent of the bladder to  $\geq 10$  mm below the symphysis pubis is strongly associated with symptoms of prolapse and has been proposed as constituting ‘significant’ anterior compartment prolapse on the basis of receiver operator curve characteristics[35][36][37], see Figure 4.4.

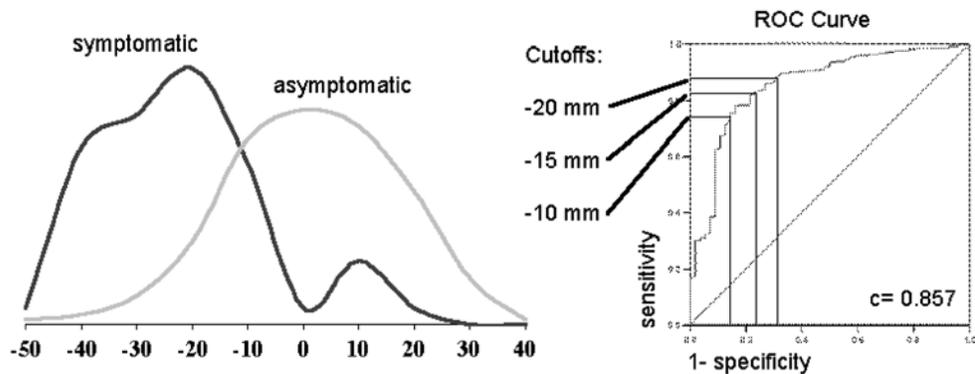


Figure 4.4: Histograms for bladder descent in mm (left) in asymptomatic (grey) and symptomatic women (black) and receiver operator curve for bladder descent as a test for symptomatic prolapse (right). Lines define proposed cutoffs. From[35], with permission.

## Colour Doppler

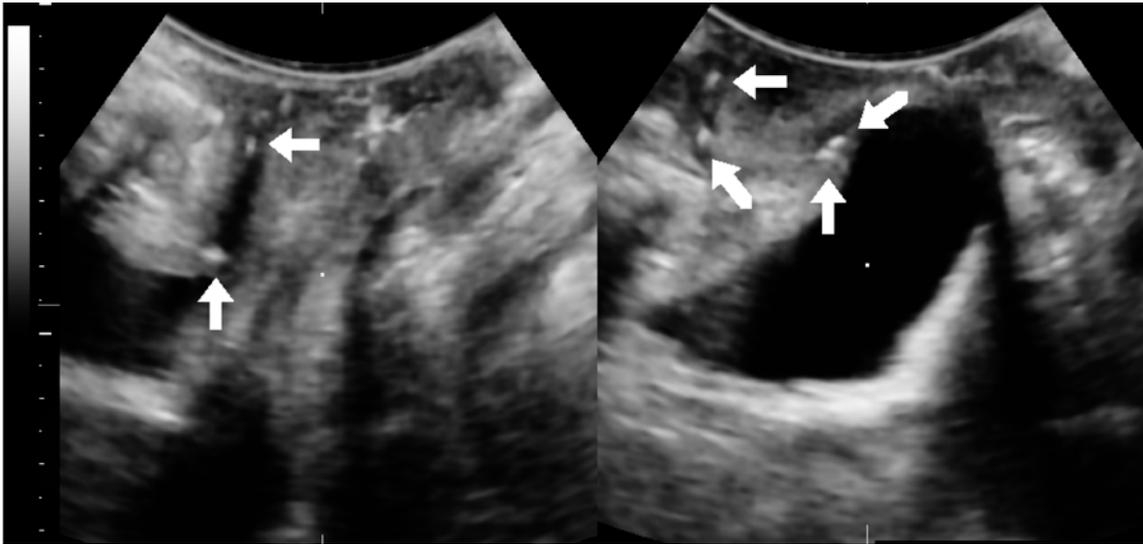
Colour Doppler ultrasound has been used to demonstrate urine leakage through the urethra on Valsalva manoeuvre or coughing[38][39][40]. Settings may vary considerably between systems which implies that no general recommendations can be given. As a rule, it makes sense to set Doppler gain and scale to values that just permit the pickup of venous flow signals, e.g. from vessels posterior to the symphyseal margin, avoiding marked flash artefact as tissues move with a Valsalva manoeuvre. Flash artefact is also responsible for the fact that observation of leakage on coughing is considerably more difficult than on Valsalva.

Routine sonographic documentation of stress incontinence during urodynamic testing clearly is feasible, and colour Doppler imaging may also facilitate the documentation of leak point pressures [40]. Whether this is in fact desired will depend on the clinician and his/ her preferences, and one may well argue that urine leakage and leak point pressures can be determined without access to expensive imaging equipment.

## Urethra

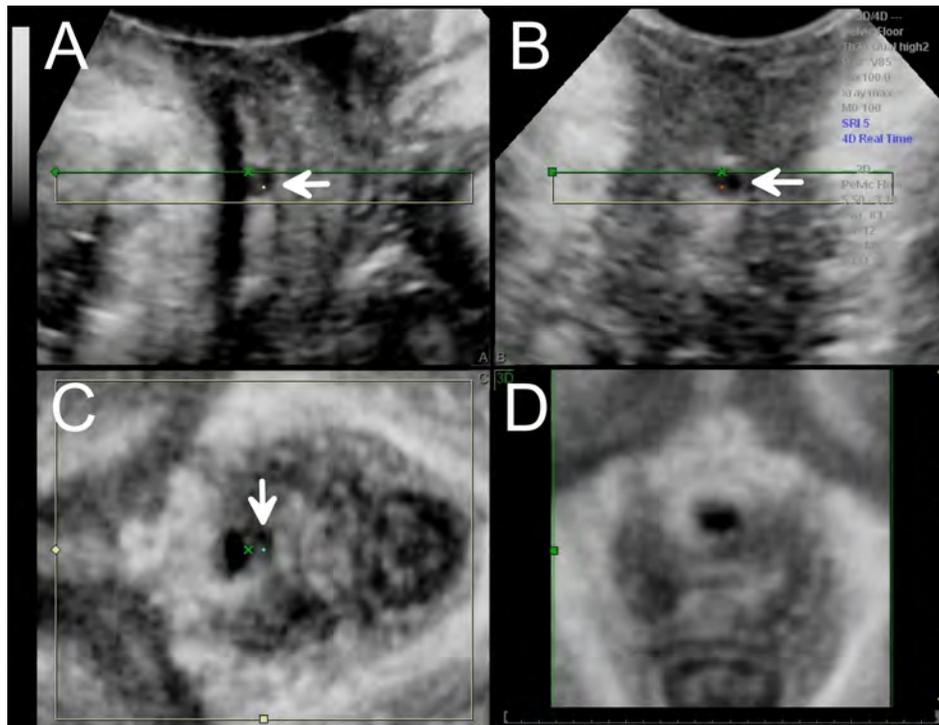
On translabial imaging, the urethra is evident as a vertical hypoechoic area (see Figures 4.1- 4.3). This area includes mucosa, vascular plexus and the urethral smooth musculature or ‘longitudinal smooth muscle’ (LSM) of the urethra. Its hypoechoic appearance is largely due to the fact that mucosal layers and smooth musculature run parallel to the incident beam (see chapter 2). This is evident whenever there is significant urethral rotation, as a more perpendicular orientation of the urethra relative to the incident beam makes the structure more isoechoic and therefore less evident.

Figure 4.5 demonstrates urethral kinking and changed echogenicity of the LSM due to urethral rotation. It also shows another common finding in the form of ‘hyperechoic foci’. They may be isolated or multiple, and probably are due to calcified urethral glands. There seems to be no association between symptoms or lower urinary tract conditions and the presence of such foci[41].



*Figure 4.5: Hyperechoic foci (arrows) in the urethra in a patient with mixed urinary incontinence, a 2<sup>nd</sup> degree cystocele and USI. Office cystourethroscopy was normal. The foci are more evident on Valsalva (right image).*

The urethral rhabdosphincter surrounds this hypoechoic structure and appears as a double hyperechoic stripe on translabial ultrasound at rest, ventral and dorsal of the urethra proper. Its appearance varies markedly depending on the approach used, ie., whether intraurethral[42], transrectal [43], or translabial/ perineal[44]. On translabial scanning at rest, the rhabdosphincter appears hyperechoic as the incident beam is perpendicular to those fibres. On transvaginal ultrasound parts of this circular or near-circular structure are vertical to the incident beam, others are parallel, and this has resulted in spurious findings, leading some authors to conclude that the rhabdosphincter is hypoechoic and non -circular. Recent improvements in tissue discrimination have made identification much easier (see Figure 4.1).



*Figure 4.6: Small urethral diverticulum in the three axial planes (A-C). The diverticulum is too small to be visible on rendered volume (D). This findings was asymptomatic.*

Translabial ultrasound is highly useful in the diagnosis of paraurethral abnormalities. Occasionally a “cystocele” will turn out to be due to a urethral diverticulum (see Fig. 4.6-8), a Gartner duct cyst (Fig. 4.9) or an anterior enterocele, all rather likely to be missed on clinical examination.

Figure 4.6 shows a small, asymptomatic posterior diverticulum, Figure 4.7 an unusual anterior diverticulum which has developed into the space of Retzius, Figure 4.8 a much more complex posterior diverticulum which surrounds the entire urethra as a complex, multiloculated mass. Figure 4.9, on the other hand, shows the main differential diagnostic entity, a Gartner cyst. Occasionally, a cystic structure may arise from the distal urethral orifice such as in 4.10, a finding that suggests a Skene gland cyst.

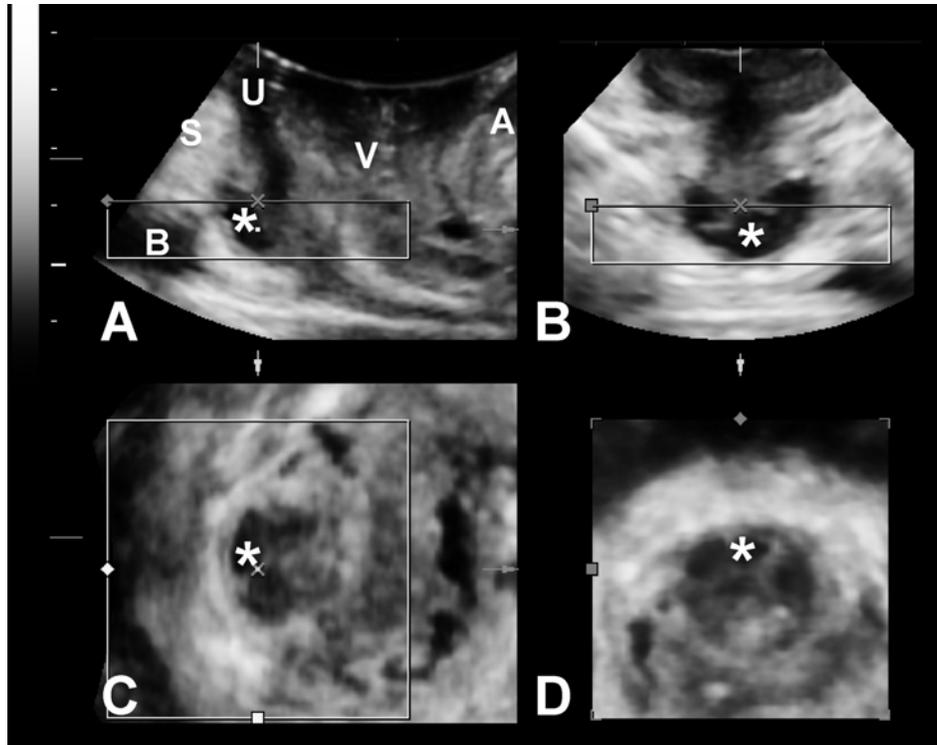


Figure 4.7: Unusual anterior urethral diverticulum (\*), developing into the Space of Retzius. S= symphysis pubis, U= urethra, V=vagina, B= bladder. From [66], with permission.

The main differential diagnosis of cystic paraurethral structures is between urethral diverticula and Gartner cysts. The latter would be treated with simple excision or marsupialization, while such an approach would convert a urethral diverticulum into a urethrovaginal fistula. Figures 4.7 and 4.8 of a urethral diverticulum shows that the ring structure of the urethral rhabdosphincter is undetectable in the vicinity of the diverticulum whereas the circular outline of the rhabdosphincter is quite obvious in Figure 4.9, suggesting a Gartner cyst. Observation of a Valsalva maneuver also helps with this differential diagnosis as diverticula are fixed to the urethra while Gartner cysts tend to be highly mobile. Finally, it is sometimes possible to

identify the tract connecting the cystic mass to the urethral lumen, confirming the diagnosis of a urethral diverticulum.

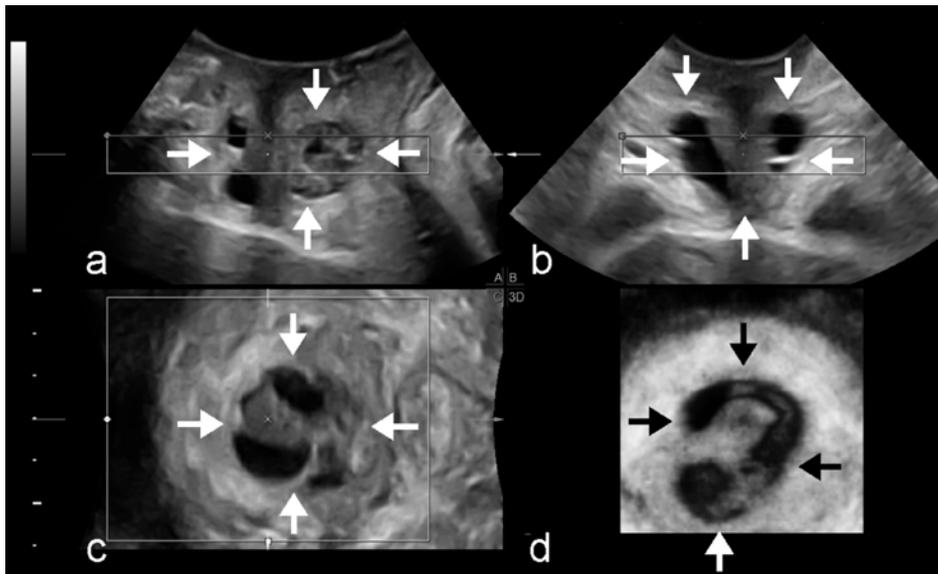


Figure 4.8: Large urethral diverticulum that surrounds the urethra almost completely (arrows).

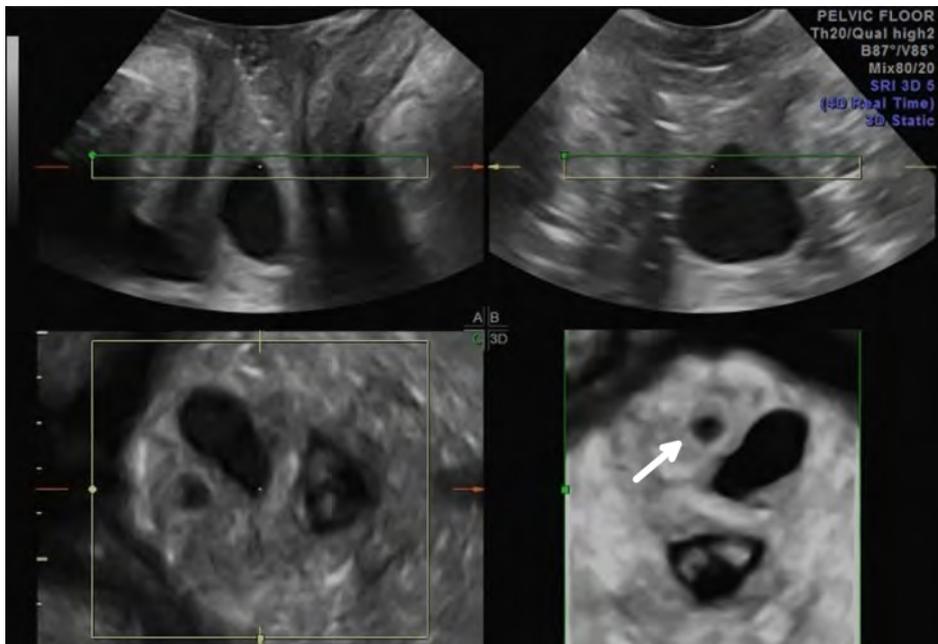
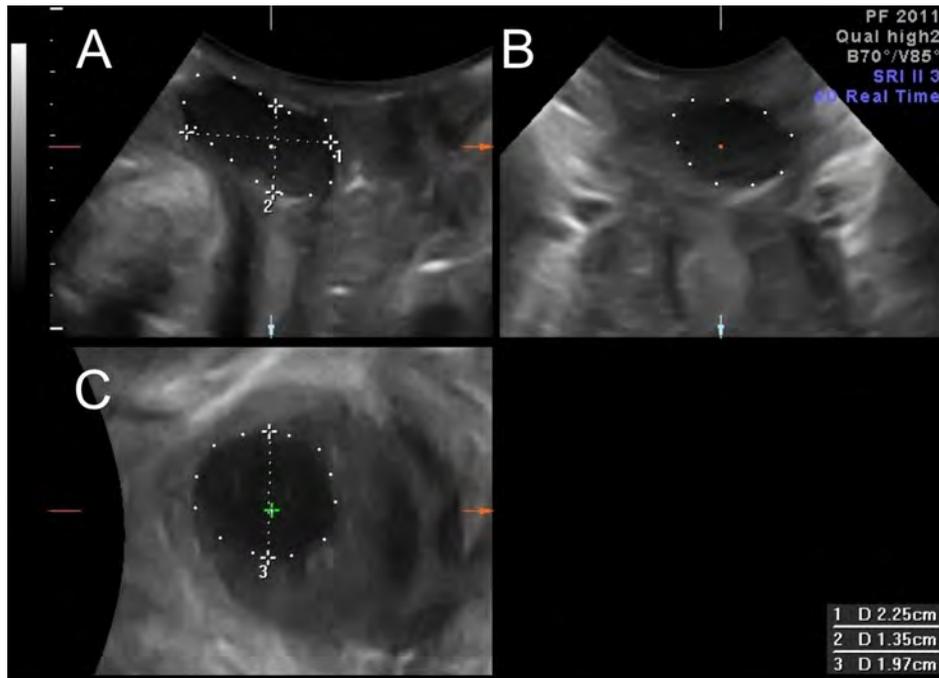


Figure 4.9: Gartner duct cyst in orthogonal planes and rendered volume. The latter (bottom right) clearly shows an intact urethral rhabdosphincter (arrow).



*Figure 4.10: Skene gland cyst (outlined) close to the external urethral orifice.*

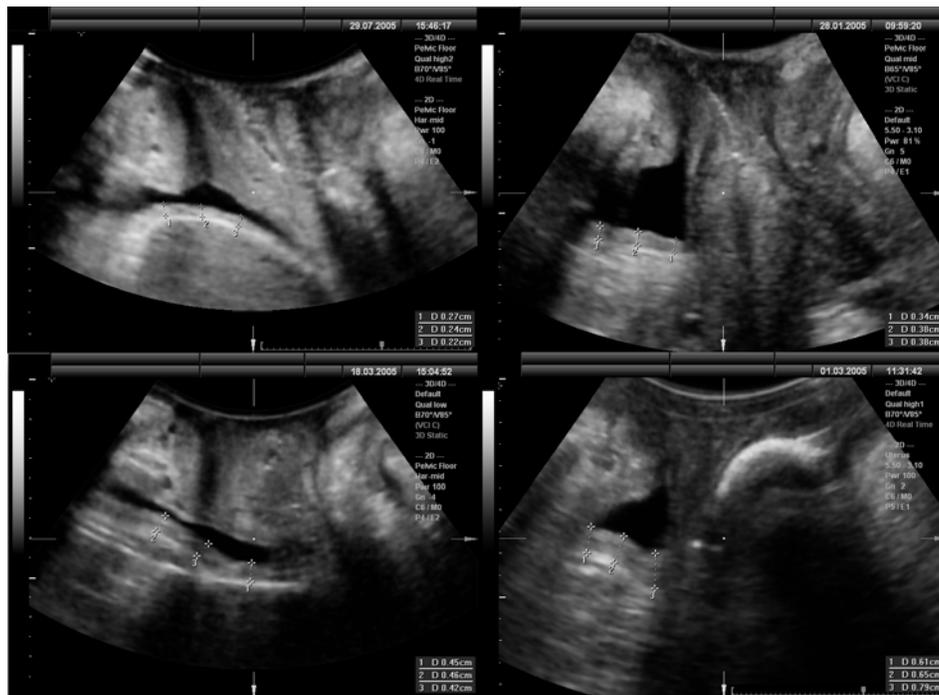
### **Effects of prolapse on urethral function**

Prolapse can affect urinary continence in various ways, and ultrasound can demonstrate such effects better than any other imaging modality. The issue of urethral kinking with cystocele (see Figure 4.5) has already been mentioned, but prolapse in other compartments may also matter for continence. In fact, the greatest effect of prolapse on voiding may not be due to cystocele but to enterocele[45], which may be explained by more immediate pressure transmission. Translabial ultrasound easily demonstrates uterine prolapse, enterocele and rectocele, all of which can compress the urethra and mask stress incontinence. A special case is the incarcerated, retroverted fibroid uterus, with distortion/compression of the bladder neck by the cervix.

It is generally assumed that levator function and morphology are important for continence, and the effectiveness of pelvic floor muscle exercises in incontinent women seems to support this concept. While this may be true for functional aspects such as reflex activity[46], it is doubtful as to whether morphological abnormalities of the levator ani are associated with urinary continence[47], and that it has little, if any, effect on urethral mobility [48]. The effect of such trauma on the success of conservative treatment with PFM exercises remains to be elucidated.

## Bladder wall thickness

Measurements of bladder wall or detrusor wall thickness (BWT or DWT) can be obtained by transvaginal and/ or translabial ultrasound[49][50]. Measurements are obtained after bladder emptying and perpendicular to the mucosa, leading edge to leading edge (see Fig. 4.11), close to the midline as identified by the urethra and bladder neck. Originally, three sites were assessed by transvaginal ultrasound (TVUS): anterior wall, trigone and dome of the bladder, and the mean of all three was calculated. The author feels that the trigone (as it is of different embryological origin) is difficult to justify as a measurement location compared to the dome. In addition, there often is marked variation in trigonal thickness between the bladder neck and the interureteric ridge.



*Figure 4.11: Detrusor wall thickness as measured at the dome after bladder emptying: mean DWT is 2.5 (top left), 3.7 (top right), 4.4 (bottom left) and 6.8 (bottom right). Measurements of 5 mm and above are thought to be associated with symptoms and signs of detrusor overactivity. From [50], with permission.*

Another approach, currently used by the author, is to measure three sites on the dome, which can be performed either by translabial/ introital or by

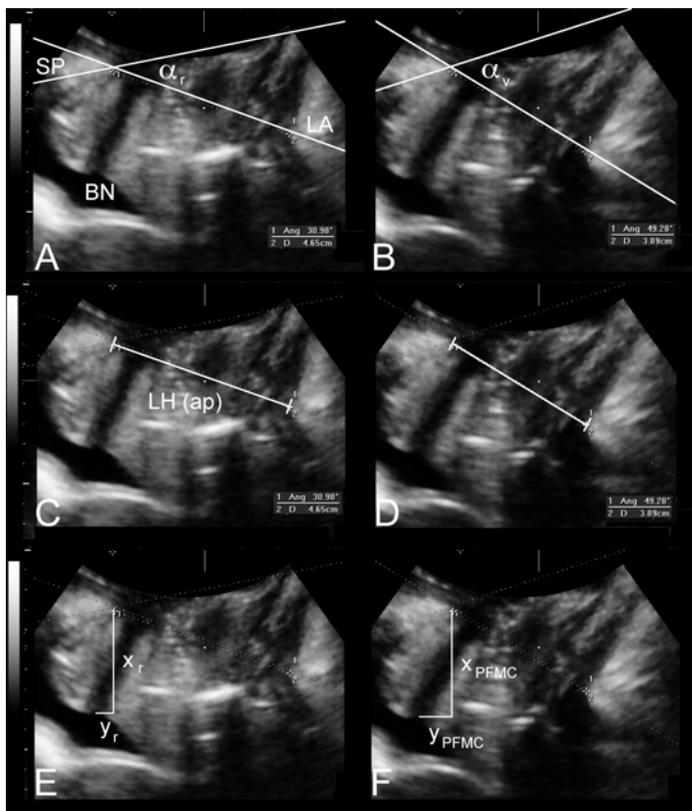
transvaginal ultrasound. Above a bladder filling of 50 ml detrusor wall thickness starts to drop [51], which is why in Urogynaecology measurements are usually undertaken after bladder emptying. DWT measurement by translabial ultrasound seems to be highly reproducible[50].

A detrusor wall thickness of over 5 mm seems to be associated with detrusor overactivity and symptoms of urge incontinence and urodynamically proven detrusor overactivity, but the strength of the association seems insufficient to be of much use in clinical practice[50]. Increased bladder wall thickness is likely due to hypertrophy of the detrusor muscle, which is most evident at the dome and can be highly variable from one location to the other; this may be the cause of symptoms or simply the effect of an underlying abnormality. In young women, detrusor wall thickness is almost universally below the threshold of 5 mm at the dome[52].

There seems to be an association between age and DWT[53] which supports the hypothesis that increased DWT is indicative of acquired detrusor hypertrophy, and probably the result of years and decades of isometric contractions against a closed outlet. This is also supported by the finding that a history of nocturnal enuresis in childhood is associated with increased DWT in women seen for bladder dysfunction in later life[54] which implies that, at least in some women, increased DWT is due to an underlying disorder that is either congenital or acquired in early childhood. It is quite likely but remains to be proven that determination of this parameter can contribute to the workup of a patient with pelvic floor and bladder dysfunction, e.g. as a predictor of postoperative voiding function or de novo/worsened symptoms of the irritable bladder.

## Levator activity

Since pelvic floor muscle exercises are generally recognised as first-line treatment in urinary (and faecal) incontinence, it is sensible to determine levator muscle function in women presenting with such symptoms and teach proper technique. A levator contraction reduces the size of the levator hiatus in the sagittal plane and elevates the anorectum, changing the angle between levator plate and symphysis pubis. As an indirect effect, other pelvic organs such as uterus, bladder and urethra are displaced cranially (see Fig. 4.12), and there is compression of urethra, vagina and anorectal junction.



*Figure 4.12: Three methods of determining the effect of a pelvic floor muscle contraction (PFMC) in the midsagittal plane, using 2D translabial ultrasound. The left hand images in each pair (A,C,E) represent the resting state, the right hand images show findings on PFMC.*

*The top pair illustrates measurement of the levator plate angle (angle between symphyseal axis and levator hiatus in the midsagittal plane), the middle pair shows reduction of the anteroposterior diameter of the levator hiatus (LH (ap)), and*

*the bottom pair illustrates bladder neck displacement on PFMC, analogous to the way bladder neck descent is measured on Valsalva. From [44], with permission.*

Perineal ultrasound has been used for the quantification of pelvic floor muscle function, both in women with stress incontinence and continent controls[55], as well as before and after childbirth[56][57]. A cranioventral shift of pelvic organs imaged in the midsagittal plane is taken as evidence of

a levator contraction. The resulting displacement of the internal urethral meatus is measured relative to the infero-posterior symphyseal margin (see Fig. 4.12). Another means of quantifying levator activity is to measure reduction of the levator hiatus in the midsagittal plane, or to determine the changing angle of the hiatal plane (the ‘levator plate angle’) relative to the central symphyseal axis (see Figure 4.12). Narrowing of the hiatus without cranioventral displacement of the bladder neck implies that the patient has increased intraabdominal pressure while contracting the levator ani. This is a common problem and should be corrected by teaching proper technique, eg by visual ultrasound biofeedback[58].

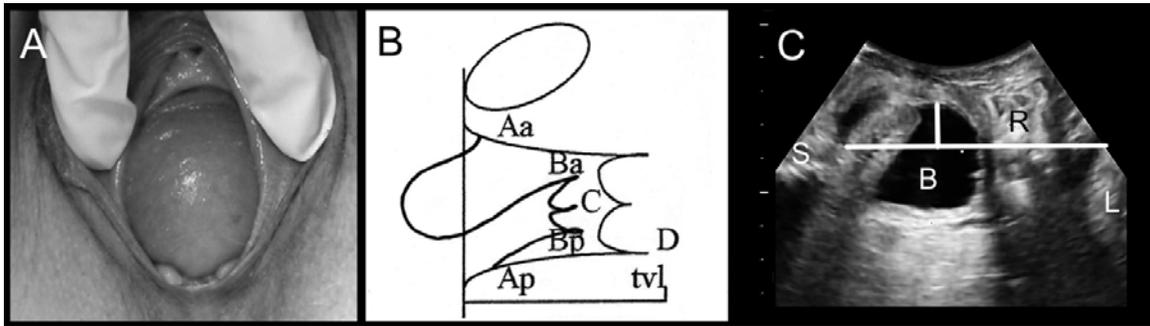
Translabial ultrasound observation of pelvic floor activity has helped validate the concept of ‘the knack’, i.e., of a reflex levator contraction immediately prior to increases in intraabdominal pressure such as those resulting from coughing[59]. Correlations between cranioventral shift of the bladder neck on the one hand and palpation/ perineometry on the other hand have been shown to be good[60]. Physiotherapists have begun to use transabdominal and translabial ultrasound to document pelvic floor muscle activity, with one author concluding that the translabial technique[61] is probably more accurate for this indication.

### **Prolapse quantification**

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[34]. A cystocele with intact retrovesical angle (first described on X-ray cystourethrography as Green type III in the 1960s[33], see Figure 4.5) 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[34]. While it is possible to distinguish the two types clinically[62], 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.

Organ descent is generally measured against a line placed through the inferoposterior symphyseal margin, see Figure 4.13. While the absence of a

posterior anchor for this reference line may reduce accuracy, especially for posterior compartment measurements, this does not seem to be a problem provided one avoids rotational transducer movement, i.e., provided the main symphyseal axis does not tilt against the horizontal plane of the field of vision on Valsalva. Repeatability of anterior compartment descent seems to be very high, even if reassessed after an interval of weeks or months[63].



*Figure 4.13: Cystocele on clinical examination (A), on ICS POP-Q quantification (B) and on translabial ultrasound (C). A horizontal line of reference is placed through the inferior margin of the symphysis pubis. A vertical line indicates maximal descent of the bladder. S= symphysis pubis, B= bladder, R= rectocele, L= levator ani. From[67], with permission.*

A bladder position of 10 mm below the symphysis pubis has been defined as the most appropriate cut- off for ‘significant bladder descent on Valsalva[35], which is equivalent to a Ba of -0.5[64]. Occasionally a cystocele will turn out to be due to a urethral diverticulum, a Gartner duct cyst or an anterior enterocele, as mentioned above. Another major argument in favour of pelvic floor ultrasound imaging is the popularity of synthetic mesh implants used in incontinence and prolapse surgery, which will be discussed in Chapter 7.

## Other findings

Residual urine can conveniently be determined at the time of a routine translabial pelvic floor assessment, with an accuracy that is at least equivalent to transabdominal and transvaginal techniques[65]. It may be necessary to let the patient perform a mild Valsalva manoeuvre in order to allow the most ventral part of the dome to rotate downwards. The two largest diameters are measured perpendicular to each other (see Figure 4.14), and the result in cm is multiplied by 5.6 to provide residual volume in ml[65].



*Figure 4.14: Determination of residual urine volume on translabial ultrasound. The two largest bladder diameters are measured perpendicular to each other and multiplied by 5.9. Deducting 14.9 gives residual urine volume in mm, in this case resulting in  $4.31 * 1.69 * 5.9 - 14.9 = 28$  ml. From[65], with permission.*



*Figure 4.15: Bladder stone (large arrow) and transitional cell carcinoma (small arrow) of the bladder, both incidental findings on translabial ultrasound performed for symptoms of stress incontinence.. There is an obvious acoustic shadow behind the bladder stone which is mobile on coughing and Valsalva. The carcinoma is immobile and iso-echoic without acoustic shadow.*



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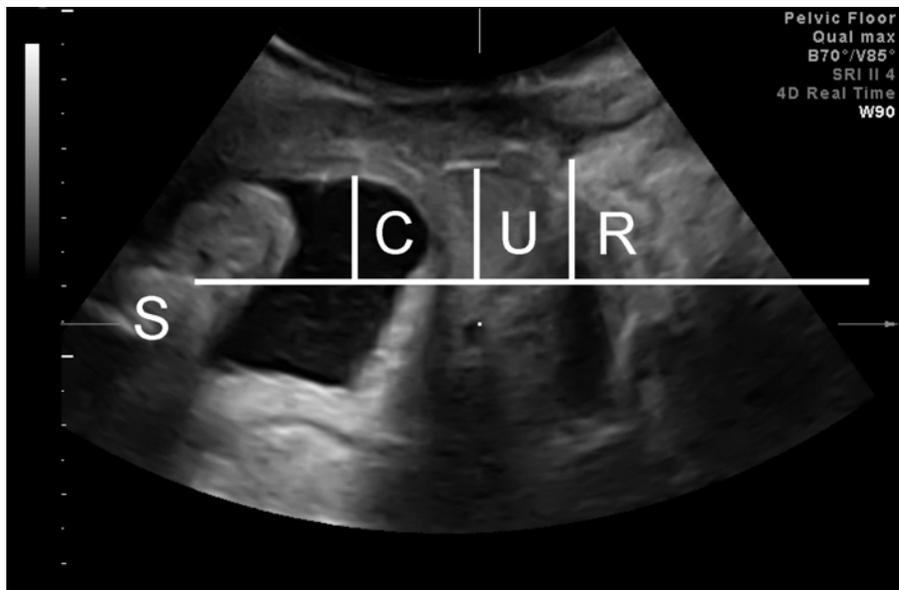


# Chapter 5

## The Central and Posterior Compartments

### Prolapse assessment

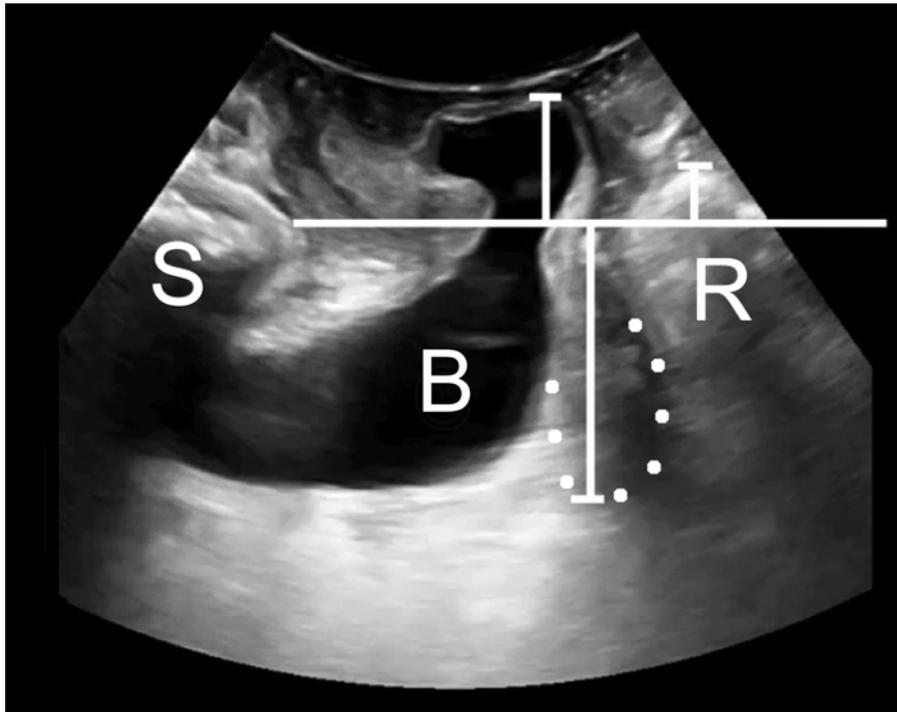
Ultrasound is increasingly used for prolapse assessment, not just for the anterior compartment, but also for the central and posterior compartment. It provides for an objective evaluation of organ descent against a bony/cartilaginous point of reference, ie., the symphysis pubis or the interpubic disc. On ultrasound continuing movement of tissues against this fixed reference point is much more obvious than movement of soft tissues against each other as, which explains why ultrasound quantification of prolapse suggests a much longer Valsalva than has been the norm on clinical examination, requiring maneuvers of at least six seconds' duration[1]. Imaging also alerts the examiner to confounders that are often overlooked on clinical examination, such as bladder and rectal filling, and the presence of bowel gas (see above).



*Figure 5.1: Prolapse quantification by transperineal ultrasound. Measurements are against a horizontal line through the inferior margin of the symphysis pubis (S). Clinically there is a 2<sup>nd</sup> degree cystocele (C) and 2<sup>nd</sup> degree uterine prolapse (U). There is no significant degree of posterior compartment prolapse; (R) indicates the rectal ampulla.*

The uterus itself is less easy to identify than either bladder (anechoic urine) and rectum (usually hyperchogenic stool and bowel gas with acoustic shadowing). It is iso-echoic, similar to vaginal muscularis, but often also produces acoustic shadowing due to the fibre density in uterine myometrium. A specular (line- like) echo often indicates the leading edge of the cervix, and the cervical canal and endometrial stripe can usually be identified.

At times, Nabothian follicles help with identification of the cervix, but in menopausal women the uterus may be so small as to be invisible. The same is true for a retroverted uterus, especially if significant rectal contents or a rectocele shadow the area of interest, and a well supported uterus may be outside the field of view. A full sonographic assessment of the uterus does of course require trans-vaginal scanning, even if fibroids or the endometrial stripe can sometimes be documented transperineally. Figure 5.1 shows a 2<sup>nd</sup> degree uterine prolapse, Figure 5.2 the apex of the vault after hysterectomy in a patient with 2<sup>nd</sup> degree cystocele.



*Figure 5.2: Appearance of a well supported vaginal vault in a patient after hysterectomy (outlined by dots) and 2<sup>nd</sup> degree systole on clinical examination. S= symphysis pubis, B= bladder, R= rectal ampulla.*

The bladder neck or the leading edge of a cystocele is used for the quantification of anterior vaginal wall descent, the cervix or Pouch of Douglas for the central compartment, and the most caudal aspect of the rectal ampulla- or the leading edge of rectocele contents- for quantification of posterior compartment descent. The inferior margin of the symphysis pubis anchors a horizontal line of reference against which descent can be measured (see Figures 5.1 and 5.2). There is no posterior point of reference with which this line can be anchored, but repeatability of prolapse assessment is high provided one avoids rotational movement of the transducer, ie., movement that changes the angle between the main axis of the symphysis and the transducer.

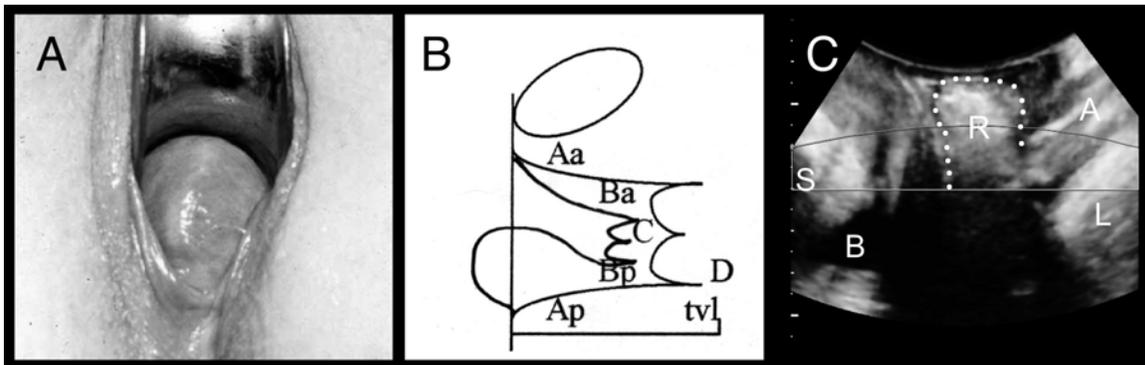
Agreement between clinical examination and ultrasound quantification of prolapse is generally high, especially for the anterior and central compartments[2][3]. Repeatability also is high, but again posterior compartment findings vary the most[4]. While the optimal cut-off for defining 'significant prolapse' (ie., a degree of descent that is likely to result in symptoms of a vaginal 'lump or bulge') is 10 mm below the symphysis for the anterior compartment, it is 15 mm above the SP for the central compartment[5], equivalent to a C of -4, and 15 mm below the SP for the posterior compartment [6], which equates to a Bp of -0.5[7]. Evidently, the uterus has to descend much less to cause symptoms of prolapse which explains the efficacy of vaginal hysterectomy for symptom relief, even if concomitant vaginal repairs commonly fail to cure anterior or posterior compartment abnormalities. The same explains the efficacy of pessary management in women with prolapse, even if a pessary often provides little support to bladder or rectal ampulla.

Finally, it needs to be mentioned that due to different viscoelastic properties, the organs bladder, uterus and rectum may require a different amount of time to reach their lowermost station during a Valsalva maneuver. It appears that uterine supports take the longest to stretch, resulting in slower downwards displacement and a higher likelihood of false-negative findings[8] if Valsalva maneuvers are not performed properly.

### **Anterior rectocele**

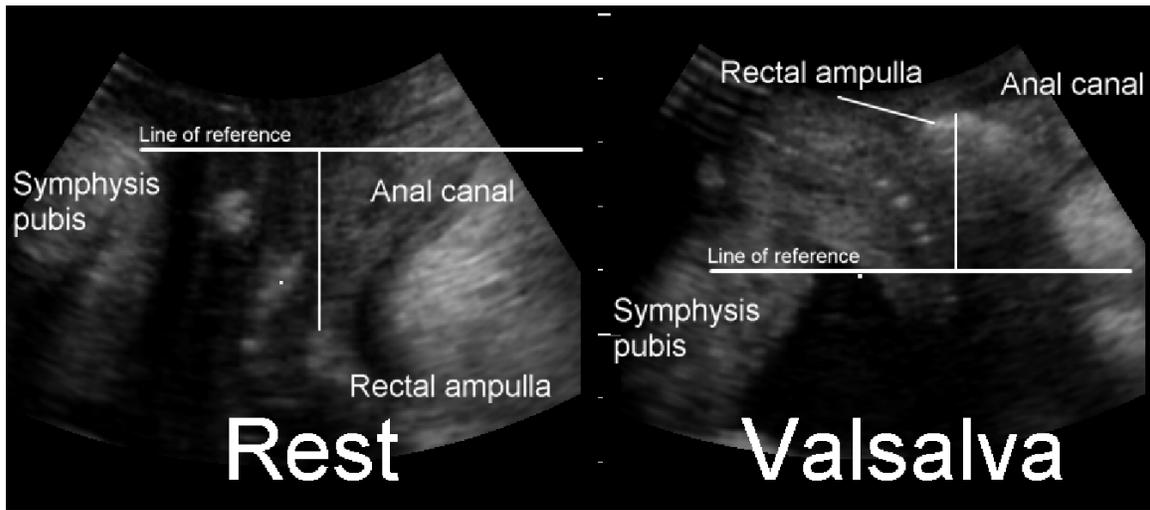
Correlations between clinical prolapse grading and ultrasound are not quite as good for the posterior compartment as they are for cystocele or uterine

descent, probably mainly due to varying stool quality and rectal filling. It is however possible to obtain information equivalent or superior to a defecation proctogram or dynamic MR defecography, with much less inconvenience to the patient, and at much lesser cost[9][10][11][12][13]. Increasingly, translabial ultrasound is used to complement or replace defaecography, with or without ultrasound gel as contrast medium[13][14]. It is likely that ultrasound will slowly replace defecation proctography in the clinical assessment of women with symptoms of obstructed defecation.

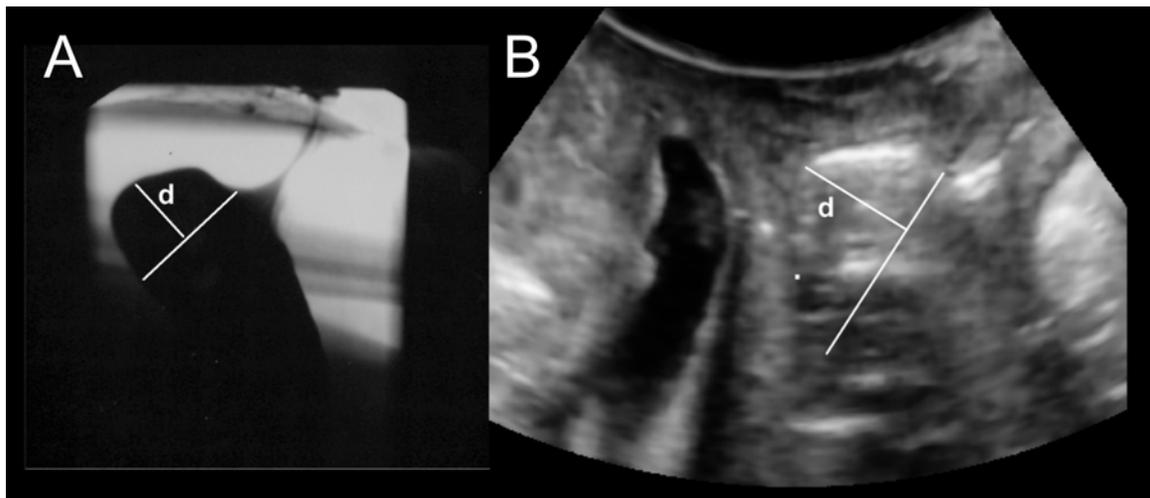


*Figure 5.3: Rectocele on clinical photograph (A), representation on POP-Q (B; Ba= -3, C= -4, Bp=+1), and appearances on imaging (C; S= symphysis pubis, B= bladder, R= rectocele, A= anal canal, L= levator ani). Modified from[15], with permission.*

Figure 5.3 shows a comparison of clinical findings, ICS POP-Q documentation and translabial ultrasound in a patient with a simple rectocele, ie., a diverticulum of the anterior rectal ampulla. The main differential diagnosis is caudad displacement of the rectal ampulla without formation of such a diverticulum, which is defined as ‘perineal hypermobility’ or ‘hypermobility of the rectal ampulla’, a condition that is shown in Figure 5.4. Perineal hypermobility may be difficult to distinguish clinically from a ‘true’ rectocele unless one examines per rectum[16]. Figure 5.5 show comparisons of translabial ultrasound and defecation proctography on maximal Valsalva, in a patient with symptoms of obstructed defecation and rectocele.



*Figure 5.4: Descent of the rectal ampulla without actual herniation of rectal contents into the vagina, termed ‘perineal hypermobility’. From[17], with permission.*



*Figure 5.5: A typical true rectocele as seen on defecation proctogram (left) and on translabial ultrasound (right). Whether such a rectocele is symptomatic will to a large extent depend on stool quality, and many are asymptomatic. From[9], with permission.*

A ‘true’ or ‘radiological’ rectocele is the commonest finding in women with posterior compartment prolapse, found in about half of a urogynaecological population[18] is a simple anterior ‘true’ or ‘radiological’ rectocele (see Fig. 5.3 and 5.5). A deficiency of the rectovaginal septum or ‘Denonvillier’s fascia’ will allow herniation of the anterior rectal ampulla and ampullary contents into the lower vagina due to the pressure differential between the ampulla (at intraabdominal pressure) and the lower vagina (at atmospheric pressure), forming a true hernia. This results in displacement of stool into

the rectocele, ie., the lower vagina, on Valsalva, making complete emptying difficult or impossible.

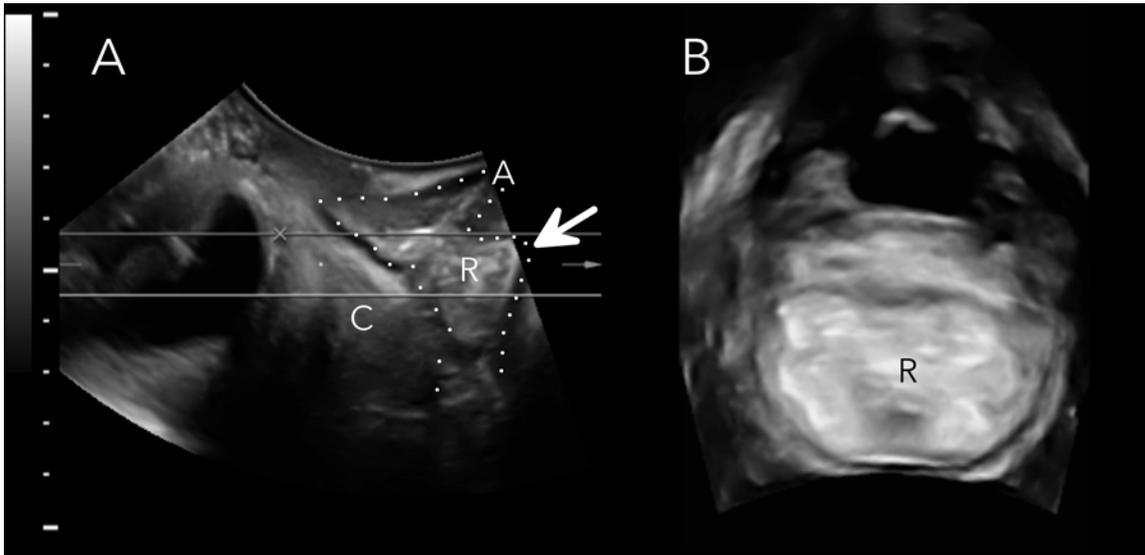
Not surprisingly, rectocele is very common in women suffering from symptoms of obstructed defecation, ie., incomplete bowel emptying, straining at stool and digitation, ie., the use of a finger to help with defecation by exerting perineal or vaginal pressure to help emptying of the ampulla recti. Occasionally, anal digitation is needed to empty. Occasionally, such symptoms can become so severe that not just laxatives, but also enemas are necessary. The lifestyle impact or bother of such symptoms in a urogynaecological population can be considerable[19]. Rectocele depth varies enormously, and even large rectoceles are sometimes asymptomatic. The multifactorial nature of obstructed defecation explains the relatively poor performance of rectocele depth for the prediction of symptoms which impairs our ability to define cut-offs for the diagnosis of 'significant rectocele'. Depths of 10 mm[20] and 15 mm [21] have been proposed; radiologists often use a cut-off of 20 mm. Figure 5.5 demonstrates depth measurement on defecation proctography and ultrasound.



*Figure 5.6: Rectocele (outlined by dots) behind a posterior compartment mesh. This rectocele develops into the perineum, not into the vagina. Her posterior compartment prolapse was cured by the mesh (arrows), but the patient still complained of symptoms of obstructed defecation. S= symphysis pubis, B= bladder, R= rectocele, A= anal canal, L= levator ani. The left image (A) shows the status at rest, the middle is taken halfway through a Valsalva (B), the right at maximal Valsalva (C).*

Occasionally, rectocele may develop not into the vagina, but into the perineum (see Figure 5.6) or the ischioanal fossa as a lateral or posterior rectocele. Figure 5.7 shows a posterior rectocele in a patient with severe ballooning and a severe bilateral avulsion that is affecting not just the puborectalis, but also the iliococcygeus muscle. The consequence is severe ballooning that extends far cranially and results not just in intussusception,

but also in a sacculation of the overdistended rectal ampulla posteriorly (see Figure 5.7); i.e., a posterior rectocele. This can be a particularly severe consequence of major maternal birth trauma. In some cases, lateral or posterior rectoceles are better understood as ‘buttock hernias’ through a deficient levator plate, and there is currently no generally accepted surgical approach.

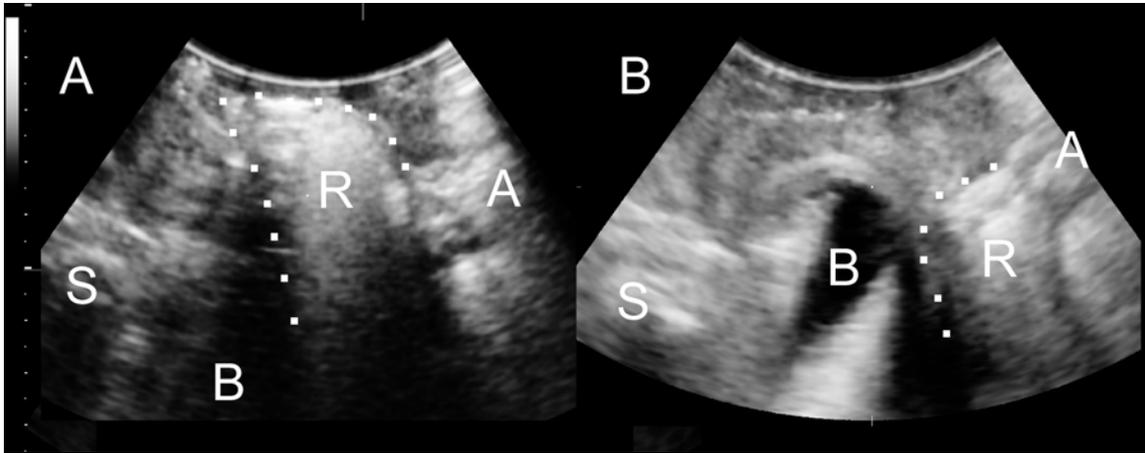


*Figure 5.7: Posterior rectocele in a patient with severe ballooning and a severe bilateral avulsion. (A) shows the anal canal and rectal ampulla in the midsagittal plane, demonstrating both an intussusception (the ampulla being inverted by a low cervix) and a posterior rectocele (arrow). C= cervix, A= anal canal, R= rectal ampulla. The dotted lines trace the anal canal, rectal ampulla/ intussusception and the posterior rectocele.*

A ‘perineal’ rectocele, on the other hand, is not uncommon after posterior compartment mesh and easily repaired using the rectovaginal septum as with a routine defect specific repair[22]. Employing the rectovaginal septum for rectocele and recto-enterocele repair, as originally proposed by Cullen Richardson[23], yields highly satisfactory anatomical results[22], as shown in Figure 5.8.

The main differential diagnosis of rectocele is with increased distensibility of the septum and/or perineal hypermobility without fascial defects[20], see Fig. 5.4. This distinction matters, as both entities may produce symptoms of prolapse, but only ‘true’ rectoceles are associated with symptoms of

obstructed defecation[24]. The RVS can often be visualised directly, but appearances at rest provide no clue as to the integrity of the structure when loaded during a Valsalva[25].



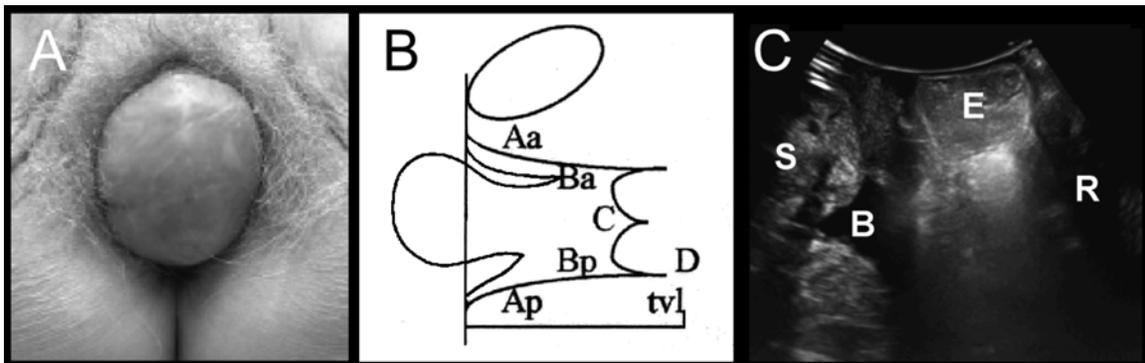
*Figure 5.8: Imaging on Valsalva, before and 6 months after successful defect specific rectocele repair. It is evident that the diverticulum of the rectal ampulla evident in (A) is no longer visible in (B). This anatomical success is strongly associated with cure of symptoms of obstructed defecation. From[17], with permission.*

The traditional distinction between low, midlevel and high rectocele is not supported by ultrasound data. From experience to date, ‘true rectoceles’ or fascial defects seem to virtually always be found in the same area, i.e., very close to the anorectal junction, and most are transverse. Lateral defects as described in the literature have never been demonstrated on imaging and very likely are iatrogenic in nature.

True rectoceles may be present in young nulliparous women[26], but they are more common in the parous[27]. Both descent of the rectal ampulla and rectocele depth seems related to parity in an almost linear fashion[28], a pattern that is very different from anterior and central compartment prolapse for which the first delivery is by far the most traumatic. In some women they clearly arise in childbirth, and if they are present before the delivery, defects tend to enlarge[29]. Interestingly, rectocele is the only form of pelvic organ prolapse that is clearly associated with obesity[30].

## Enterocecele

One of the main advantages of translabial ultrasound is the ease with which rectocele can be distinguished from enterocele[20]. The latter is diagnosed if there is a herniation of fluid- containing peritoneum, small bowel, sigmoid or omentum anterior to the anorectal junction, separating the vagina from the rectal ampulla (see Figure 5.9). Hysterecomy is considered to be the main risk factor for enterocele, and the majority of patients will have other concomitant pelvic floor abnormalities such as ballooning and/ or avulsion (see Chapter 7).



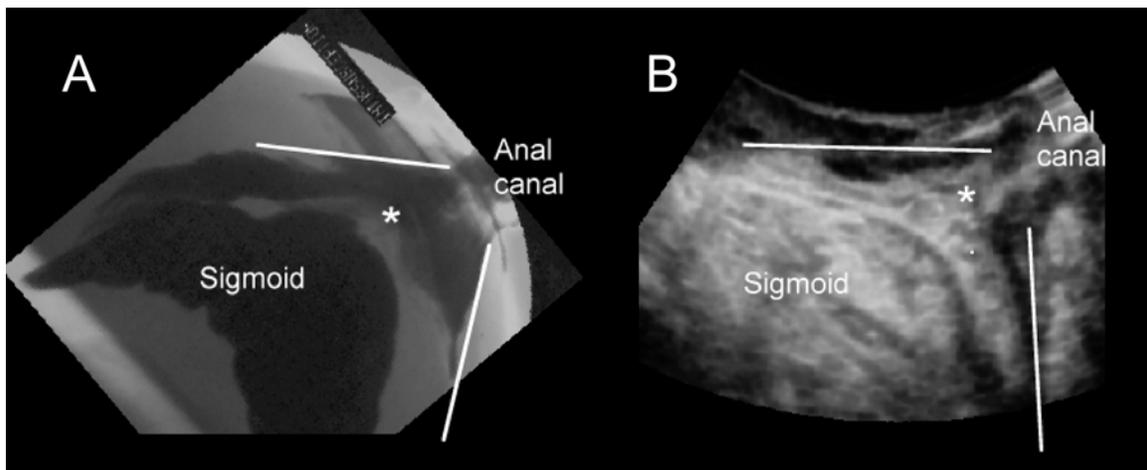
*Figure 5.9: Vault prolapse and enterocele on clinical photograph (A), representation on POP-Q (B; Ba= -3, D= +2.5, Bp=-1), and appearances on imaging (C; S= symphysis pubis, B= bladder, E= enterocele, R= rectal ampulla). The herniation is filled by a loop of small bowel. Peristalsis often puts the diagnosis beyond doubt. From [15], with permission.*

Enterocoele is frequently overlooked on clinical examination although it is quite common, with a prevalence on imaging of 10-15% of a urogynaecological population[18]. It is associated with symptoms of prolapse and obstructed defecation and can cause voiding dysfunction, likely due to extrinsic compression of the urethra[31]. At defaecography, multiorgan opacification is necessary for the diagnosis of enterocele, and this exposes the patient to a relatively high dose of radiation. Magnetic resonance imaging (MRI) has the advantage of demonstrating all compartments as well as the capability to perform a limited dynamic investigation, but MRI is expensive and not widely available, and dynamic imaging provides for low spatial and temporal resolution compared to ultrasound.

With transperineal imaging it is easy to detect enterocele. In the midsagittal plane. A maximal valsalva will demonstrate downwards movement of iso- to hyperechoic abdominal contents between bladder ventrally and rectal ampulla dorsally, with or without vault prolapse. Small bowel peristalsis may help with the identification of structures filling the hernia. Quite commonly, rectocele and enterocele co-exist in the same patient.

## Anismus

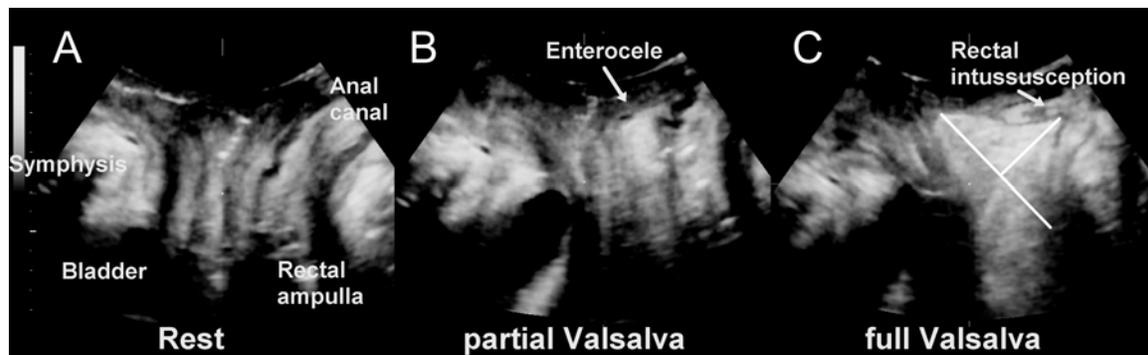
Anismus may be evident as a spastic levator that does not allow descent of pelvic structures during Valsalva. While the diagnosis on principle requires actual defecation, one could argue that a combination of persistent co-activation of the levator ani[32] and the absence of other (anatomical) explanations for obstructed defecation would make a diagnosis of anismus very likely. It is also evident that ‘anismus’ on defecation proctography or MR defecography may often be artefactual due to the highly embarrassing nature of both tests. Any judgment as to the relative performance of the different methods will have to await validation of these competing methods against symptoms, which will require large numbers of patients.



*Figure 5.10: Rectal intussusception on defecation proctography (a) and translabial ultrasound (b). The lines show splaying of the anal canal. In this case the intussusception is propelled by the sigmoid colon, as shown on fluoroscopy. The apex of the intussusciens is indicated by (\*). From [9], with permission.*

## Rectal intussusception and rectal prolapse

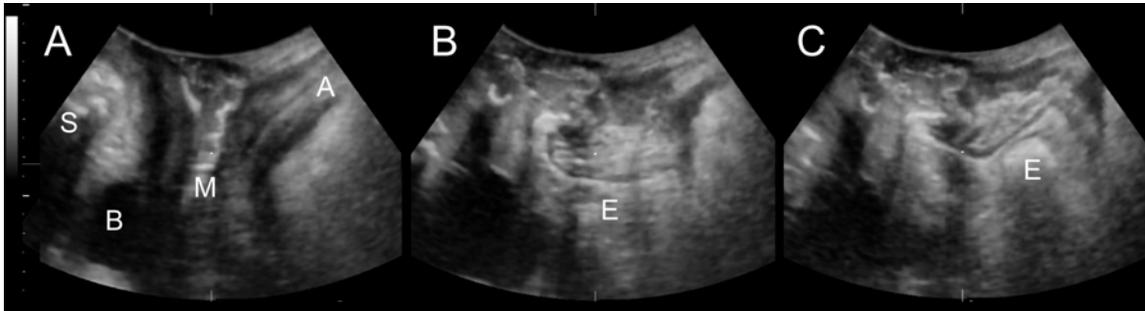
A more severe functional abnormality than rectocele, and much less common at about 4% of a urogynaecological population[33], is rectal intussusception, an inversion of the anterior aspect of the rectal ampulla into the anal canal, akin to a sock being inverted. Rectal intussusception is occasionally demonstrated in women without any symptoms of evacuatory dysfunction, but it is strongly associated with symptoms of obstructed defecation[18] and both arising from such symptoms[19]. However, the method is also capable of demonstrating clinically apparent rectal prolapse. Normally, the anal canal is tubular, with little difference between luminal diameters along most of its length (see Figures 5.3-5.8). In rectal intussusception, rectal wall and small bowel or other abdominal contents (such as, occasionally, the uterus) enter the proximal anal canal, producing an arrow-shaped distension on Valsalva (see Figures 5.10 - 5.13).



*Figure 5.11: Development of a rectal intussusception on Valsalva, midsagittal plane. There is an enterocele which is invisible at rest (A), but during Valsalva it initially compresses the rectal ampulla (B) to then invaginate the rectal mucosa and muscularis (C) into the anal canal which opens up in a typical conical configuration. The lines in (C) illustrate measurement of intussusception depth.*

Occasionally, this may occur after a successful central or posterior compartment procedure such as a vault suspension or a posterior mesh, which converts a vaginal enterocele into an intussusception, with the enterocele descending down the anal canal rather than into the vagina (see Figure 5.12). An abnormally mobile anteverted uterus may impinge on the rectal ampulla and virtually ‘plug’ it on Valsalva, a situation that is termed a ‘colpocele’ by radiologists (see Figure 5.7 and 5.13), and rarely a retroverted

uterus may cause the same effect, with the uterine fundus rather than the cervix forming part of the intussusciens.

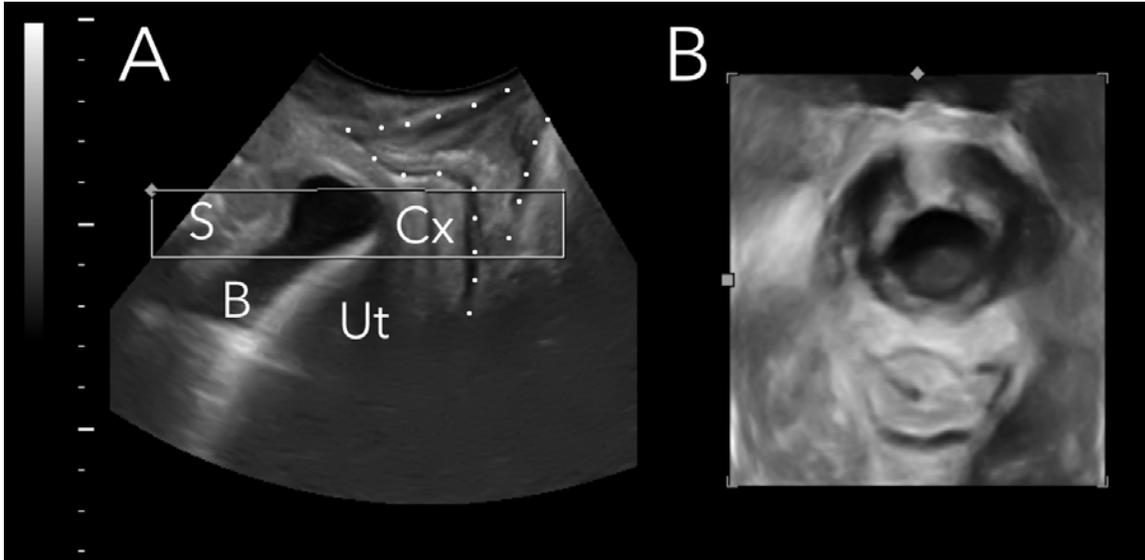


*Figure 5.12: Intussusception after posterior compartment mesh. (A) shows the status at rest, (B) on mild Valsalva, (C) on maximal Valsalva. S= symphysis pubis, B= bladder, M= posterior compartment mesh, E= enterocele/ intussusception. From[34], with permission.*

The appearance of rectal intussusception is pathognomonic, regardless of content, and very similar to images obtained on defecation proctography[9]. If there is overt rectal prolapse, the enterocele will be seen to ‘flow’ through the anal canal, inverting rectal mucosa, until the prolapse exits through the external anal sphincter. The maximal depth of an intussusception may be measured by connecting the most proximal aspects of the internal anal sphincter and measuring to the apex of the intussusception (see Figure 5.11). Demonstrating a rectocele or intussusception may not just be diagnostically useful. Images and video clips can be used to show the patient the cause of her symptoms, and make it apparent that her efforts at forceful evacuation tend to exacerbate the anatomical problem. This may help break the ‘vicious cycle’ of obstructed defecation once the patient understands that her behaviour is making matters worse rather than better.

Rectal intussusception is a particularly interesting condition as it is the one posterior compartment abnormality that is clearly associated with abnormal pelvic floor anatomy. The larger the levator hiatus is, the more likely is intussusception[33], and levator avulsion seems to be a risk factor due to its enlarging effect on the hiatus. Gynaecologists and urogynaecologists, needless to say, tend to ignore the condition as they rarely have a chance to diagnose it unless they use imaging in the work-up of prolapse patients. The author feels that it may be possible to treat rectal intussusception and

possibly even rectal prolapse by providing hiatal reduction surgery[35] and/or a minimally invasive rectopexy, utilising the rectovaginal septum by suspending it to the sacrospinous ligaments. However, it will be many years before such novel procedures are fully evaluated.



*Figure 5.13: First degree uterine descent, with the cervix 'plugging' the anal canal on Valsalva in a patient with obstructed defecation and rectal intussusception. (A) shows the midsagittal plane, (B) a rendered volume in the axial plane, showing moderate hiatal ballooning. S= symphysis pubis, B= bladder, Ut= uterine fundus, Cx= cervix. The intussusception is outlined by dots, with splaying of the anal canal clearly evident.*

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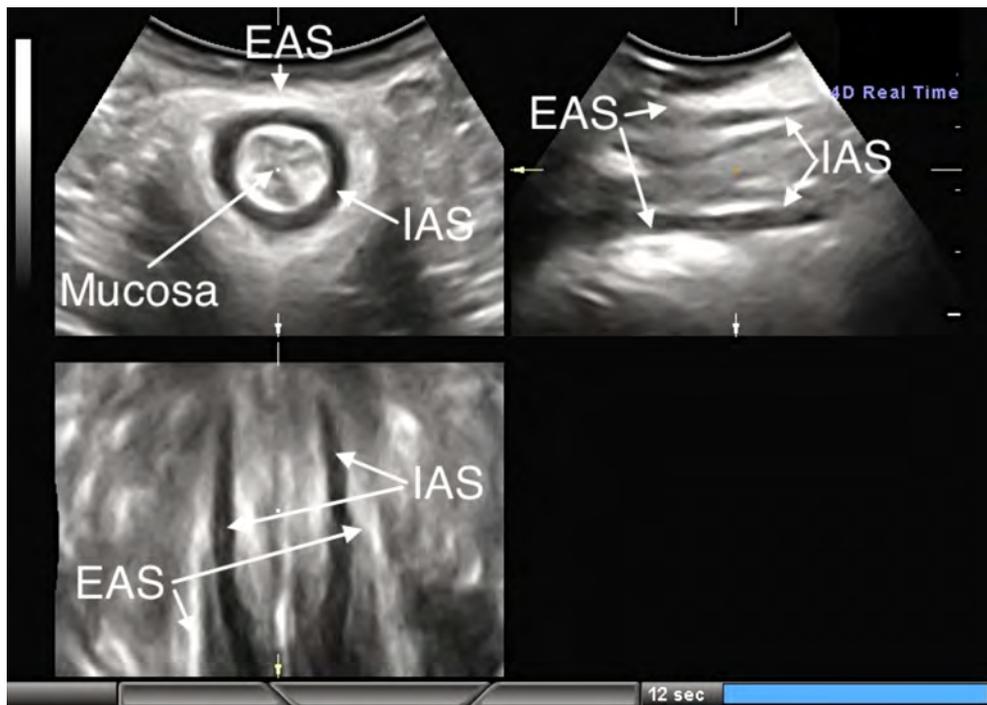
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# Chapter 6

## Anal Sphincter Imaging

To date, the anal sphincter has usually been imaged by endo-anal ultrasound, using high resolution probes with a field of vision of 360 degrees. This method is firmly established as one of the cornerstones of a colorectal diagnostic workup for anal incontinence and covered extensively in the colorectal and radiological literature[1] [2][3][4], and obstetricians have contributed substantially to the popularisation of this technology[5]. Due to the limited availability of ultrasound systems capable of endoanal imaging, Obstetricians and Gynaecologists have taken to using high-frequency curved array probes placed exoanally, i.e., transperineally, [6] [7][8] in the coronal rather than the midsagittal plane as described for all other applications in this text. Over the last few years there is an increasing number of publications using volume ultrasound to image the sphincter [9][10][11][12][13][14], and the author's unit has standardised and validated a tomographic method for demonstrating the entire sphincter [15].

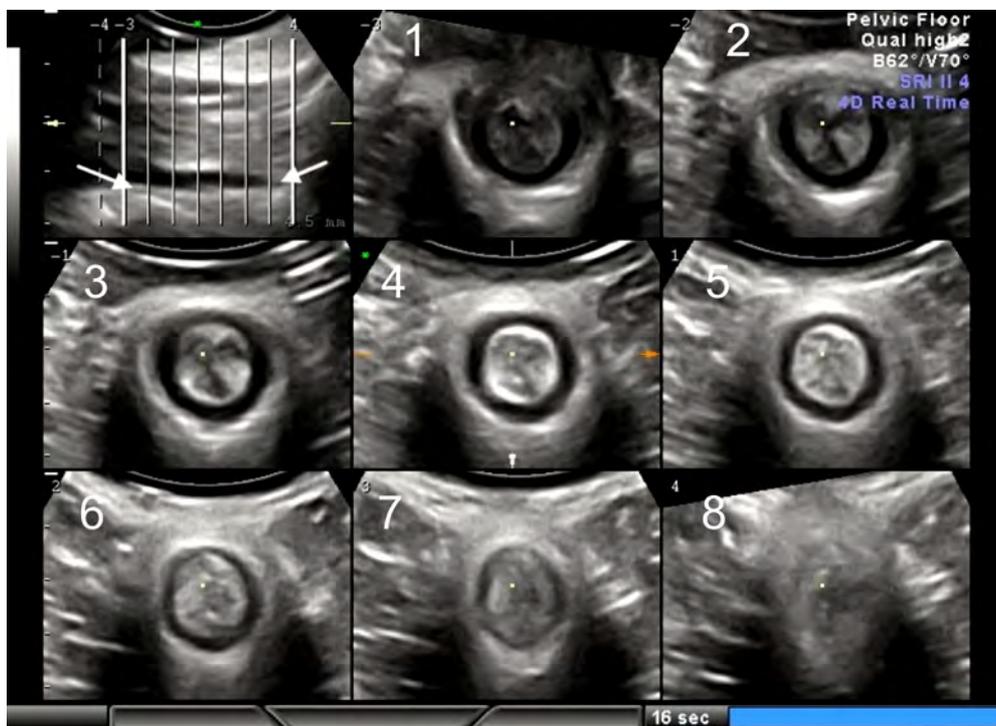


*Figure 6.1: Orthogonal views of EAS, IAS and anal mucosa on 3D/ 4D translabial sphincter imaging. The top left image is the coronal plane, top right is the midsagittal plane, and the bottom left is an axial view of the anal canal.*

This method has the potential to replace endoanal imaging. Reduced cost and minimal inconvenience for the patient are already leading to enhanced research capabilities, with multiple publications in the last few years. Systems capable of

exoanal sphincter imaging are increasingly widespread and much cheaper and more versatile than those used for endoanal scanning, resulting in greater clinical use. Hopefully this will allow maternal birth trauma, ie., levator and anal sphincter trauma, to become a key performance indicator of maternity services[16].

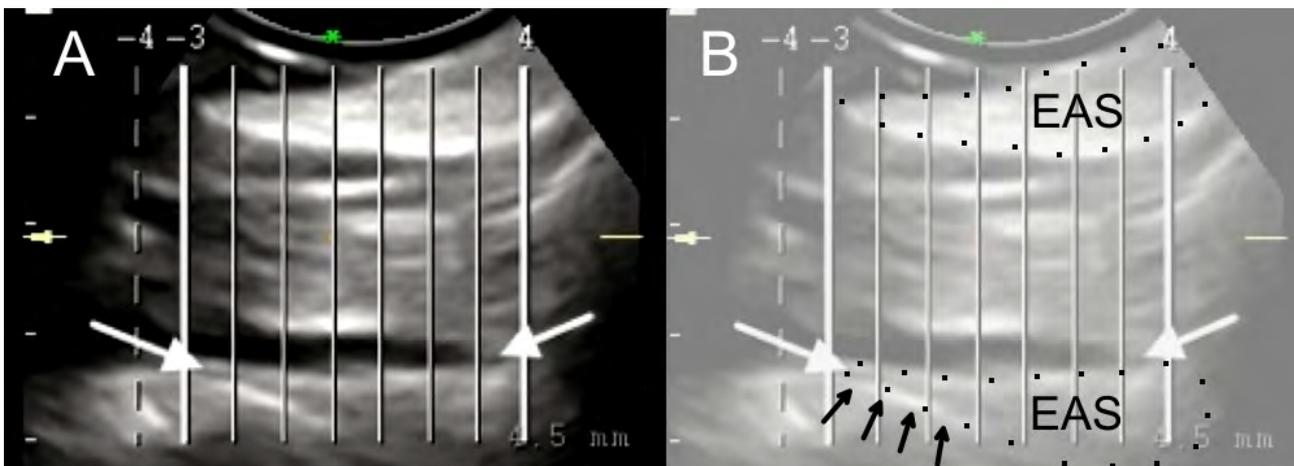
Volume transducers have the advantage of an inbuilt ‘standoff pad’ due to the fact that a curved array of piezoelectric crystals is oscillating in an oil bath rather than being in direct contact with the patient’s skin. A transverse transducer placement (as shown in Figure 2.3) also makes it easier to keep a minimum distance from the structures in question, allowing focussing in the area of greatest interest, ie., the first 2 cm. Acquisition angles and aperture are reduced relative to imaging for the levator and prolapse. Harmonics are set to high, and frequencies maximised to allow for optimal resolutions. The resulting orthogonal views are shown in Figure 6.1, and Figure 6.2 shows appearances in a normal nulliparous patient in the three orthogonal planes (6.1) and in a tomographic representation (6.2).



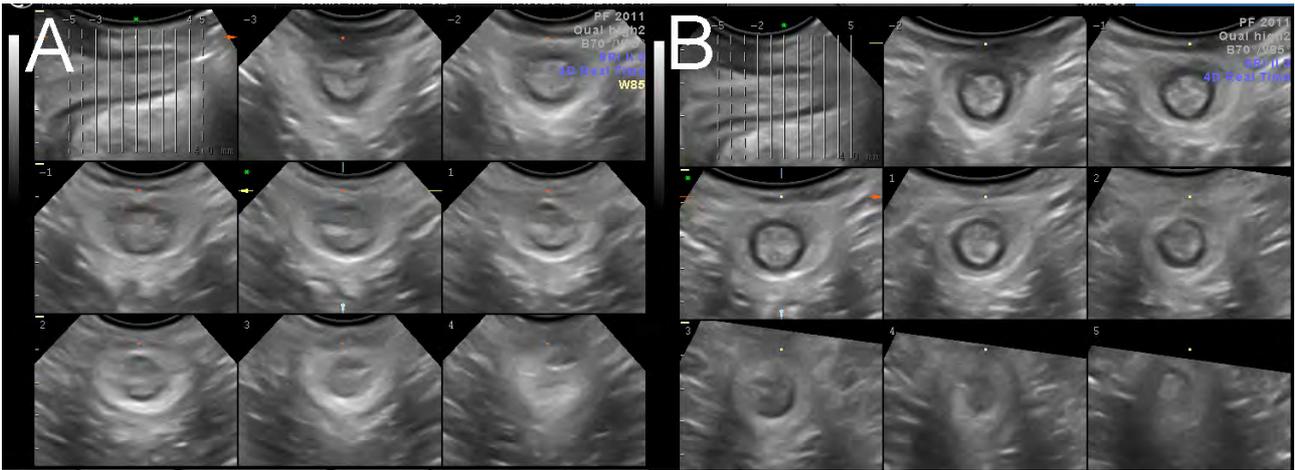
*Figure 6.2: Tomographic translabial imaging of a normal anal sphincter in nulliparous patient. The top left hand image shows the midsagittal plane, the remaining 8 images represent coronal slices through the anal canal. The location of those slices is given by the vertical lines in the midsagittal plane. Slice 1 is represented by the leftmost vertical line in the top left image, slice 8 is the bold line at the right of the midsagittal plane image. The arrows illustrate the landmarks used to place these slices in the midsagittal plane: the left arrow indicates the cranial margin of the EAS, the right arrow the caudad margin of the IAS. Slice 1 is located above the EAS, slice 8 below the IAS within the subcutaneous component of the EAS.*

Imaging is usually undertaken on pelvic floor muscle contraction as this seems to enhance tissue discrimination. The mucosa is visualized as a hyperechoic area, often star-shaped, representing the folds of the empty anal canal[7]. The internal anal sphincter (IAS) is seen as a hypoechoic ring, the external anal sphincter (EAS) as an echogenic structure surrounding the internal sphincter. There may be some variation of appearances depending on age and hormonal status, and at times subdivisions of the EAS can be identified. On contraction the anal canal narrows slightly, the mucosal star may be less pronounced, and defects of the sphincter will become more obvious.

On ultrasound, sphincter defects appear as a discontinuity of the ring structures of the external and/ or internal anal sphincters. In the coronal plane, defects are conveniently described using a clock face notation. In the longitudinal plane sphincter defects can be described by measuring the length of the defect relative to total sphincter length. The internal anal sphincter (IAS), while very clearly visible, seems to commonly show deficiencies ventrally (between 10 and 2 o'clock) even in nulliparae. It is therefore not surprising that IAS defects seem less predictive of anal incontinence than EAS damage[15].



*Figure 6.3: The crucial step in tomographic imaging of the anal sphincter is identification of the fascial plane between levitator ani and external anal sphincter and hence the cranial termination of the EAS. The arrows in A show the cranial margin of the external anal sphincter (left arrow) and the caudal margin of the internal anal sphincter (right arrow). The latter is required since the termination of the subcutaneous EAS is often obscured by artefact due to the proximity of skin and folds of the anal verge. The vertical lines in A show the location of eight slices, with the leftmost slice placed cranial to the EAS margin, the rightmost slice couched to the IAS termination. B shows the extent of the EAS (dotted line) and the location of the fascial plane (black arrows) between EAS and puborectalis muscle.*



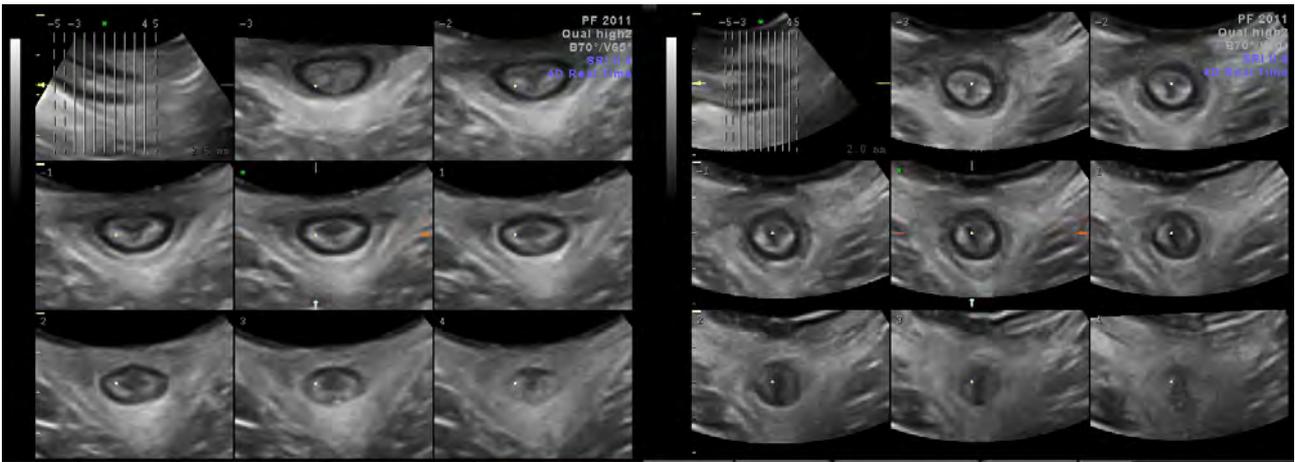
*Figure 6.4: Transverse transducer placement markedly improves tissue discrimination as the primary transducer plane provides for optimal beam forming and focussing.*

Care needs to be taken to retain the entire external anal sphincter within the field of vision towards the end of the maneuver. Transverse transducer placement improves tissue discrimination (see Figure 6.3). The operator needs to minimise pressure on the perineum, especially if it is deficient, to distance the EAS as much as possible from the transducer surface, and to avoid compression of the sphincter (Figure 6.4).

While several studies have been undertaken to compare exo-anal with endoanal sphincter imaging, none of those studies has validated the different methods against symptoms. One of the most recent studies claimed that translabial 4D imaging underestimated EAS defects, but of course it is the other way round: endoanal imaging distends defects, overestimating their size.

Validation of competing methods can be undertaken by testing the sensitivity and specificity of those methods for the prediction of symptoms of fecal incontinence, similar to what will be required to test the relative performance of translabial ultrasound, defecation proctography and MR defecography. To show superior performance of one method over another (ie., statistically significantly different areas under the curve on ROC statistics) will likely require large data sets and may even be impossible. Such proof may at any rate be seen as of limited relevance by those that appreciate the much greater availability and convenience of exo-anal imaging. It is already clear that defects seen on exoanal or transperineal imaging are associated with anal incontinence, both postpartum after repair of obstetric anal sphincter injuries (OASIS)[11] and in later life[15]. Tomographic imaging allows for easy documentation of the entire EAS from the subcutaneous aspect of the EAS to its cranial termination which is identified dorsally to avoid any confounding effect of OASIS (see Figure 6.2). This method should enhance repeatability and allows for

much easier demonstration of the extent and severity of the defect compared to endo-anal imaging.



*Figure 6.5: Imaging of the anal sphincters is improved if one avoids any degree of pressure on the perineum. This is facilitated by generous amounts of gel placed centrally.*

A ‘residual anal sphincter defect’ has been defined as a defect of 30 degrees or more in the circumference of the EAS in at least 4 out of 6 slices (Figure 6.5), and this seems to distinguish well between symptomatic and asymptomatic women. Based on the 2/3 rule used in endoanal ultrasound (ie., 2 out of 3 slices need to show a defect of 30 degrees or more in order for a diagnosis of a ‘residual external anal sphincter tear’ to be made), we require a defect of 30 degrees or more to be seen in 4/6 tomographic slices (see Figure 6.6). However, further work is needed before the method can be regarded as fully standardised, since endo-anal ultrasound likely over-estimates defects due to distension of the anal canal by the probe and direct comparison of findings may be inappropriate.

In the meantime it is possible to describe a range of abnormal appearances. Residual anal sphincter defects are common in women after a first vaginal delivery, at between 10 and 25% [12][17], with much higher rates after Forceps, which is the main clinical risk factor with an odds ratio of between 3 and 5, similar to what is commonly observed for clinical sphincter trauma. In general, anal sphincter injuries seem to occur much more frequently than previously reported, although this may well be due to ineffective intrapartum detection rather than covered, truly ‘occult’ defects [17]. Either way, prevalence figures given in the literature are very likely to be substantial underestimates and comparisons between studies, institutions or individuals are near-useless until such time as standardised imaging information is available.

The greatest utility of sphincter imaging will likely be in postnatal follow-up, especially after a first vaginal delivery. Immediately after childbirth and for the first few days after a repair appearances are usually very confusing. Intrapartum imaging

is unlikely to be of assistance. For the first few weeks, suture material, oedema and haematoma can impair appearances to such a degree that imaging is very difficult. A steady state seems to be reached after 10-12 weeks when such imaging is best undertaken. Further improvement of appearances after this time seems unlikely [13].

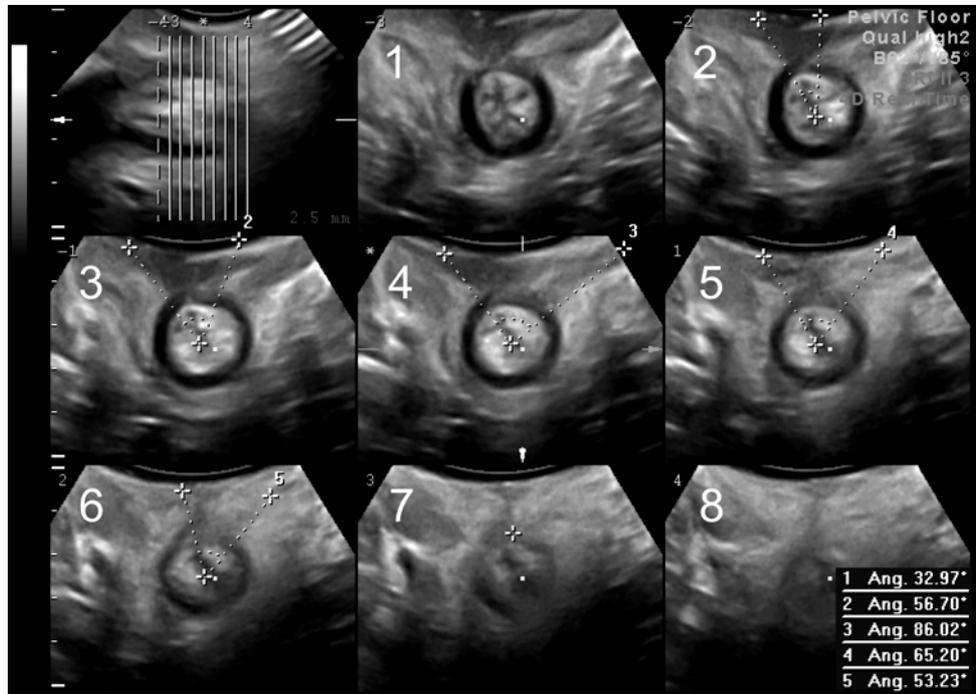


Figure 6.6: Old EAS defect demonstrated in slices 2-6, with angle measurements between 32 and 86 degrees. The defect also seems to affect slices 7 and 8 but at less than 30 degrees circumference.

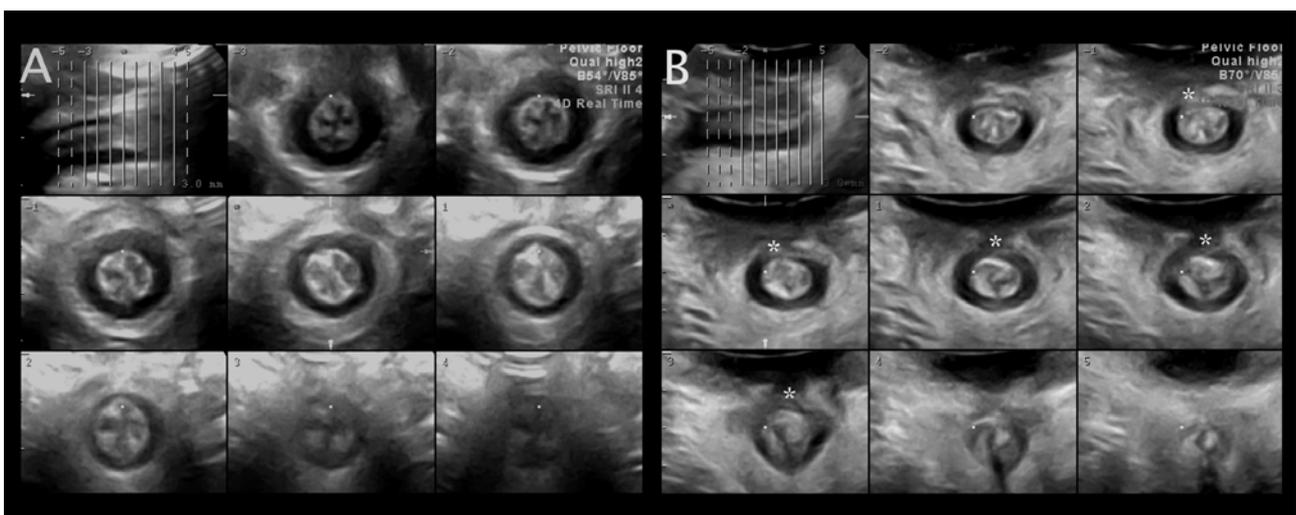
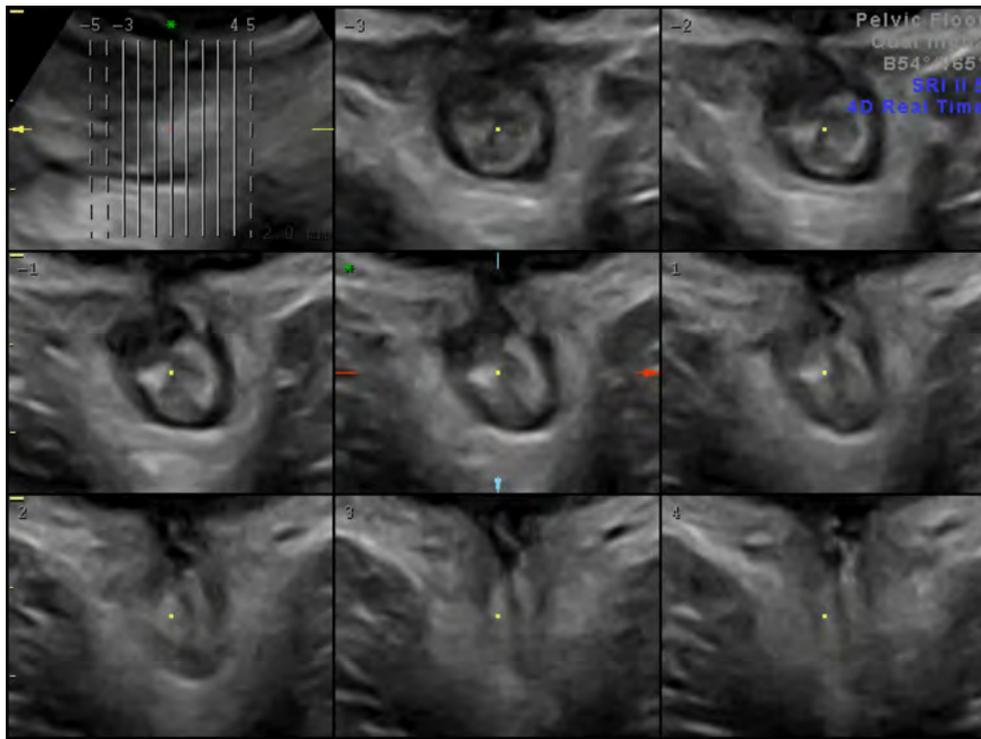


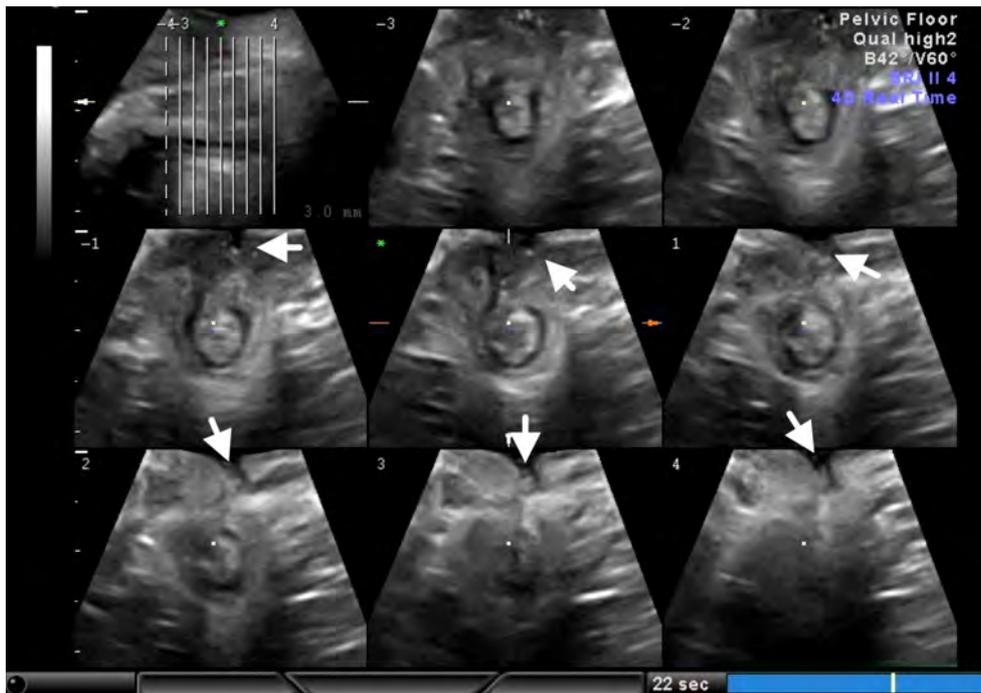
Figure 6.7: A comparison of pre- and postnatal imaging in a primiparous patient before and after an undiagnosed and unrepaired 3B tear. In Delivery Suite attending staff documented a 2nd degree perineal tear. The defect is indicated by a '\*’.



*Figure 6.8: A 3c tear after end to end repair. It is evident that a substantial defect remains which affects the entire EAS and most of the IAS.*

Figure 6.7 demonstrates typical findings in a patient with an undiagnosed, unrepaired anal sphincter injury, before and after childbirth. The clinical diagnosis in this case was of a 2nd degree tear. The retracted ends of the EAS are not re-approximated, and there is none of the distortion and suture material that is commonly seen a few months after OASIS. Imaging women after a first vaginal birth is likely to uncover a large proportion of undiagnosed tears. If individuals and institutions were truly interested in practice improvement, ie., better detection and management of maternal birth trauma, then postnatal imaging would be required [16]. Another obvious benefit would be the opportunity to audit results after OASIS repair. A large proportion of women after OASIS will show residual defects, and such defects are associated with symptoms of anal incontinence even very few months after childbirth [11]. However, any attempt at improving outcomes, whether by clinical audit or randomised controlled intervention trials, will have to use sphincter imaging as an intermediate outcome measure as anal incontinence often has a substantial latency, ie., it takes many years to develop after a sphincter tear.

After repair of 3<sup>rd</sup> and 4<sup>th</sup> degree tears ultrasound commonly demonstrates residual defects (see Figures 6.8-9), and the extent of such incompletely or inadequately repaired defects seems associated with decreased sphincter pressures and an increased risk of anal incontinence. Figure 6.8 shows an inadequate end to end repair with substantial residual defect, Figure 6.9 is a similarly disappointing result after an overlap repair of a 3c tear, and Figure 6.10 shows a small rectovaginal fistula after repair of a 3c tear.



*Figure 6.9: Status after unsuccessful overlap repair of a 3c tear, showing substantial distortion and a marked perineal scar (arrows). The patient was fecally incontinent.*

Childbirth and obstetric trauma is by far the dominant cause of anal sphincter defects and a major and growing source of obstetric litigation worldwide[18]. The main risk factor is considered to be instrumental vaginal delivery[19], with Forceps more risky than Vacuum[12]. Anal incontinence is common after third and fourth degree tears, even if they are recognized and repaired at the time of injury, and can have a devastating effect on a woman's quality of life. The condition may have been underreported due to the social stigma involved. Early recognition and repair of sphincter injuries are likely to be of benefit[20]. Pelvic floor ultrasound is likely to play a major role in the evaluation of patients after traumatic delivery, and in practice improvement activities in this field as it is almost universally available due to the widespread uptake of 3D/ 4D imaging by perinatal ultrasound departments. The main obstacle is not cost (which would be minimal) but rather the limited availability of teaching. In some jurisdictions, such as in the UK, Australia and New Zealand, there may also be substantial political resistance to any diagnostic intervention that draws attention to negative consequences of vaginal childbirth due to the irrational fixation of midwives, administrators, politicians and some obstetricians on Caesarean Section rates [16]. In these jurisdictions, change may only occur due to public and medicolegal pressure, and the most urgent task is to reduce Forceps deliveries[21].

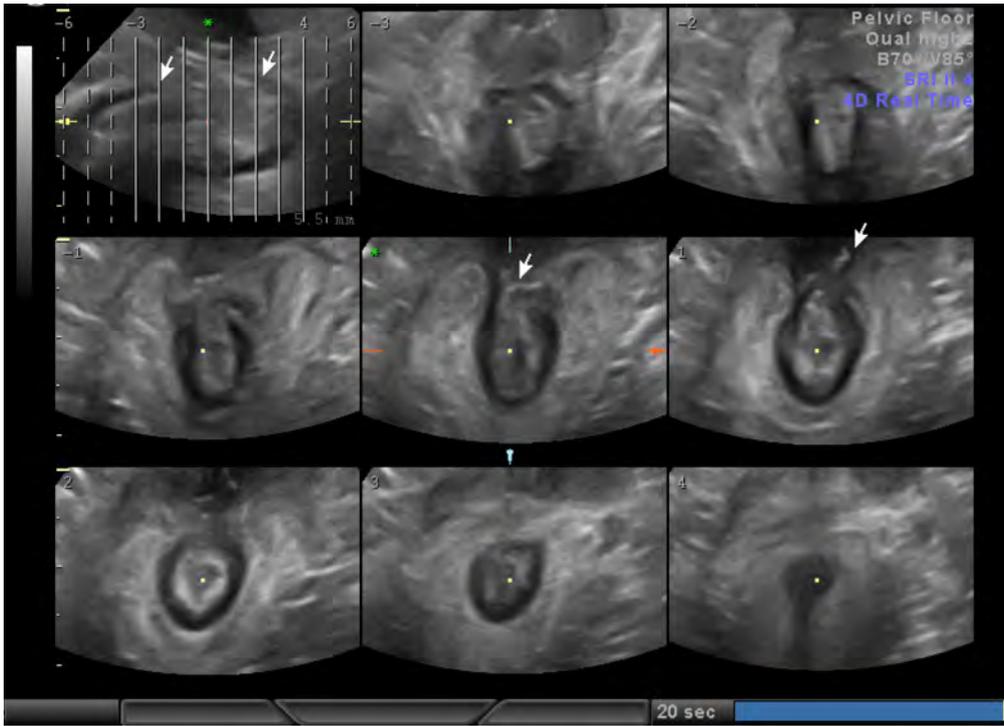


Figure 6.10: Small rectovaginal fistula 3 months after insufficiently repaired 3c tear. The fistula is a small filiform echogenic line, indicated by arrows in two central slices. The two arrows in the top left hand image indicate the longitudinal extent of the internal anal sphincter defect.

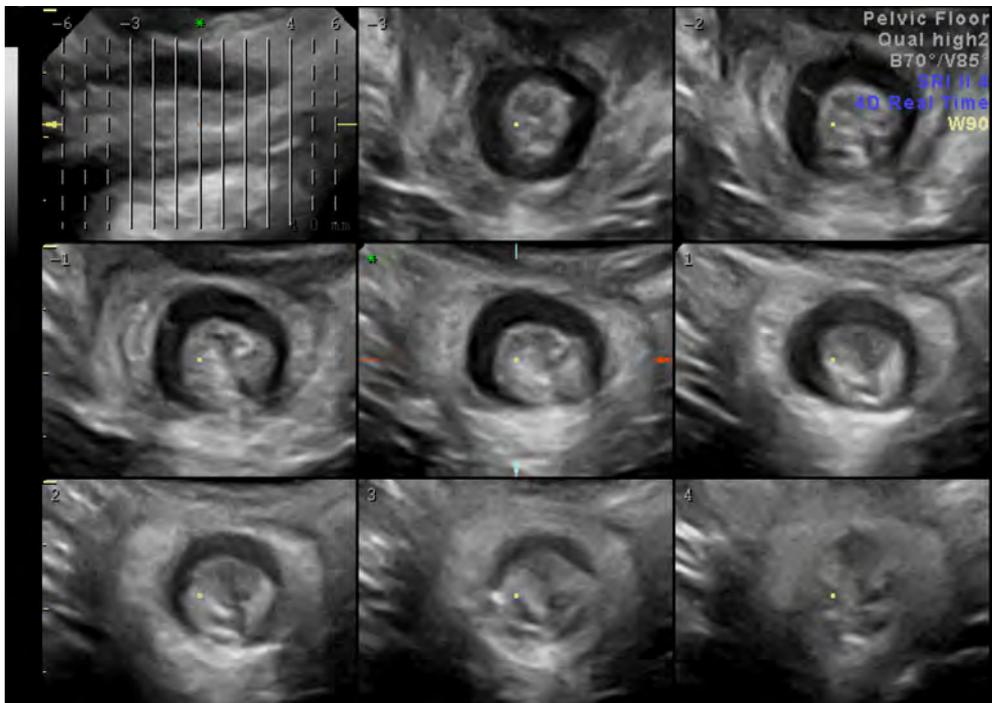
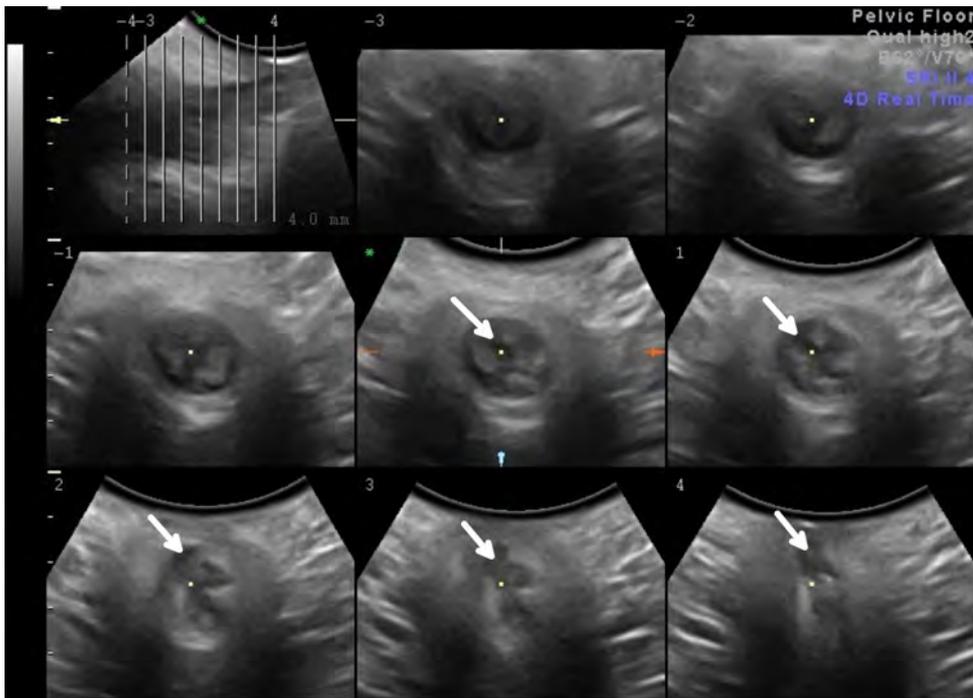


Figure 6.11: Status after hemorrhoidectomy in 60 year old patient with mild anal incontinence. The internal anal sphincter is invisible between 4 and 7 o'clock in most slices and thickened over the remaining circumference, indicating iatrogenic trauma.

Finally, it should be mentioned that translabial 3D/ 4D imaging of the anal sphincter may also have benefits for colorectal surgeons who unfortunately are much less likely to have access to suitable equipment and tend to use endo-anal ultrasound. Figure 6.11 shows typical appearances after a hemorrhoidectomy during which the internal anal sphincter was inadvertently split in the 5 o'clock position. In fact, occasionally hemorrhoids themselves are visible on translabial imaging. They are apparent as anechoic structures filling the mucosal star, extending to the anal verge. Sometimes they interfere with tomographic imaging as they can obscure the distal margin of the internal anal sphincter, especially if inflamed, as in Figure 6.12.



*Figure 6.12: Inflamed hemorrhoid on tomographic imaging, indicated by arrows. Hemorrhoids can obscure the distal aspect of the internal anal sphincter and sometimes even the EAS, interfering with the assessment.*

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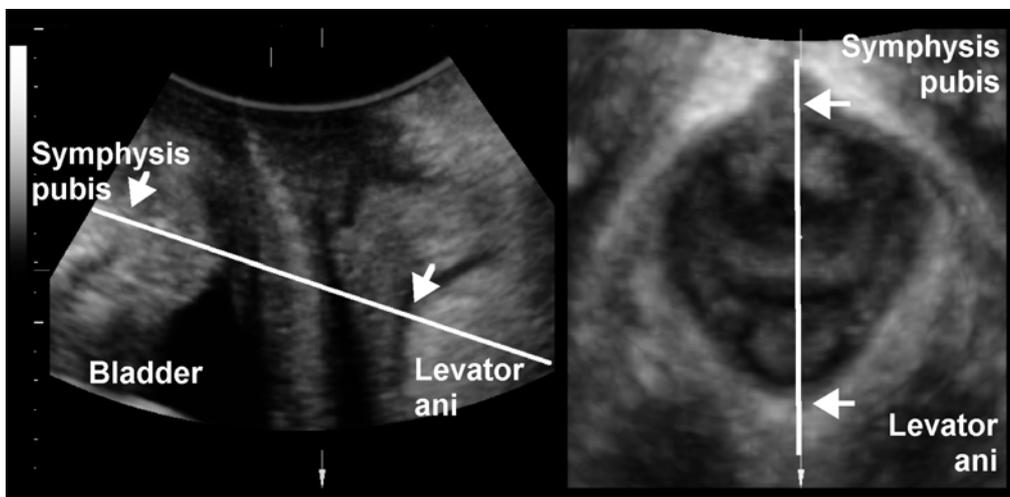
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# Chapter 7

## Levator Assessment

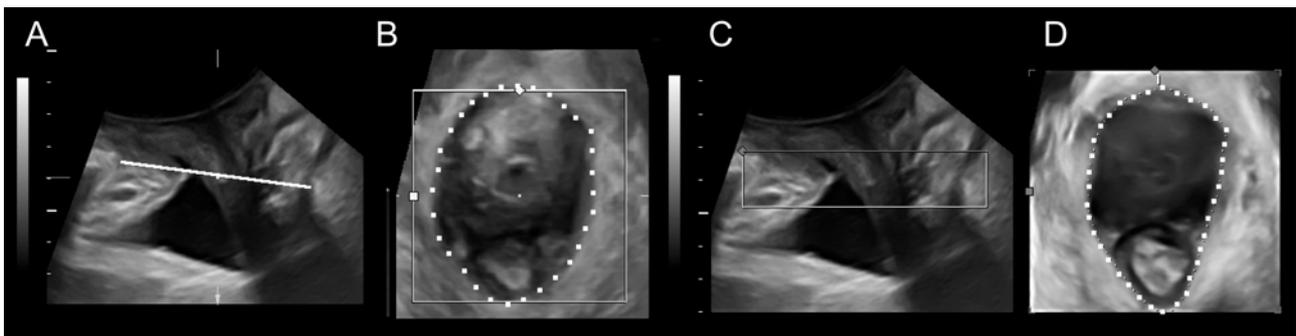
The topic of pelvic floor assessment- that is, the evaluation of the levator ani muscle complex- is increasingly attracting attention. This is due to the realisation that a majority of vaginally parous women is affected by some form of pelvic floor trauma[1][2][3]. We now know that 'pelvic floor trauma' is much more than what we were taught to identify in delivery suite, ie., perineal and anal sphincter trauma. In about half of all women after vaginal childbirth there is substantial alteration of functional anatomy affecting the puborectalis component of the levator ani muscle[2]. The integrity of this structure, which encloses the largest potential hernial portal in the human body, is currently the best- defined aetiological factor in the pathogenesis of prolapse[4]. Hence, the assessment of a patient with female pelvic organ prolapse is incomplete without evaluation of the levator ani.

Until recently, imaging of the levator ani or pelvic floor muscle required magnetic resonance imaging. The universal introduction of simple, practical 3D/ 4D ultrasound systems has entirely changed this situation, making anatomical and functional assessment of the levator accessible to the majority of obstetricians and gynaecologists in developed countries, and to many in the developing world.



*Figure 7.1: Determination of hiatal dimensions: The left hand image shows the location of the plane of minimal dimensions as seen on the midsagittal view. This plane is tilted in a ventrocaudal to dorsocranial direction as evidenced by the line transecting the image running from the posterior surface of the symphysis to the anterior margin of the most central aspect of the puborectalis loop (arrows). The right image represents the plane of minimal dimensions in the axial or C plane, with the vertical line showing the location of the midsagittal plane. Arrows identify the minimal sagittal diameter of the hiatus. From[9], with permission.*

The inferior aspects of the levator ani were identified in early studies using transvaginal techniques[5] and translabial freehand volume acquisition[6] as well as on translabial ultrasound using a Voluson system[7], but the focus of these reports was on the urethra and paraurethral tissues. With translabial acquisition, the entire levator hiatus and surrounding muscle (puborectalis or pubovisceralis muscle) can be visualized, provided acquisition angles are at or above 70 degrees, although angles of 80 or 85 degrees are preferable in the assessment of female pelvic organ prolapse. As with MR imaging, it is currently very difficult to distinguish the different components of the pubovisceral or puborectalis/ pubococcygeus complex. However, this seems unnecessary both for anatomical and functional assessment.



*Figure 7.2: Hiatal area measurement. A and C show the midsagittal plane. B demonstrates hiatal area measurement in a single axial plane, D the same measurement in a rendered volume of 1-2 cm thickness placed between the symphysis pubis and the anorectal angle. From [14], with permission.*

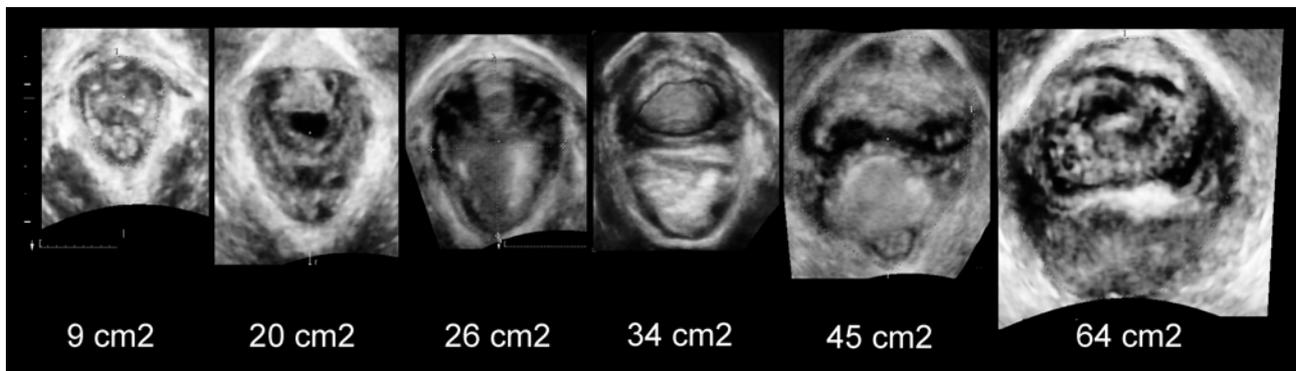
A number of studies have demonstrated findings in nulliparous women, with no major asymmetries of the puborectalis muscle found on MRI[8] and on ultrasound[9] [10], supporting the hypothesis that significant morphological abnormalities of the levator are likely to be evidence of delivery- related trauma (see below). As regards biometric parameters of the puborectalis complex and the levator hiatus, there has been good agreement between 3D ultrasound and MRI, both for dimensions of the levator hiatus[9][11] and levator thickness[9][12].

In general, it is to be expected that ultrasound measurements should be more reproducible due to the ease with which measurements in the axial plane can be obtained in the plane of minimal dimensions, whether at rest, on Valsalva or on pelvic floor muscle contraction. This is largely due to the real time nature of pelvic floor ultrasound and the fact that it acquires true volumes, allowing planes for measurement to be determined arbitrarily, and at any time after the acquisition. On MRI, the plane of minimal dimensions is difficult to image reproducibly due to slow acquisition speeds, even of single predefined planes.

Figure 7.1 demonstrates the process of obtaining the plane of minimal dimensions in a true axial plane on translabial ultrasound. Another option for hiatal area

measurements is the use of rendered volumes which may compensate for the non-euclidean or 'warped' nature of the levator hiatus, especially on Valsalva in women with significant prolapse[13][14], as shown in Figure 7.2. However, not all 3D ultrasound systems allow measurements in a rendered volume, limiting the utility of this technique.

Mesasurement of hiatal dimensions by translabial ultrasound is highly reproducible [9][15][16][17]. There is marked inter-individual variation of hiatal dimensions in nulliparae[9], and the degree of distension required to deliver a term baby vaginally varies widely as a result[18]. It is not surprising that the hiatus is irreversibly overdistended in many women[2]. Limits of normality for hiatal distensibility have been defined both as mean + 2 standard deviations in nonpregnant nulliparae[9], and with the help of receiver operator characteristics statistics in symptomatic women[19], with both approaches yielding a cut-off of 25 cm<sup>2</sup>. This can be stratified into mild (25- 29.9 cm<sup>2</sup>), moderate (30-34.9 cm<sup>2</sup>), marked (35-39.9 cm<sup>2</sup>) and severe (40 cm<sup>2</sup> or more). Excessive distensibility of the hiatus ('ballooning'), whether as a result of childbirth or congenital, is associated with symptoms and signs of prolapse[19] and with the complaint of vaginal laxity[20]. Figure 7.3 shows the enormous variation in hiatal dimensions that may be encountered, even in parous women.

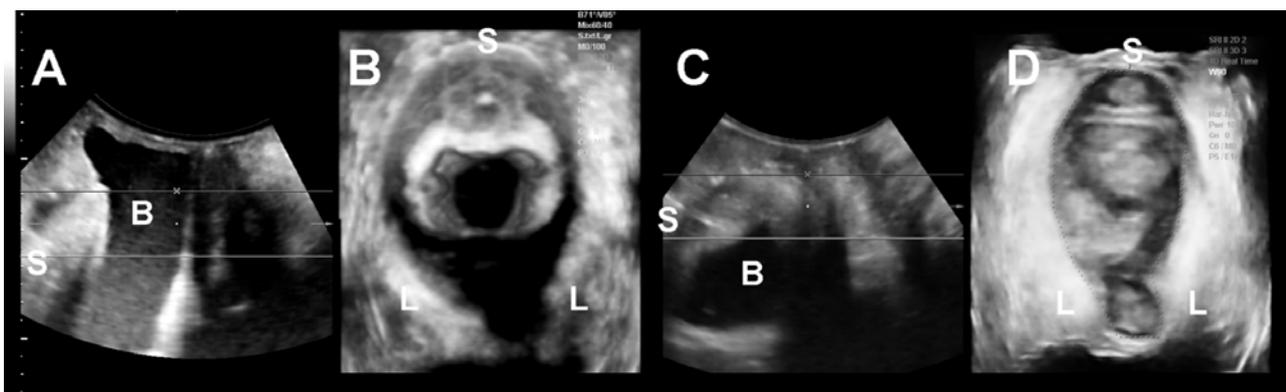


*Figure 7.3: The variation in hiatal dimensions on Valsalva is huge, even in vaginally parous women. Measurements between 6 and 68 cm<sup>2</sup> have been obtained by the author, equivalent to Gh+Pb measurements of between 4 and 14 cm.*

Relative enlargement of the hiatus on Valsalva is clearly a measure of compliance or elasticity which may influence the progress of labour[21][22], pelvic floor trauma and future prolapse. The degree to which voluntary or involuntary activation of this muscle influences the measurement of hiatal distension[23] has however limited its utility as a biometric measure. In short, while hiatal dimensions and/ or distensibility seems to influence labour outcome, it is probably not strong enough a predictor to be used in clinical practice.

On the other hand, vaginal childbirth most obviously impacts on width and distensibility of the hiatus, with the first baby having the most marked effect[24]. In some, there is no change whatsoever even after a difficult Forceps delivery, but in others a normal birth of a small baby results in irreversible overdistension. And finally, hiatal dimensions are likely to affect treatment outcome if (or when) treatment for pelvic floor dysfunction becomes necessary. Marked enlargement of the levator hiatus on Valsalva ('ballooning') is likely to reduce the likelihood of successful pessary management, and it also makes successful prolapse correction less likely[25]. In women with a hiatal area on Valsalva of over 40 cm<sup>2</sup> there seems to be a high likelihood of posterior compartment prolapse after a colposuspension procedure or a large cystocele after sacrospinous colpopexy.

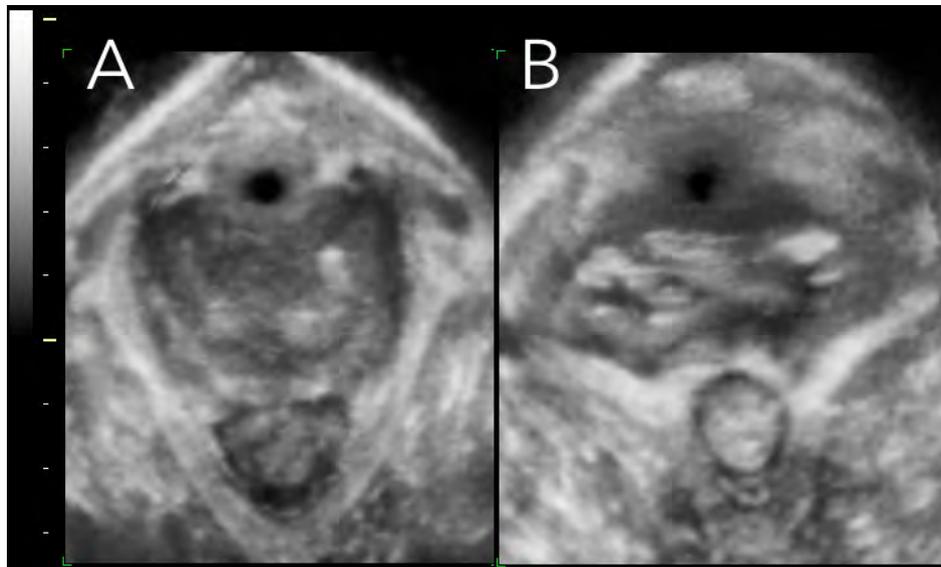
To date, very few attempts at addressing hiatal overdistensibility have been documented in the world literature. In the 1970s, an Australian surgeon proposed a highly invasive levatorplasty to reduce hiatal dimensions[26], although high morbidity prevented more general uptake of the technique. Most recently, the author has proposed a minimally invasive levatorplasty, the 'puborectalis sling procedure', [27] which is currently the subject of a multi centre randomised controlled trial. Figure 7.4 shows successful hiatal reduction in a patient after 'puborectalis sling'.



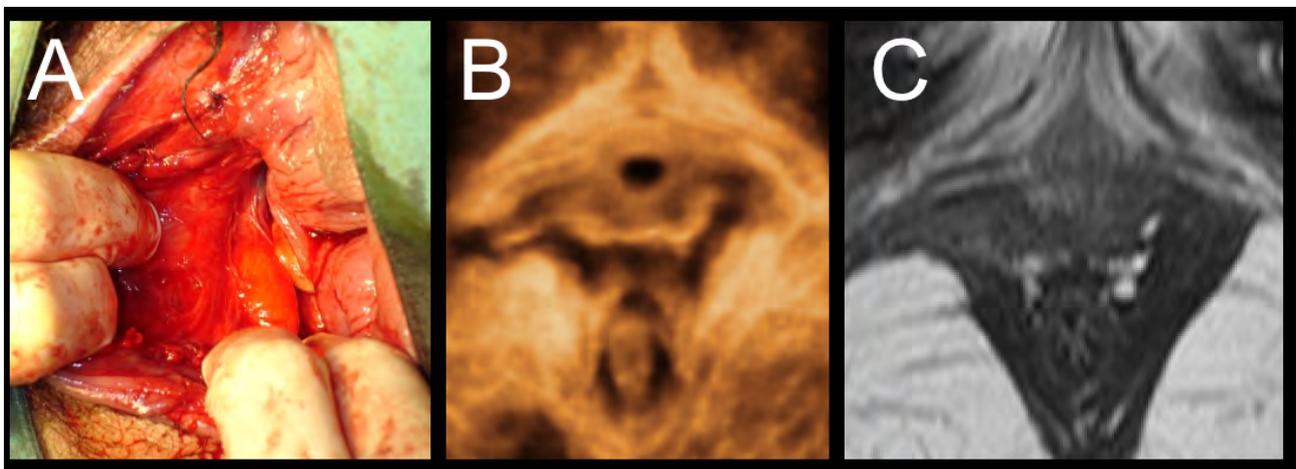
*Figure 7.4: Surgical reduction of the levator hiatus. A and C are representations of the midsagittal plane, B and D show the axial plane of minimal hiatal dimensions. A and B were obtained before a 3- compartment prolapse procedure, C and D six months postoperatively. The hiatus has been reduced from 40 to 24 cm<sup>2</sup>.*

The commonest morphological abnormality of the levator ani, a unilateral avulsion of the pubovisceral muscle off the pelvic sidewall, is clearly related to childbirth (see Figures 7.5-7.6 and 7.9- 11) and is palpable as an asymmetrical loss of substance in the inferomedial or ventrocaudal portion of the muscle, that is, the portion of the levator ani muscle that inserts on the inferior pubic ramus. Such abnormalities have been described in cadavers[28], although this may require tomography as levator defects are difficult to identify on dissection. Immediately after childbirth, diagnosis

is often difficult as most such tears are occult. However, occasionally an avulsion is exposed by a large vaginal tear such as the one seen in Figure 7.6.



*Figure 7.5: Bilateral avulsion injury as seen on rendered volume. The left image was obtained at 37 weeks' gestation in a nulliparous patient. The right image shows a bilateral major defect of the pubovisceral muscle 4 months after vaginal delivery in the same patient.*



*Figure 7.6: Right-sided puborectalis avulsion after normal vaginal delivery at term. The left hand image shows appearances immediately postpartum, with the avulsed muscle exposed by a large vaginal tear. The middle image shows a rendered volume (axial plane, translabial 3D ultrasound) 3 months postpartum, and the right hand image shows magnetic resonance findings (single slice in the axial plane) at 3.5 months postpartum. Modified with permission, from[29].*

The digital detection of morphological abnormality was first described over 70 years ago[30] and is eminently feasible[31][32] but seems to require significant training[33][34]. In women with poor resting tone and minimal or absent voluntary function, defects may be difficult to detect by digital examination. Thinning of muscle, which may be obvious on imaging, is harder to palpate than gaps in the continuity of the muscle or complete absence as in avulsion injury. Bilateral defects (see Figure 7.5) may also be more difficult to palpate due to the lack of asymmetry, but they are not uncommon.

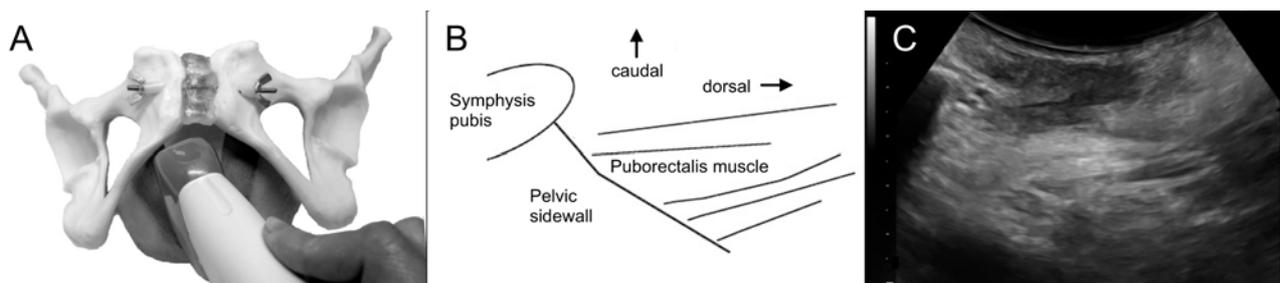


Figure 7.7: Demonstration of levator integrity on 2D translabial ultrasound in an oblique parasagittal plane: transducer orientation is shown in (A), a schematic drawing in (B) and appearances of a normal puborectalis in (C).

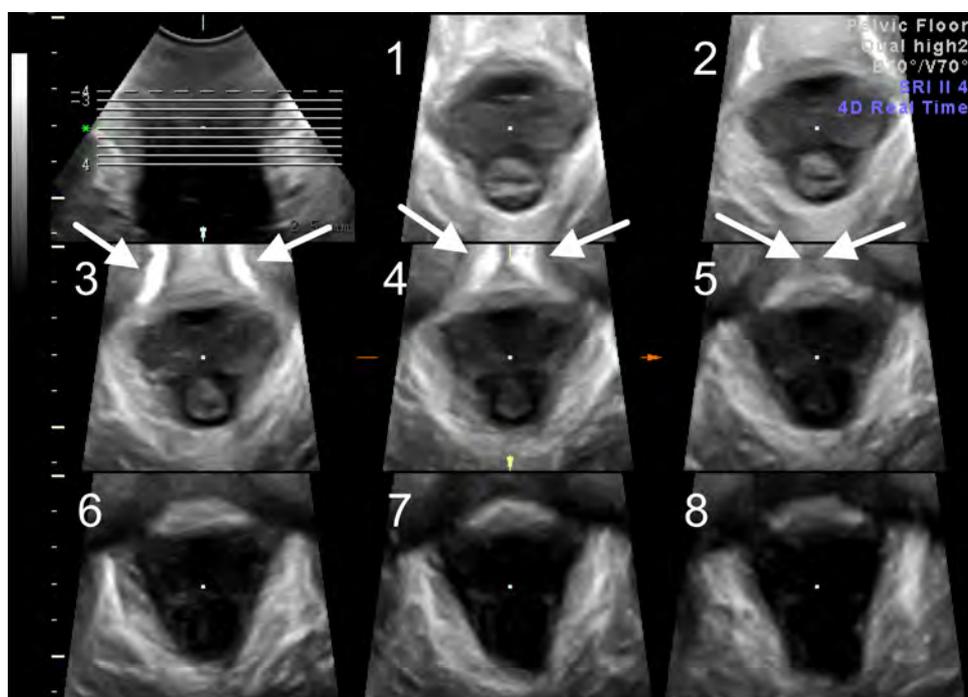
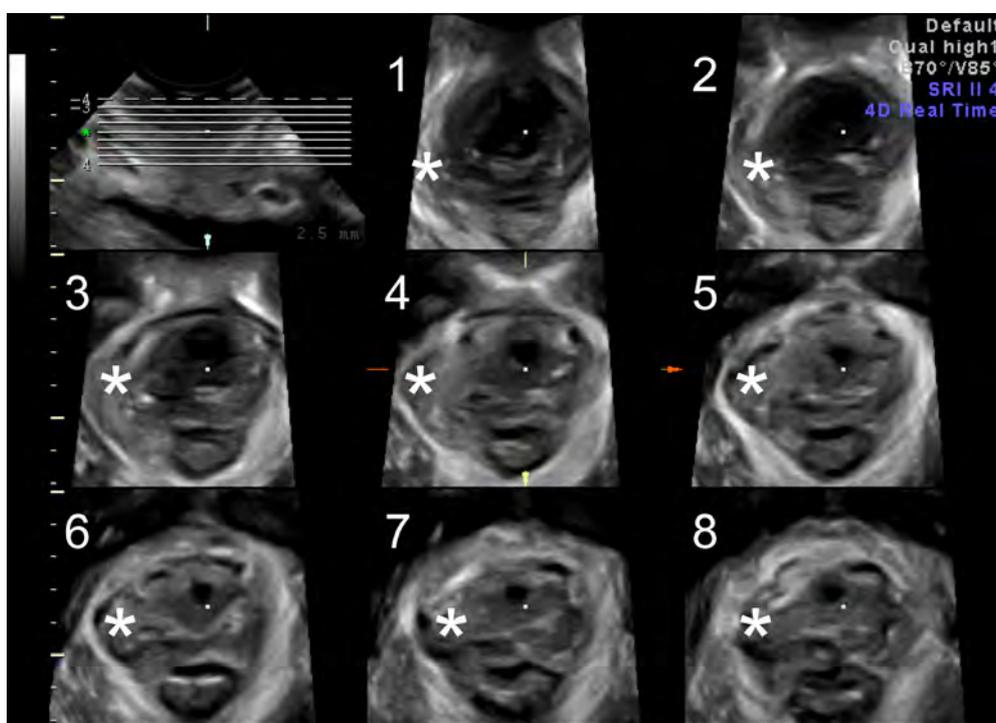


Figure 7.8: Tomographic imaging of a normal levator in a nulliparous patient on pelvic floor muscle contraction. This orientation is obtained by identifying the plane of minimal hiatal dimensions as in 7.1 or 7.3 and adding parallel slices at 2.5 mm interstice interval. The arrows indicate the symphysis pubis which appears open in slice 3, closing in slice 4 and closed in slice 5.

The detection of avulsion defects by translabial 3D/ 4D ultrasound is usually undertaken on pelvic floor muscle contraction to enhance tissue discrimination. It seems highly reproducible[35][36]. Both rendered volumes (surface/ transparency mode, rendered from caudally to cranially) and single slices in the C or axial plane may be utilized to help with the identification of defects, and on principle it is even possible to diagnose avulsion on 2D translabial ultrasound[37]; see Figure 7.7. However, tomographic imaging (TUI) of the puborectalis[38][38] seems to be the most reproducible and convenient method, and it is at least equivalent to MR imaging of levator avulsion [39][40]. Figure 7.8 shows a standard representation of a normal pelvic floor on TUI, with the interstice interval set to 2.5 mm, and the central slice showing the symphysis pubis closing medially. This technique is very likely to enclose the entire puborectalis muscle[41].

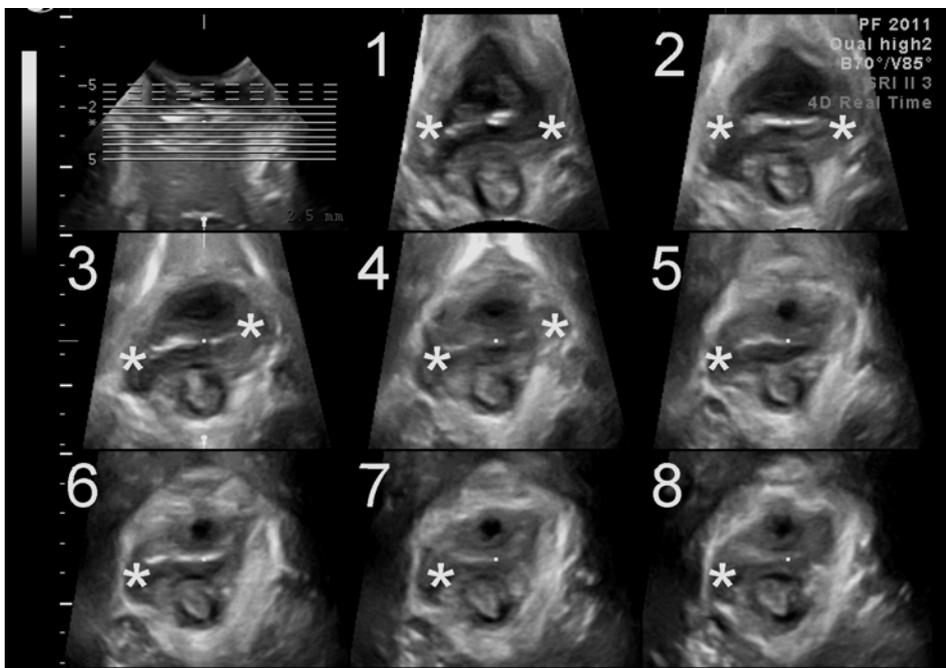


*Figure 7.9: Tomographic imaging of a typical right-sided avulsion affecting all 8 slices, indicated by (\*). The defect appears on the left, as seen from ciudad. In such cases one often finds large venous structures, evident as anechoic tubular spaces, especially on the side of the avulsion.*

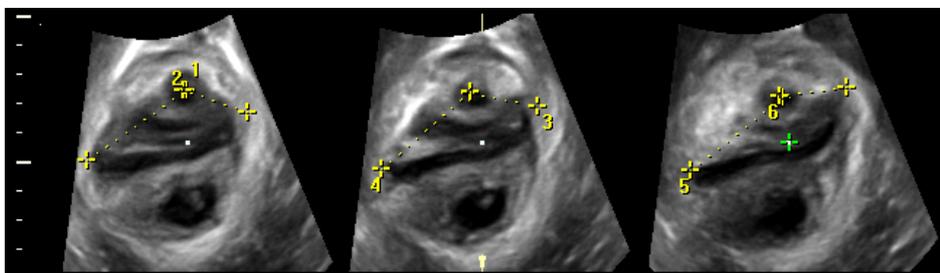
A typical right-sided avulsion is shown in Figure 7.9; in order to diagnose a full avulsion, at least the three central slices of a tomographic series need to show an abnormal insertion[42]. Figure 7.10 shows a bilateral avulsion for which this is not the case on the patient's left; hence, the right side is rated as a complete avulsion while the left is not. The likelihood of a false positive diagnosis seems very low[10]. In doubtful cases measurement of the 'levator- urethra gap' or LUG may help diagnosis, with 2.5 cm the cut- off in Caucasians[43], see Figure 7.11. Once one is more familiar with the identification of defects by vaginal palpation, an internal

examination will further help with the interpretation of ultrasound findings, especially if they are equivocal.

Over the last ten years more than a dozen studies have defined the prevalence of avulsion, with numbers ranging between 6 and 20% for normal vaginal delivery, between 9 and 41% for Vacuum and between 26 and 89% for Forceps (see Table 7.1). Most importantly, the difference in prevalence between Vacuum and Forceps is striking in all comparative studies, providing a composite odds ratio of about 5. Forceps is in fact the single major modifiable risk factor, which is important as the clinician commonly has a choice of instrument if operative vaginal delivery is indicated. Maternal trauma in the form of levator and anal sphincter tears is a strong argument against the use of Forceps, which is particularly pressing in view of the recent revival of Forceps, including rotational deliveries, in the UK and Australia[44].



*Figure 7.10: Tomographic imaging (TUI) of bilateral levator trauma, complete on the right and incomplete on the left. Clearly abnormal slices are indicated by (\*).*



*Figure 7.11: TUI of a complete right- sided avulsion, showing Levator- urethra gap (LUG) measurements in the three central slices. All three right- sided measurements (ie., those on the left aspect of each slice) are below 2.5 cm, ie., clearly normal. The three opposite measurements are all over 3.5 cm.*

Various, birth weight, head circumference and length of second stage have also been described as risk factors, but those are difficult to impossible to modify. Both major perineal tears and vaginal sidewall tears[45] are predictors of avulsion, alerting the clinician to a higher likelihood of levator tears. Most are occult in Delivery Suite, although large vaginal tears can expose such trauma[29].

Author	Year	n	follow-up	% full avulsion	OR FD vs NVD (95% CI)	OR FD vs VD (95% CI)
Dietz and Lanzarone [1]	2005	50	4 months	36%; 4 FD only	-	-
Kearney et al. [67]	2006	160	9-12 months	NVD 12%, VD 17%, FD 66%	15.3 (4.5-55)	10 (1.3-96)
Krofta et al. [68]	2009	76	1 year	FD only, 64%	-	-
Valsky et al. [69]	2009	210	3 months	19%; no FD	-	-
Shek et al. [2]	2010	367	3-6 months	NVD 12%, VD 9%, FD 35%	4 (1.3- 12.4)	5.6 (1.05- 32.9)
Kearney et al. [70]	2010	157	over 1 year	NVD 6% (8/129), FD 53% (20/38)	16.8 (5.9- 49.4)	-
Cassado G et al. [71]	2011	164	?	NVD 15%, FD 50%; no VD	10.3 (3-37.4)	-
Blasi et al. [72]	2011	52	1 day	31%; no FD	-	-
Eisenberg et al. [73]	2011	73	1 year	NVD 20%, VD 41%, FD 89%	32 (4.5- 301)	11.4 (2-74)
Albrich et al. [74]	2012	159	2-3 days	40%; one FD only	-	-
Chan et al. [75]	2013	339	2 months	NVD 15%, VD 33%, FD 71%	13.7 (3.6-56)	5 (1.2-22.8)
Van Delft et al. [76]	2014	191	3 months	NVD 10%, VD 13%, FD 48%	8.4 (2.5-29.3)	5.9 (1.3- 29.1)
Caudwell Hall et al. [77]	2014	844	4.6 months	NVD 13%, VD 13%, FD 44%	5 (2.6-9.4)	5.3 (2.3- 12.6)
Memon et al. [78]	2014	79	10 years	no NVD; VD 15%, , FD 50%	-	5 (1.63-15.3)
Chung et al. [79]	2014	289	2 months	no NVD; VD 17%, FD 40.5%	-	3.42 (1.6-7.3)
Durnea et al. [80]	2014	202	1.8 years	NVD 6%, VD 18%, FD 55%	18.2 (5.3-67)	5.3 (1.6-18)
Lin et al. [81]	2015	193	23 years	NVD 13%, FD 26%	2.45 (1.04- 5.08)	-
Volloyhaug et al. [82]	2015	606	20 years	NVD 13%, VD 15%, FD 41%	4.35 (2.56- 7.4)	4.16 (2.28-7.59)

Table 7.1: Prevalence of levator avulsion after vaginal birth and odds ratios of avulsion in Vacuum versus NVD and Forceps versus Vacuum (modified from [44], with permission.

The clinical significance of levator avulsion is now well established. Avulsion increases the levator hiatus[46], reduces pelvic floor muscle strength[47][48], which is commonly noticed by patients [49][50]. In fact, levator avulsion seems to be a marker for psychological trauma after childbirth, up to and including post traumatic stress disorder[51]. The association between avulsion and urinary [52][54] as well as fecal incontinence [55][53] is less well defined.

Table 7.2 shows a list of studies examining the association between avulsion and prolapse, with anterior and central compartment prolapse being most likely[54]. However, avulsion is also associated with rectal intussusception, a less common cause of posterior compartment prolapse and obstructed defecation[55]. Even more important for the pelvic reconstructive surgeon, avulsion is associated with prolapse recurrence after pelvic reconstructive surgery; see Table 7.3 for a listing of studies. Hence, levator assessment should be a core component of the preoperative evaluation of women with pelvic organ prolapse.

Surgical correction of avulsion on principle appears feasible, although attempts at postnatal repair have been unsuccessful to date[29]. In women with symptomatic prolapse one may consider reattachment of the retracted muscle to the inferior pubic ramus, a procedure that does not involve great technical difficulty[56]. Unfortunately, the levator is commonly not just disconnected, but also over- distended, and such over distension will remain even after the muscle is reconnected.

Author	Year	n	Population	Odds ratio (95% confidence interval)
Dietz et al. [36]	2006	338	symptomatic Caucasians	Cystocele 3.8 (1.9-7.7) Uterine prolapse 2.7 (1.3- 5.9)
DeLancey et al. [83]	2007	286	symptomatic Caucasians	any prolapse 7.3 (3.9- 13.6)
Dietz et al. [56]	2008	781	symptomatic Caucasians	any prolapse 6.1 (3.95- 9.5)
Dietz et al. [48]	2012	764	symptomatic Caucasians	any prolapse for unilat. avulsion: 2.8 (1.4- 5.4) bilat. avulsion: 4 (1.8- 9.1)
Rostaminia et al. [84]	2013	223	symptomatic Caucasians	any prolapse for "moderate defect": 3.2 (1-3- 7.7) any prolapse for "severe defect": 6.4 (2.4- 17.4)
Chung et al. [85]	2014	328	postpartum Chinese, 8w pp.	Prolapse symptoms: 2.1 (0.9-4.5)
Kamisan Atan et al. [86]	2014	194	cross-sectional, Caucasians, 23 yrs pp	any prolapse: 4.9 (2.1-11.1)
Volloyhaug et al. [82]	2015	608	cross-sectional, Caucasians, 20 yrs pp	any prolapse: 9.9 (5.7- 17.1)
Caudwell Hall et al. [87]	2015	844	postpartum Caucasians, 3-6m pp.	Prolapse symptoms: 5.4 (2.3- 12.7) any prolapse (n= 201): 7.6 (3.2-18)

Table 7.2: Association between levator avulsion and symptoms and/ or signs of female pelvic organ prolapse.

Author	Year	n	Follow-up in years	Woman-yrs	OR/ RR* for recurrent prolapse
Dietz et al. [88]	2010	83	4.5	374	2.8-2.9*
Model et al. [89]	2010	106	>5	>500	3.37
Morgan et al. [90]	2011	83	6 weeks	10	3.08
Weemhoff et al. [91]	2012	157	2.6	408	2.4
Wong et al. [92]	2014	209	2.2	460	2.24
Rodrigo et al. [25]	2014	334	2.5	835	2.19
Crosby et al. [93]	2014	42	6.6	277	6.6
Notten et al. [94]	2014	137	1	137	1.4 - 2.4
Abdul Jalil et al. [95]	2014	207	1.25	259	2.5

Table 7.3: Association between levator avulsion and recurrent prolapse after pelvic reconstructive surgery.

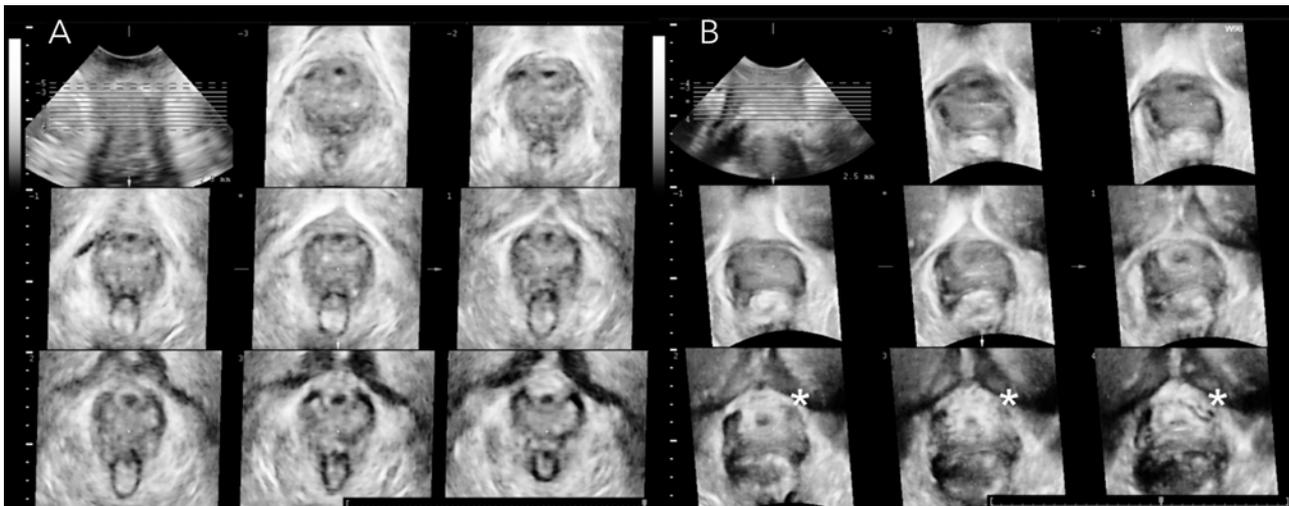
Prevention of major levator trauma is an issue that will open up a fertile field for clinical research. A first attempt at using antenatal vaginal dilators to change pelvic floor biomechanical properties, ie., to increase distensibility of the levator hiatus, has not been able to show any beneficial effect[57]. Other avenues to be explored may include intrapartum dilators, levitator paralysis via dense epidural or pudendal nerve block, and modification of operative delivery. Forceps is the main risk factor for avulsion, as mentioned above[44]. Its abandonment is likely to reduce the lifetime

risk of prolapse surgery by about 1/3, as has occurred in Denmark over the last 30 years[58].

### Paravaginal supports

It has long been speculated that anterior vaginal wall prolapse and stress urinary incontinence are at least partly due to disruption of paravaginal and/ or paraurethral support structures, i.e., the endopelvic fascia and pubourethral ligaments, at the time of vaginal delivery[59]. Commonly, it is assumed that such abnormalities would result in blunting of vaginal fornices. In light of current knowledge, the loss of tenting documented in some studies was probably at least partly due to levator avulsion.

Abnormal fornices can be documented transabdominally[60][61], by endoprobes[62], by MRI [63] as well as with translabial ultrasound [64], and while most studies have not controlled for concomitant levator trauma, it seems that in some patients such changes can occur without avulsion[64]. Figure 7.12 shows abnormal fornices in a patient with intact levator ani in a patient 3 months after vaginal delivery, suggesting isolated fascial trauma.



*Figure 7.12: Abnormal fornices (marked with \* in B) 3 months after vaginal childbirth. The abnormality affects the cranial aspects of the left vaginal fornix and was associated with a Stage 2 cystocele.*

### Urethra and urethral supports

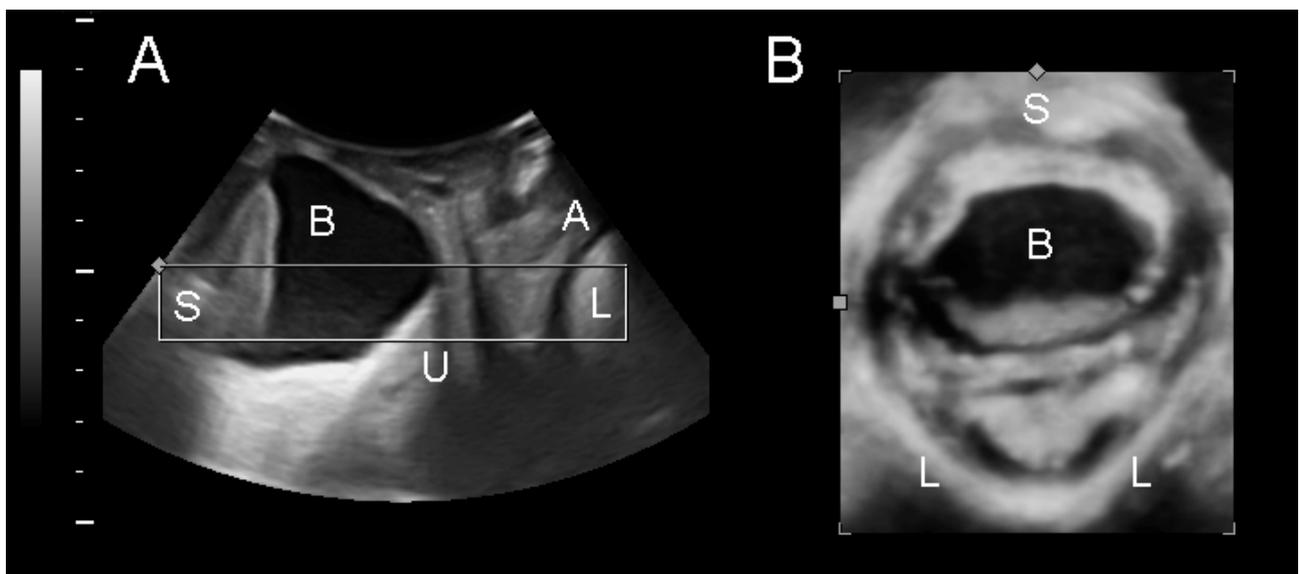
The first use of 3D pelvic floor ultrasound, albeit with a transvaginal probe, was in investigating urethral structure[65]. While there seems to be disagreement as to what has actually been measured in some of the studies of urethral sono-anatomy, it

appears that the volume of the hypoechoic structures surrounding the urethra (smooth muscle, vascular plexus and mucosa) is associated with closure pressure[65]. On 3D ultrasound in the axial plane one is able to detect a circular hyperechogenic structure surrounding the midurethra which corresponds to the striated urethral sphincter (see Figures 7.9-11).

It is less clear however whether observation of static urethral anatomy is of any clinical relevance, except in case of localised abnormalities such as paraurethral or paravaginal masses and suburethral slings. We do, after all, have inexpensive and practical diagnostic tools to assess urethral function. In the author's opinion, resolutions at present are not sufficient for translabial ultrasound to contribute to the assessment of urethral function.

### Other findings

At times, imaging in the axial plane can help clarify anatomical relationships in more complex prolapse cases, especially if there is significant asymmetry. The extent of a cystocele may become more obvious (see Figure 7.13), and major levator trauma can cause highly asymmetrical distension of the hiatus[66], even in women with otherwise excellent muscle, high resting tone and normal or near-normal pelvic organ support (see Figure 7.14). Rendered volumes in the axial plane can demonstrate rectoceles very clearly (7.15). Cystic structures in the vagina are more easily assessed on 3D ultrasound, especially as regards their relationship with the urethra as shown in Chapter 4. The localisation of slings or other implants is also made easier using orthogonal planes (see Chapter 8).



*Figure 7.13: Severe hiatal ballooning in patient with 3rd degree symptomatic cystocele and 1st degree uterine prolapse. S= symphysis pubis, B= bladder, U= uterus, A= anal canal and L= levator ani.*

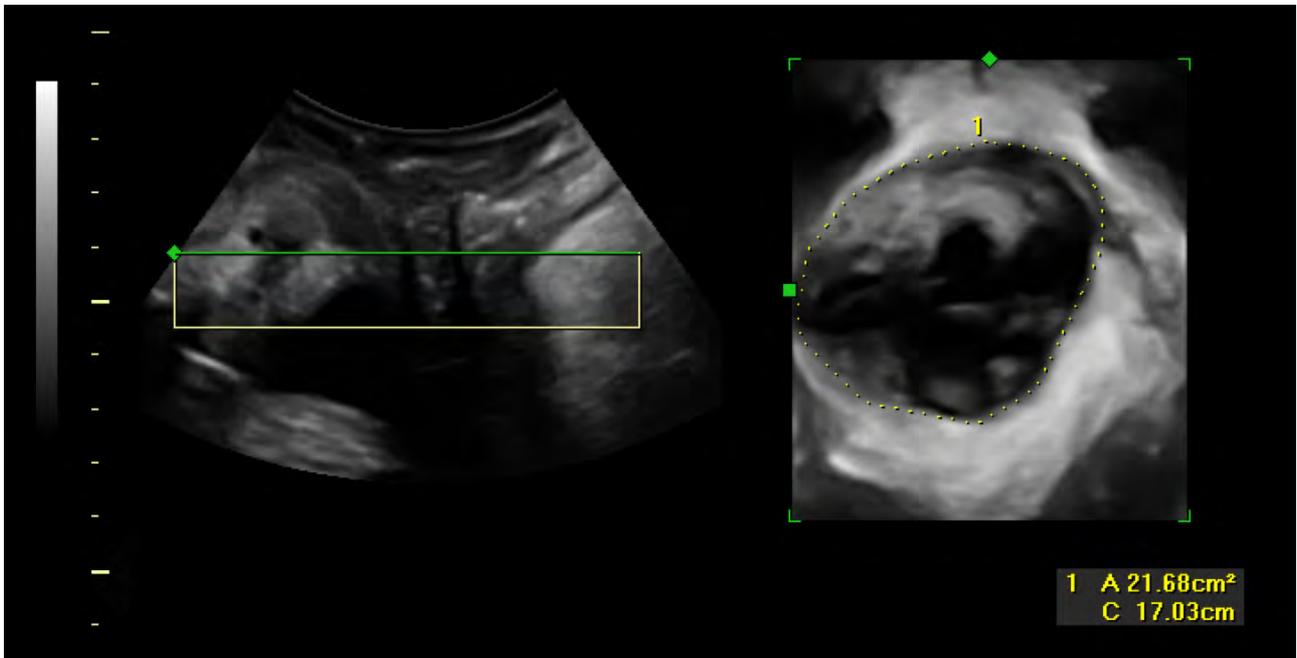


Figure 7.14: Asymmetrical hiatus after right-sided avulsion despite normal hiatal area (stippled line) and pelvic organ support. This patient was asymptomatic.

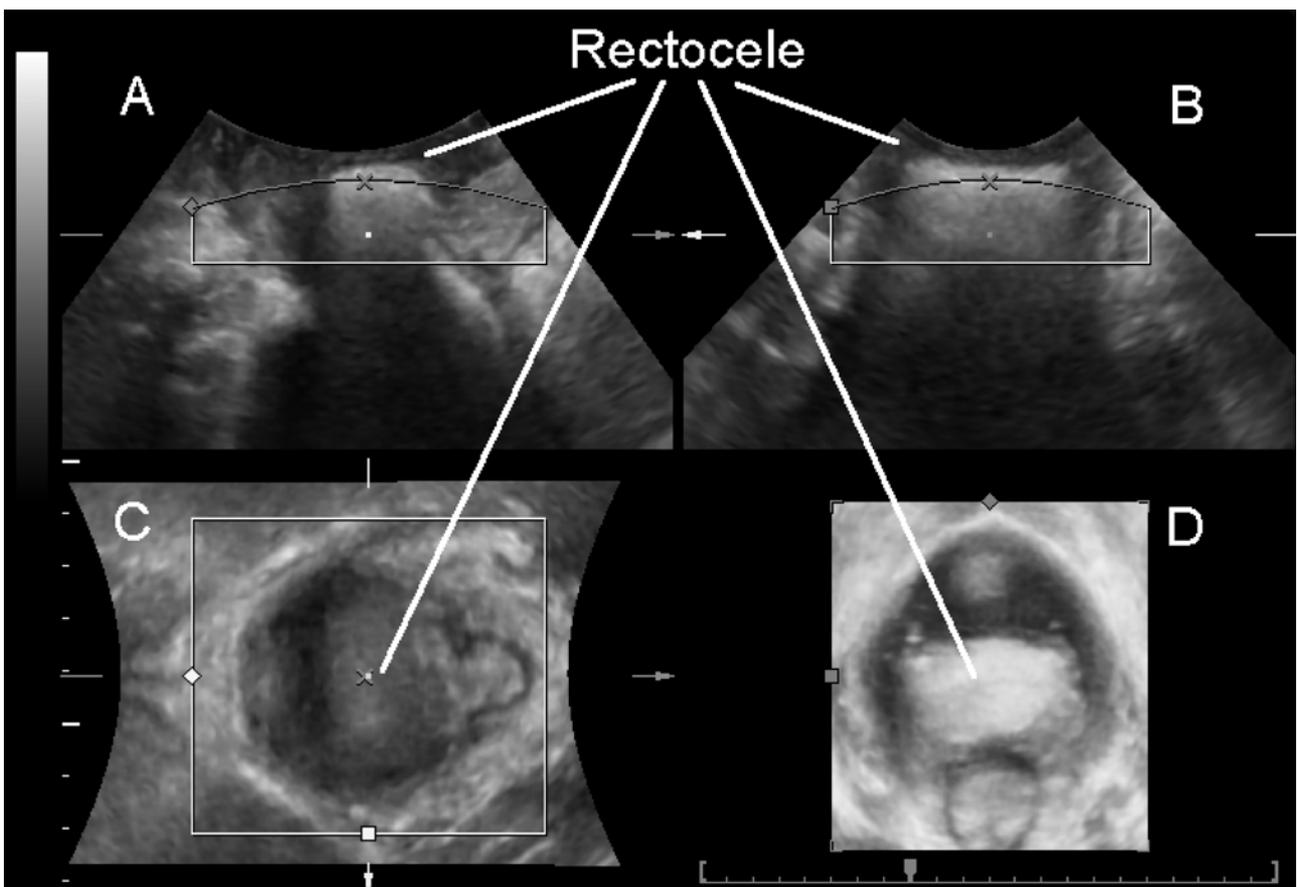


Figure 7.15: Rectocele with otherwise normal pelvic organ support and levator anatomy. Panel C and D show clearly that the rectocele fills a large proportion of the hiatus.

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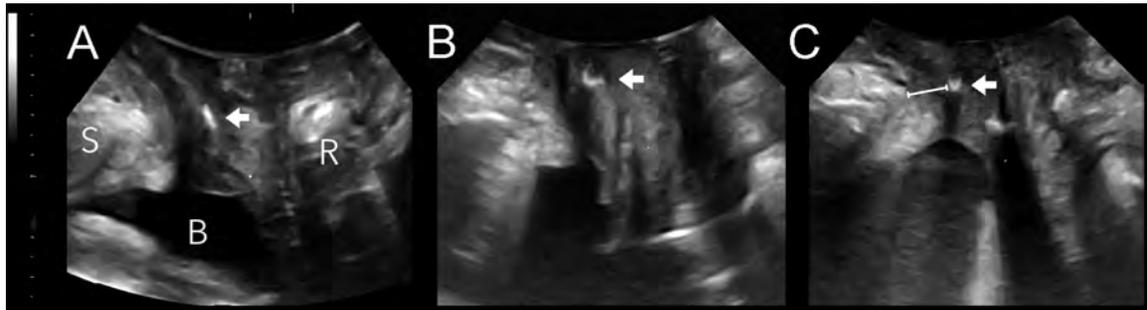


# Chapter 8

## Imaging of implant materials

### Suburethral slings

The imaging of synthetic implants is a major factor in the uptake of pelvic floor ultrasound in clinical practice, in particular as currently used mesh implants are impossible to identify on magnetic resonance and xray imaging[1][2][3]. Synthetic suburethral slings such as the tensionless vaginal tape (TVT), suprapubic arc tape (SPARC), intravaginal slingplasty (IVS), Monarc and transobturator TVT (TOT) and, to a lesser degree, single-incision minislings, have become very popular during the last 10 years and are now the primary anti- incontinence procedures in many developed countries[4]. These slings are not without their problems, even if biocompatibility is markedly better than for previously used synthetic slings, and they differ from each other in some important aspects.

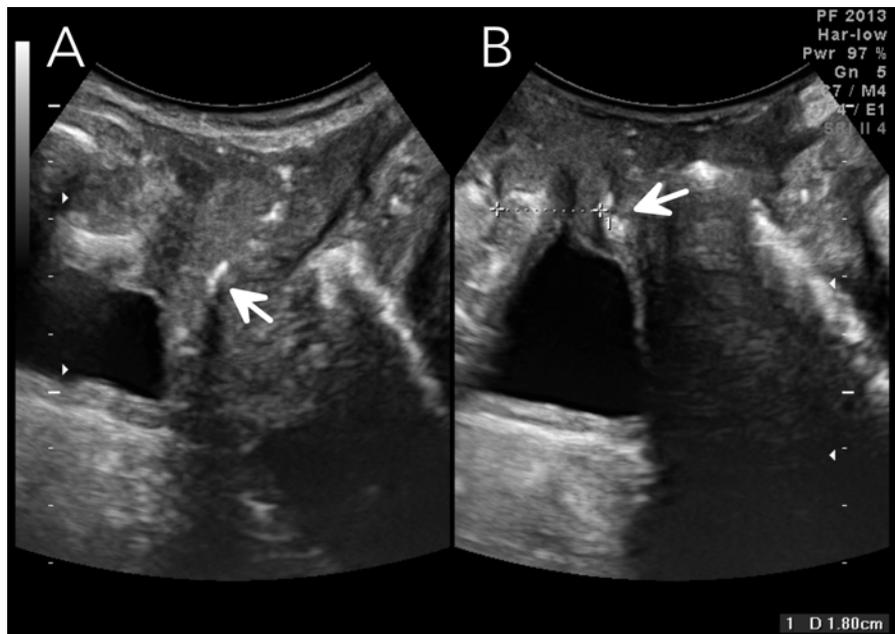


*Figure 8.1: Suburethral tape placed at mid-urethral level (arrow) in the midsagittal plane at rest (A), on light Valsalva (B) and maximal Valsalva (C). The distance measurement in (C) shows the sling- pubis gap (SPG), the most suitable measure of sling ‘tightness’. In this case it is about average at 1 cm. S= symphysis pubis, B= bladder, R= rectum.*

Imaging may be indicated in research, in order to determine location and function of such slings, and possibly even for assessing in vivo biomechanical characteristics. Clinically, complications such as recurrence of stress incontinence, voiding dysfunction, erosion and postoperative symptoms of the irritable bladder may benefit from imaging assessment. Often, patients will not remember the exact nature of previous incontinence

or prolapse surgery, and implants may be identified in women who are not aware of their presence, let alone their type.

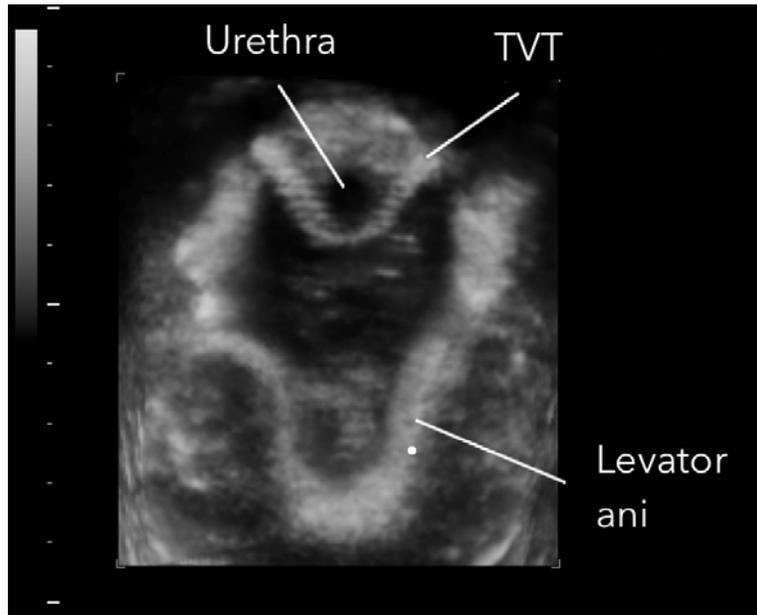
Allografts such as Pelvicol or Permacol are difficult to detect after as short a time as two months, and the echogenicity of fascial grafts seems to vary widely. In contrast, most of the modern synthetic implant materials are highly echogenic, with TVT, Sparc, TOT, TFS (Tissue Fixation System) and Monarc usually being more clearly visible than the IVS. Minislings are commonly indistinguishable from the more traditional implants, and solid plastic anchors are surprisingly difficult to locate.



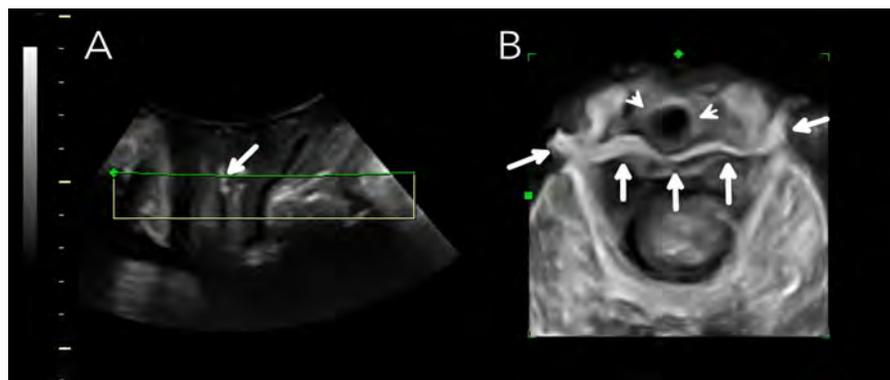
*Figure 8.2: Suburethral sling (TVT) placed at the bladder neck rather than midurethrally. The Sling- pubis gap is very high at 1.8 cm. This situation is usually associated with recurrent stress incontinence.*

Figure 8.1 shows a transobturator tape at rest, on suboptimal and on optimal Valsalva. While this particular tape is easily visible in all three frames, the echogenicity of a sling will depend on the angle between tape and incident beam, and suburethral tapes should of course be observed through a full Valsalva manoeuvre to assess function. Location of the tape relative to the bladder neck and external meatus is easily documented, but the most important factor seems to be the minimal distance ('sling- pubis gap') between the symphysis pubis and tape on maximal Valsalva, as shown in 8.1 c [5]. Sling- pubis gaps of over 15 mm suggest an insufficiently compressive

tape [6]. Occasionally, a suburethral sling will be found close to or even above the bladder neck, which may cause a colposuspension- like distortion of the bladder neck, providing a degree of support in cases of cystocele. However, such slings will of course fail to provide dynamic compression of the urethra and are associated with recurrent stress incontinence (Figure 8.2).



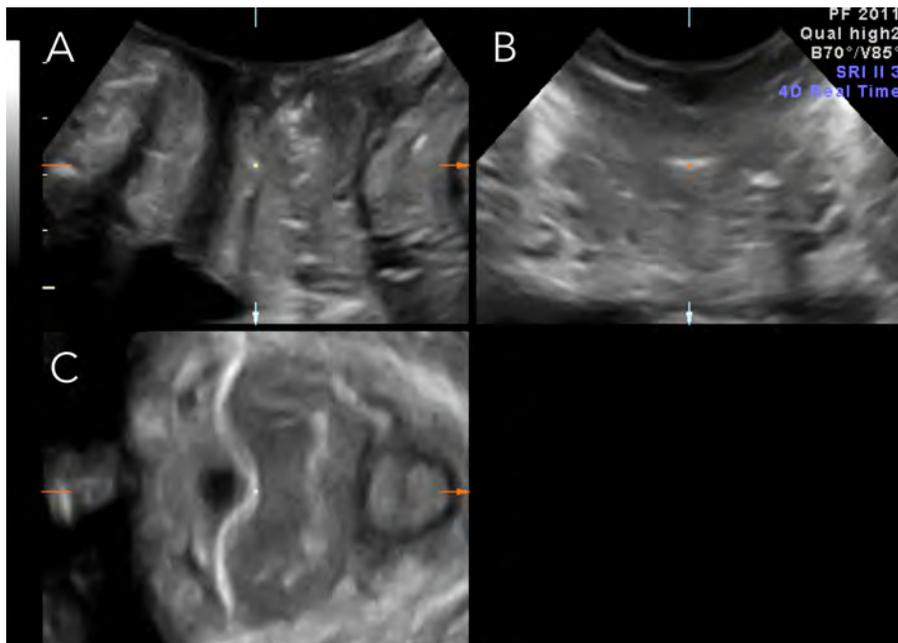
*Figure 8.3: Axial plane view of a TVT, with the V- shape of the tape clearly evident. Retropubic and transobturator tapes are impossible to distinguish in the midsagittal plane, but the difference in location is easy to appreciate in the axial plane.*



*Figure 8.4: Transobturator tape (Monarc TM) in the midsagittal (A) plane and in an axial rendered volume (B). The implant is indicated by arrows. It is obvious that the tape surrounds the urethral rhabdosphincter (short arrows) without perforating its fascia.*

3D ultrasound can locate the implant over its entire intrapelvic course [7], from the pubic rami to behind the urethra, and back up on the contralateral side (see Figure 8.3). Variations in placement such as asymmetry, varying width, the effect of tape division and tape twisting can be visualized, although such variations in sonographic appearance should be judged with caution in asymptomatic patients.

The difference between transobturator tapes and TVT- type implants, difficult to distinguish on 2D imaging (compare Figures 8.3 and 8.4), is readily apparent on rendered volumes (see Figures 8.3 and 8.4). Sectional plane imaging, ie., depicting the implant in all three orthogonal planes simultaneously, is particularly useful in demonstrating the entire implant and can help substantially with surgical planning, similar to the situation with urethral diverticula. Figure 8.5 shows a transobturator tape that is almost invisible in the midsagittal plane at rest, but very obvious in the C or axial plane.



*Figure 8.5: Transobturator tape in the three orthogonal planes: midsagittal (A), coronal (B) and axial (C). This particular tape is difficult to see at rest in A and B, but very obvious in the axial plane. Whenever findings are equivocal it is prudent to image the area in question in the three orthogonal planes to define the true spatial extent of a finding.*

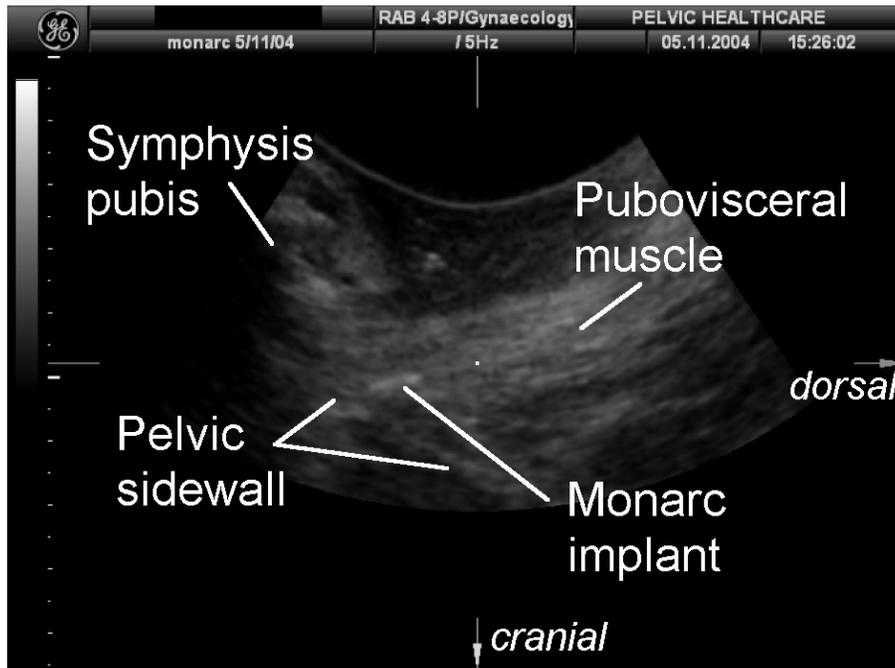


Figure 8.6: Oblique parasagittal view (A plane) showing a Monarc implant traversing the most ventrocaudal aspects of the levator ani muscle.

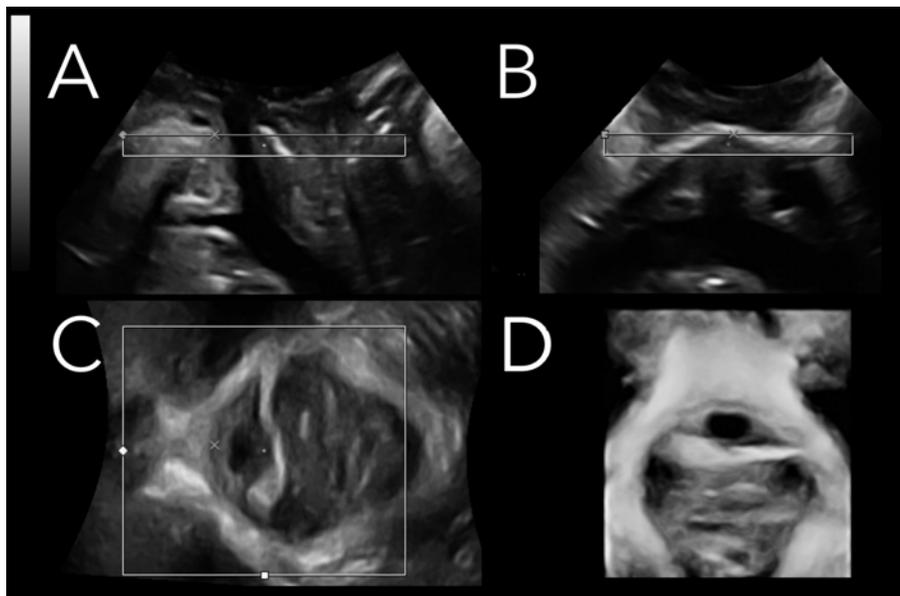


Figure 8.7: 3D- representation of an Adjust TM minisling on Valsalva. In the midsagittal plane (A) it is seen in a typical midsagittal location, of somewhat more echogenic appearance and more linear than a retropubic or transobturator tape. The coronal (B) and axial planes (C) and the renewed volume in the axial plane (D) show that the lateral terminations/ sling anchors are usually impossible to determine. The course of such implants appears very similar to transobturator tapes, and they may be mistaken for such.

Another way of determining the nature of a suburethral sling is to follow the tape in oblique parasagittal views until the levator ani insertion is reached. Most transobturator tapes seem to traverse the muscle (see Figure 8.6), uni- or bilaterally- or at least to get very close to its insertion [8].

It may also possible, to a degree, to distinguish different types of materials, with some implants, such as the IVS or TFS, showing distinct sonographic properties. The IVS, a TVT - analogue used mainly in continental Europe and Australia, is often difficult to identify in stills and requires careful assessment of cine loops of images as it appears narrower and less echogenic. Mini slings (Figure 8.7) are often wider and less curved than retropubic or transobturator slings, possibly due to less efficient fixation, but there have been no systematic studies of the effectiveness of minisling anchoring.

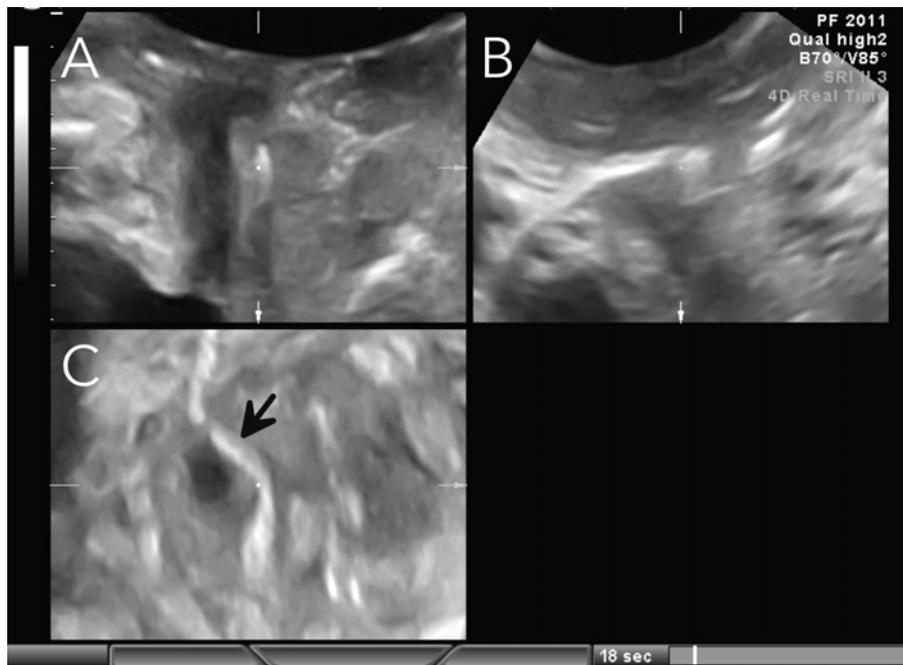
The TFS (Tissue Fixation System) is a special case as it has also been used to treat prolapse (see below), which means that such tapes may be found in unexpected locations such as under the trigone, and in the perineum, and due to the peculiar implantation mechanism they may be very asymmetrical. TFS implants often appears thicker and wider than standard slings, and are clearly less deformable, ie., stiffer (Figure 8.8).



*Figure 8.8: Illustration of the three commonest locations for TFS tapes. These implants are much less elastic than standard suburethral slings and often appear thick and linear, as in these two patients. In (A) there is a mid-urethral tape (left arrow) and another under the bladder base (cardinal ligament tape). In B there is a mild recurrent cystocele with a suburethral tape (left arrow) and another tape in the perineum (right arrow). The latter are particularly likely to erode and cause chronic pain.*

Invented by the originator of the ‘Integral Theory’, the Australian gynaecologist Peter Papa Petros, it is based on the proposition that pelvic floor disorders are due to ‘ligamentous laxity’, hence amenable to cure by the creation of ‘neo-ligaments’ placed around the urethra, under the trigone, at the apex, in the posterior vaginal wall and in the perineum.

There is one RCT claiming good results in the cure of stress urinary incontinence, but very little evidence of efficacy for other indications such as prolapse, exclusively provided by internal audit of case series. TFS tapes may give rise to a number of unusual complications and high rates of chronic pain syndromes[9]. The most vexing of those complications are erosion into vagina, urethra, bladder and anal canal, pain arising from perineal implants that are supposed to cure obstructed defecation, vaginal laxity and fecal incontinence, and pain syndromes caused by apical tapes, with anchors lodged in the sacral hollow. Often, sonographic imaging is helpful in determining the location of such tapes (see Figure 8.8 for urethral, perineal and trigonal tapes), although apical tapes are too distant to allow reliable imaging.



*Figure 8.9: Tethered transobturator tape, with asymmetrical appearances in B and C. This is due to excessively deep dissection during placement, resulting in a tape that is placed partly through the urethral rhabdosphincter (arrow). The clinical significance of this is currently uncertain.*

Appearances are quite distinctive and differ from 'normal' slings such as a TVT, TOT, Monarc etc. in that the TFS is stiffer, appears more echogenic and wider, and is less deformable (Figure 8.8). Unfortunately, the large plastic anchors used to fixate the tape are very difficult to locate sonographically since very little acoustic energy is reflected back at the transducer. However, anchor positions can be inferred from the lateral termination of such tapes.

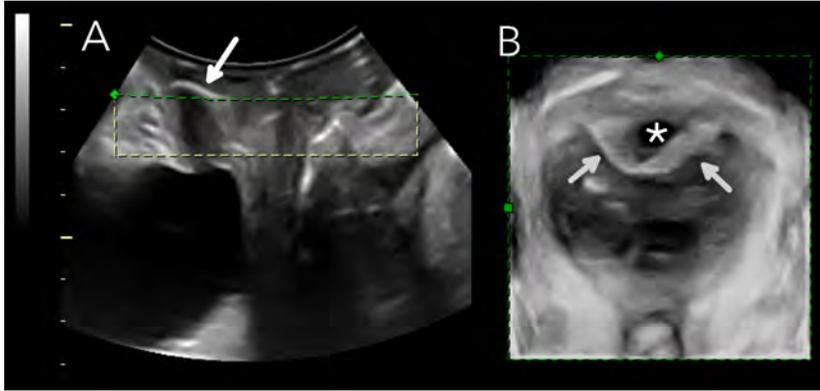
Identification of the specific type of implant, often impossible from available information and patient history, can be important in the assessment of postoperative sling complications. An IVS tape is much more likely to erode than the TVT, and it seems to cause unusual foreign body reactions, leading to sequestration of the tape, chronic infection, sinus formation etc [10]. The Sparc, an upside-down TVT analogue, generally seems flatter and wider than TVTs, and the TFS never assumes the curled-up appearance seen for TVT or transobturator tapes. However, most suburethral tapes can assume a tight c- shape, in particular on Valsalva. The more pronounced this effect is at rest, the tighter one may assume the tape to be, although this observation is not a good measure of functional effect [5].

The position of suburethral tapes does not seem to change much over time, although a gradual displacement of the TVT together with surrounding tissues has been described, in particular in women after concomitant anterior repair[11][12].

As regards the location of slings relative to the urethra and/ or the bladder neck, it has been claimed that mid-urethral placement is preferable or even essential for success, but the author agrees with others who hold that variations in placement do not seem to have much of an impact on success [13][14]. From a theoretical point of view, if suburethral slings work by 'dynamic compression', [15] ie., kinking or compression of the urethra against the postero- inferior contour of the symphysis pubis whenever intraabdominal pressure is raised, then it should not matter much for success as to whether the sling is placed around the proximal, central or distal urethra.

The best measure of tape 'tightness' or compressive effect seems to be the sling- pubis gap (SPG) measured on maximal Valsalva, which is associated with voiding function and cure of stress incontinence[5], see Figures 8.1 and

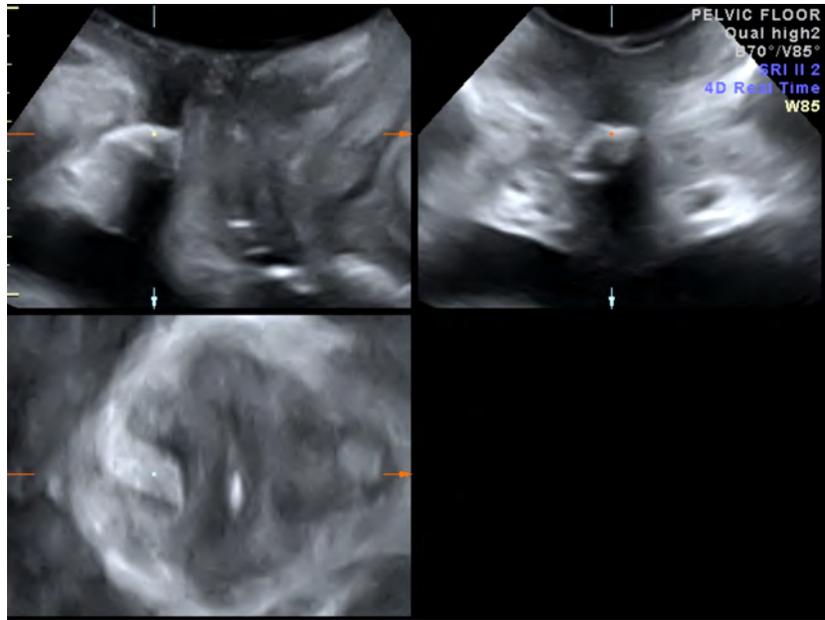
8.2. However, of course urethral bulk and/ or quality is a confounder for the relationship between sling- pubis gap and compressive effect, so that a given measurement may be associated with insufficient compression in one patient and a perfect result in another.



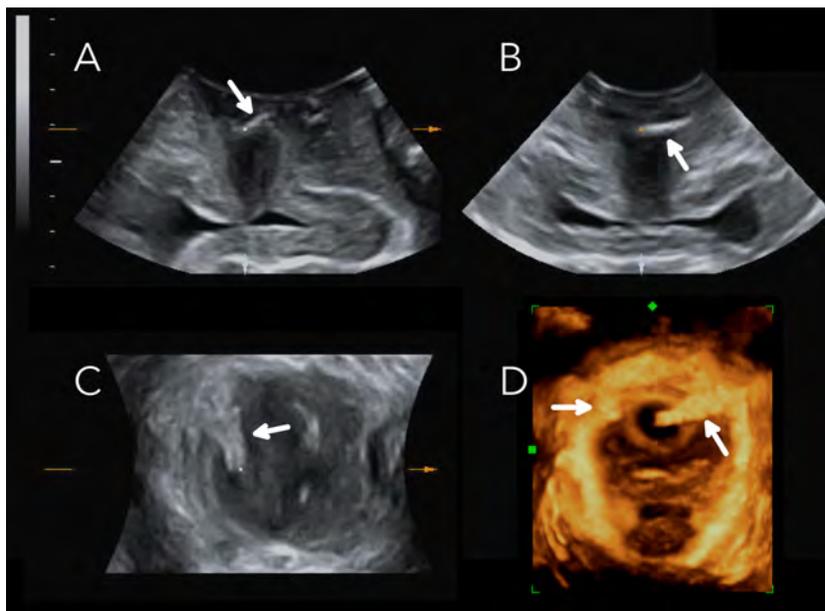
*Figure 8.10: TVT placed through the urethral rhabdosphincter on the patient's left. In the midsagittal plane appearances are suggestive of a perforation, but the axial plane rendered volume shows that the longitudinal smooth muscle (\*) is untouched. A urethroscopy was normal.*

The degree of obstruction (and therefore the likelihood of stress continence and postoperative voiding dysfunction) is likely to depend on at least three factors: the physical location of the sling (i.e., placement relative to the urethra), its biomechanical properties (i.e., stiffness or elasticity) and the stiffness or elasticity of surrounding tissues (i.e., the degree of urethral mobility or prolapse). Location or placement on its own does not seem to be the dominant predictor of success, as seen above. Biomechanical properties vary greatly between different types of implants[16], but on its own this factor does not seem to affect outcomes greatly[17]. The degree of urethral mobility may well be at least as important a predictor of outcome, as shown on xray imaging[18], but the author has been unable to confirm this on ultrasound[6]. The strongest predictor of postoperative stress continence seems to be urethral closure pressure[6].

Translabial ultrasound will at times identify suboptimal sling placement, that is, slings that lie deep to the rhabdosphincter fascia, resulting in partial perforation of the urethral muscle. This may result in sling 'tethering' if it is unilateral (see Figure 8.9 and 8.10), and this can occur even with a tape that appears completely normal in the midsagittal plane (Fig. 8.9).

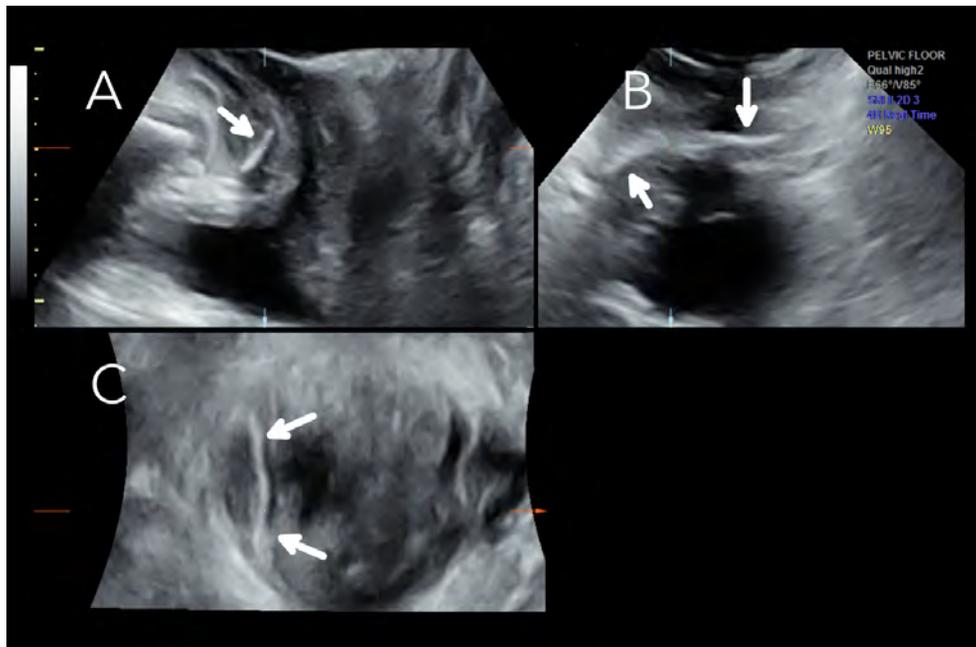


*Figure 8.11: Retropubic tape placed deep to the rhabdosphincter. Such tapes are usually apparent on urethroscopy and often symptomatic.*



*Figure 8.12: Status after lateral division of a stenotic TVT (arrows). The patient was seen several years after TVT placement and 3 months after tape division. The detrusor muscle is hypertrophic (visible in A and B), suggesting long-standing obstruction. The rendered volume in D shows the lateral aspects of a divided tape, with the right remnant (situated on the patient's left) extending into the centre of the urethra, suggesting perforation. This tape was visibly perforated on urethroscopy.*

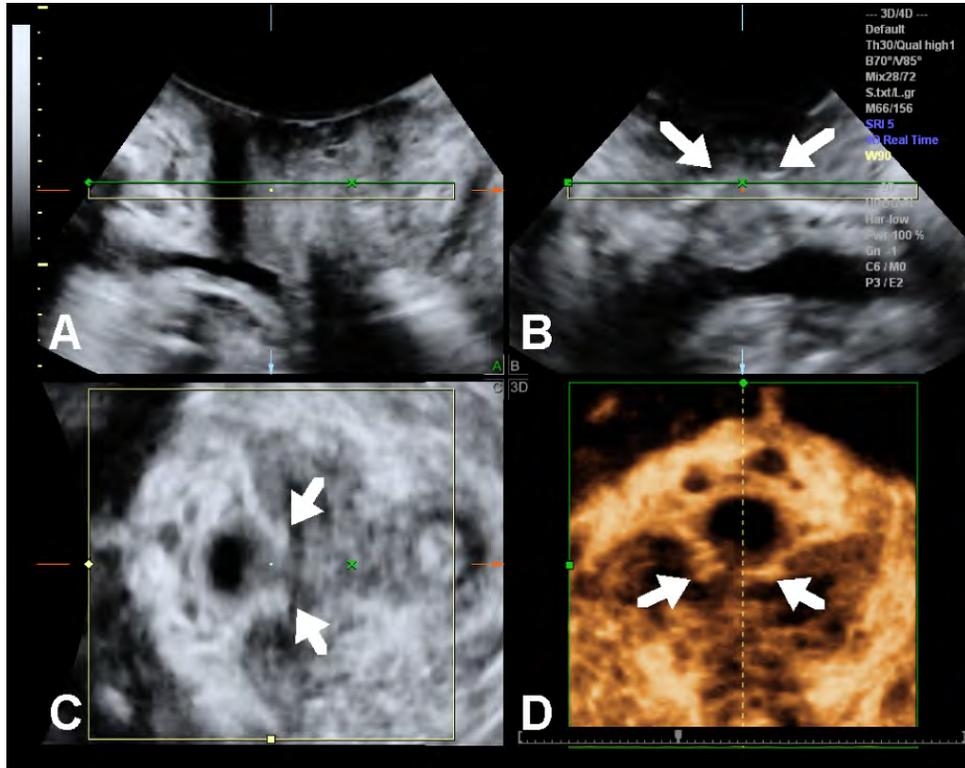
Sometimes however a tethered tape may look highly abnormal in the midsagittal plane, with appearances suggesting an obvious perforation, even in patients whose urethroscopy will turn out to be normal (see 8.10), or in a sling that seems to lie within the longitudinal smooth muscle (see Figure 8.11). In both cases perforation or erosion into the lumen has to be excluded, unless the patient is completely asymptomatic, in which case medium-term follow-up seems advisable.



*Figure 8.13: Suburethral tape imaged in the space of Retzius over 5 years after placement in an intermittently symptomatic patient, suggesting urethral transection. The urethroscopy showed scarring at the mid-urethral level, but no visible mesh.*

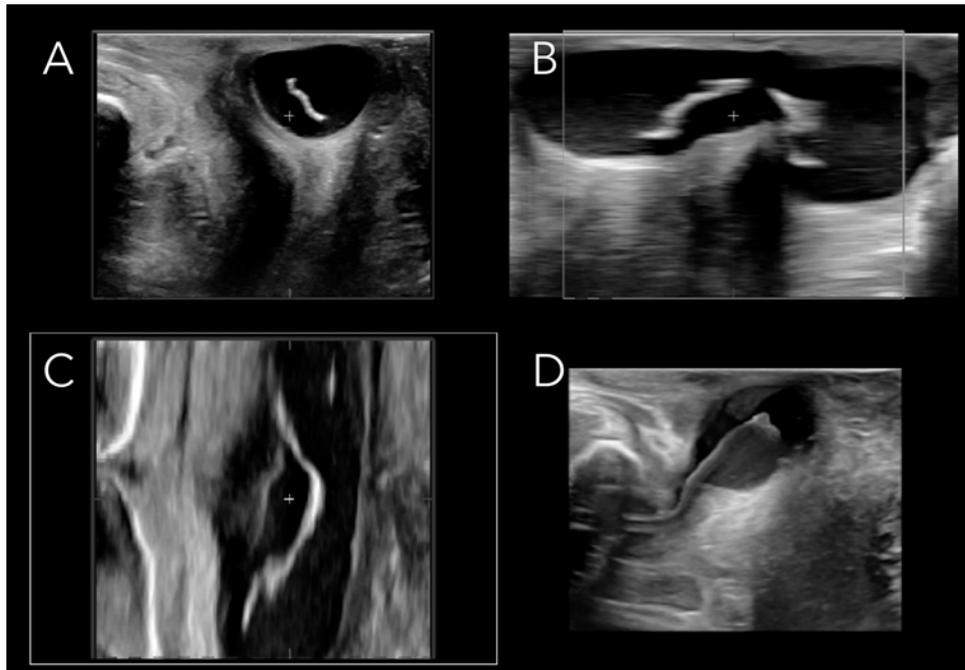
Figure 8.12 shows aTVT that had resulted in a stricture and substantial, lasting voiding dysfunction, as evidenced by a hypertrophic detrusor of a thickness of over 1 cm. Panels C and D suggest that part of the sling had been removed, which was indeed the case here. By the time of this assessment theTVT was visible within the lumen on urethroscopy. Cross-sectional planes such as seen in Figures 8.9, 8.11 and 8.12 can help substantially with location of a sling that requires partial or complete removal.

Occasionally, one will document a sling that is located on the wrong side of the urethra (Figure 8.13) which implies that urethral transection has occurred in the past. This is a rare complication the author has now observed three times. It can be regarded as the natural end-stage of urethral tape erosion, if symptoms such as recurrent urinary tract infections and dysuria do not prompt intervention. It may not require any action, provided the urethra has healed and the implant is no longer exposed.



*Figure 8.14: Status after division of obstructive TVT. The tape is invisible in the midsagittal (A) plane as the remnants have moved laterally, but easily identified in the other planes (arrows). Usually one finds a gap of 7-10 mm after sling division.*

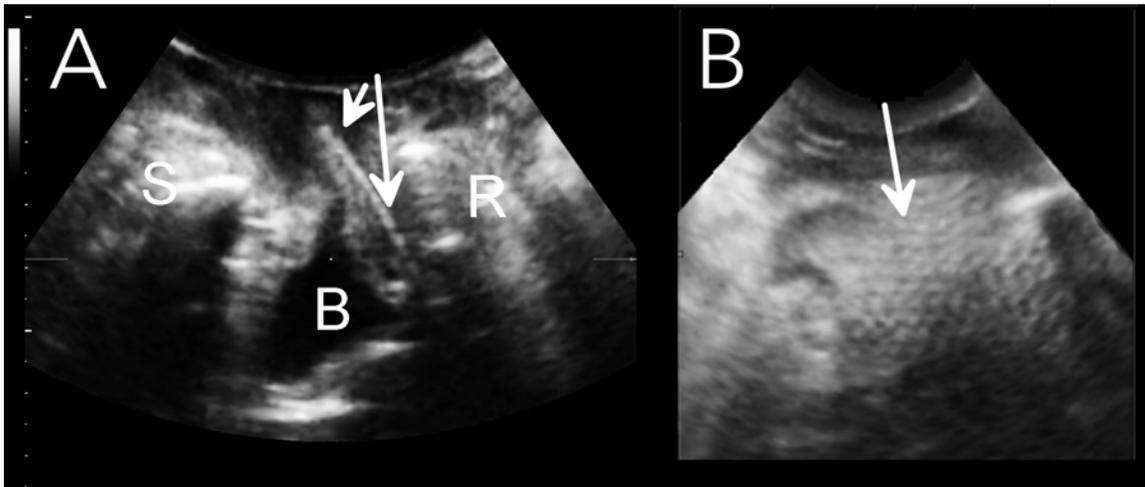
Imaging is also useful in documenting the outcome of sling division in women with voiding dysfunction due to obstruction (Figure 8.14), and very occasionally it will demonstrate a rare sling complication such as seroma formation surrounding a mesh implant (Fig. 8.15).



*Figure 8.15: Seroma formation around TVT three years after implantation. The serum was drained without further sequelae. Image courtesy of Catrina Panuccio, Adelaide.*

## Implants used in pelvic reconstructive surgery

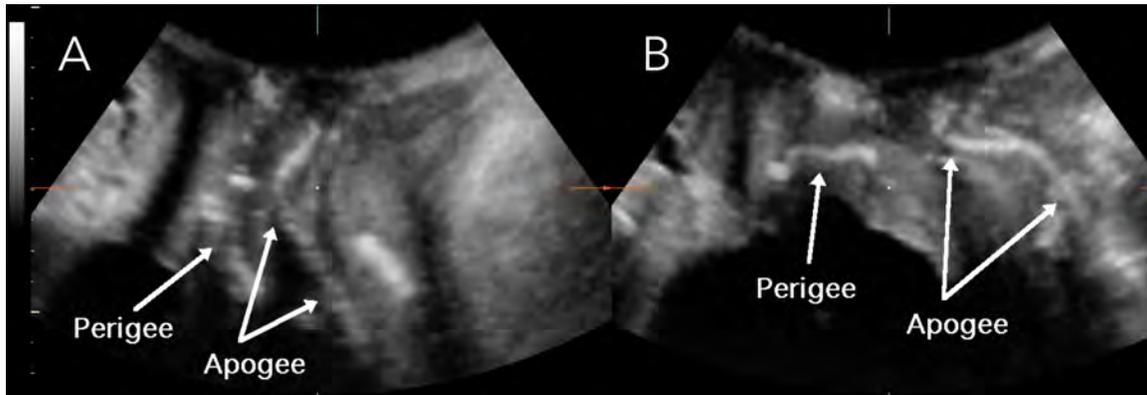
Between 2004 and 2010 there was a worldwide trend towards mesh implantation, especially for recurrent prolapse. However, complications such as failure and mesh erosion are not uncommon [19] and have led to a backlash, driven by medicolegal action, mainly in the US. As most biomedical manufacturers are located there, research and development has come to a virtual standstill. This is a pity, since it has recently become clear that some forms of prolapse are virtually incurable by conventional means[20] and that such patients are very likely to benefit from mesh placement. In addition, currently available implants are nowhere near perfect and both patients and surgeons would likely benefit from further development in the field.



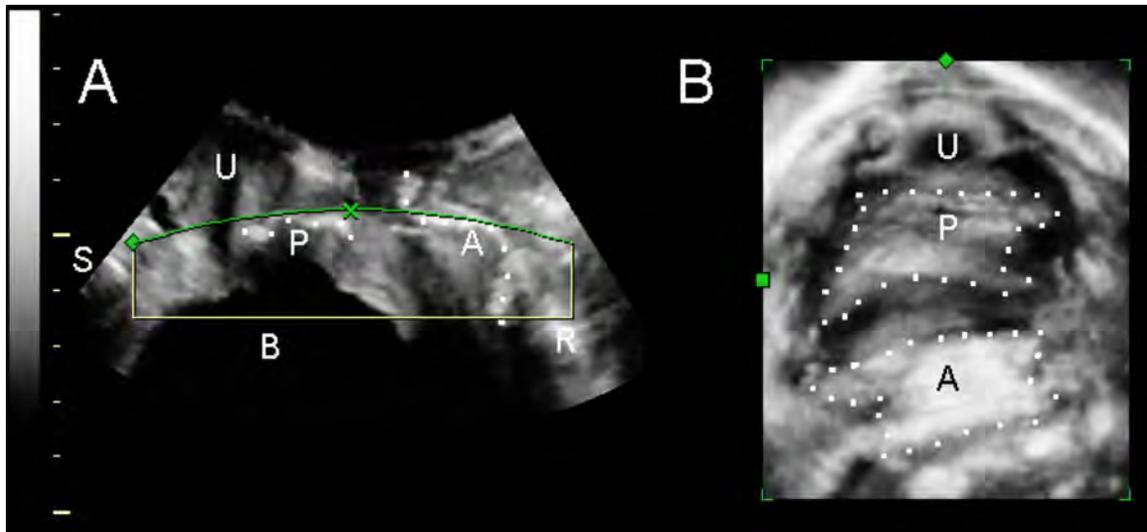
*Figure 8.16: Anterior compartment mesh in the midsagittal plane (A) and an oblique coronal plane, showing the mesh weave (B). It is evident that in some cases an anterior compartment mesh may come to be situated much lower than expected; in this case under the mid-urethra.*

Imaging is very useful in determining functional outcome and location of such implants (see Figures 8.16- 8.23). Traditional materials such as Marlex and Mersilene as well as the obsolete Goretex implants are highly echogenic, as are the more modern materials such as Prolene and combination meshes such as Vypro. Figure 8.16 shows an anterior compartment mesh in the midsagittal and coronal planes, with the latter clearly demonstrating mesh weave. Mesh dimensions can be determined

with reasonable accuracy, and sonographic assessment has put paid to the concept of mesh shrinkage or contraction as a significant cause of mesh complications[21][23]. Anterior compartment meshes are often more easily identified than those in the posterior vaginal wall, especially in women with rectocele or stool impaction. However, on principle meshes are visualised as linear echogenic structures regardless of placement (see Figure 8.17).



*Figure 8.17: Appearances of anterior and posterior compartment mesh in the midsagittal plane at rest (A) and on Valsalva (B).*



*Figure 8.18: Anterior and posterior compartment mesh in patient with severe ballooning, midsagittal plane (A) and Axial plane rendered volume (B), maximal Valsalva. There is marked ballooning of the hiatus to about 50 cm<sup>2</sup>, with the two implants forming bars across the hiatus. Evidently, the mesh has not reduced ballooning which generally is very similar to preoperative findings. P= Perigee (TM), A= Apogee (TM)*

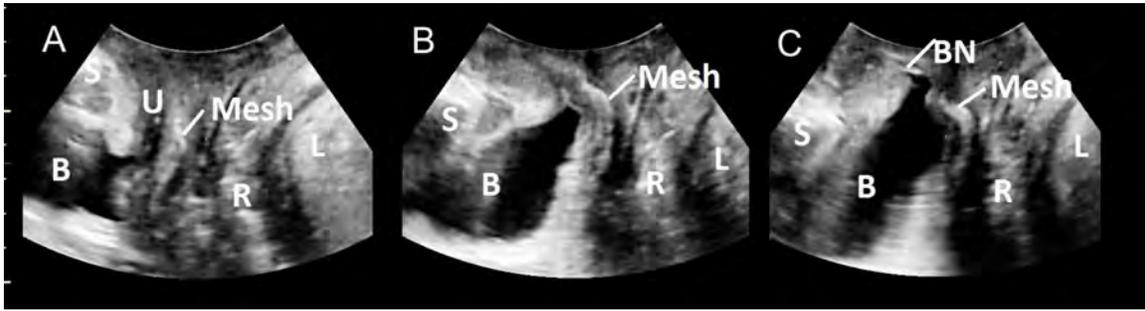


Figure 8.19: Anterior mesh failure: (a) at rest; (b) on submaximal Valsalva maneuver; (c) on maximum Valsalva. Cystocele recurrence ventral and caudal to well-supported mesh suggests that the caudal aspect of the implant was insufficiently secured to the bladder neck, leading to dislodgement of the mesh from the trigone. B, bladder; BN, bladder neck; L, levator ani muscle; R, rectum; S, pubic symphysis; U, urethra. From [22], with permission.

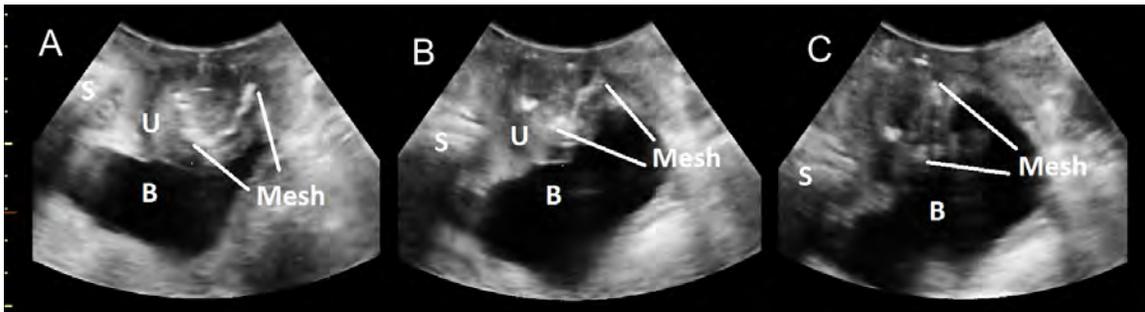


Figure 8.20: Apical mesh failure: (a) at rest; (b) on submaximal Valsalva maneuver; (c) on maximum Valsalva. Cystocele recurrence dorsal to the mesh with high mobility of the cranial mesh aspect suggests dislodgement of apical attachment. B, bladder; S, pubic symphysis; U, urethra. From [22], with permission.

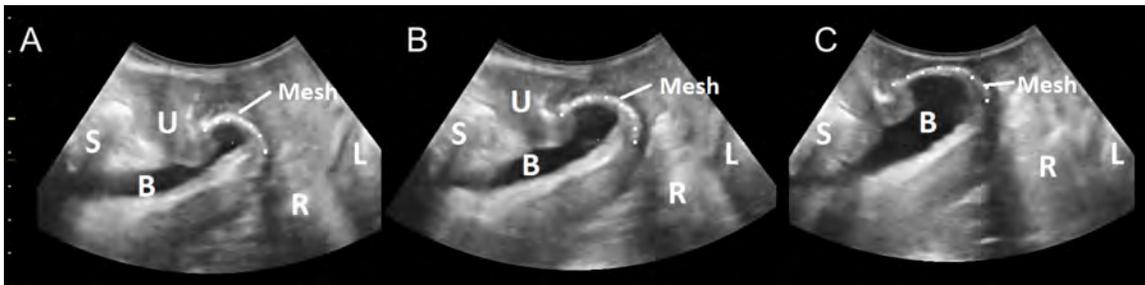


Figure 8.21: Global mesh failure: (a) at rest; (b) on submaximal Valsalva maneuver; (c) on maximum Valsalva. Cystocele recurrence behind the mesh is associated with high mobility of the entire mesh on Valsalva, suggesting dislodgement of both lateral and apical attachments. B, bladder; L, levator ani muscle; R, rectum; S, pubic symphysis. From [22], with permission.

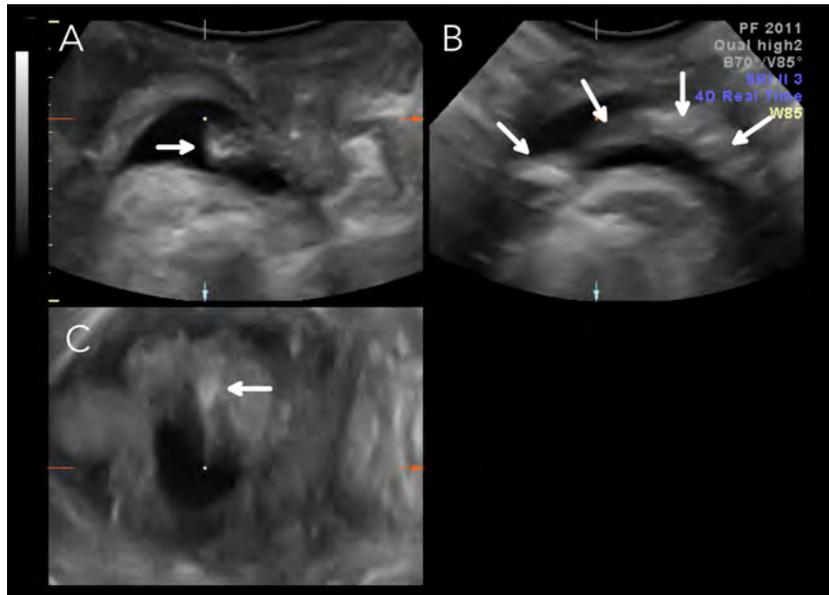
Vaginal mesh will often fold, especially in the case of the Anterior Prolift which is clearly too large for the space it is implanted into, and fixation to underlying tissues seems to reduce this effect. When seen in the axial plane, such as in Fig. 8.18, it is clear that mesh can cover or ‘block’ a large proportion of the hiatus, even in women with severe ballooning. However, it is also obvious that anchoring arms may come under very substantial strain. In the opinion of the author, the main problem with mesh techniques has always been fixation rather than materials, even if manufacturers have tended to focus on the latter. Anchoring is not an issue for vault suspension, for which the sacral promontory with the anterior longitudinal ligament of the spine allows reliable mesh anchoring. However, until the advent of transobturator fixation there were no demonstrably successful techniques for anchoring meshes used for cystocele repair. Having said that, anchoring over the obturator foramen using anchors seems ineffective[24], and even anchoring by mesh arms placed through the obturator foramen can dislodge and lead to recurrence.

There seem to be three distinct forms of anterior compartment mesh failure[22], illustrated in Figures 8.19-21. The least common- and the easiest to remedy- is likely due to faulty surgical technique rather than patient factors. Dislodgment of the mesh from the bladder neck/ trigone may result in ‘anterior recurrence’, ie., a cystocele recurrence anterior to a mesh that is well- anchored to the side wall or the sacrospinous ligaments (Fig. 8.19). This often is associated with de novo or worsened stress urinary incontinence. Such cystocele recurrence is easy to treat since resuspension of the bladder neck to the mesh is very likely to be successful. Of course a suburethral sling may also be required.

Figure 8.20 shows an anterior compartment mesh repair that has failed apically, with dislodgment of superior transobturator arms. This is associated with patient factors such as hiatal ballooning and avulsion. Clearly, apical resuspension is required in such cases. If all lateral and apical anchoring fails the appearances are very different, as shown in Figure 8.21. We term this ‘global recurrence’, and it is commonly observed in women after overlay mesh or mesh that is insufficiently anchored to the pelvic sidewall, such as the Anterior Elevate (TM) or the Proxima (TM).

It is unfortunate that manufacturers have paid so little attention to issues of mesh anchoring, with only one study in ten years considering the mechanical integrity of transobturator anchoring by mesh arms[25]. It should be technically easy, after all, to increase resistance to pull-through by increasing surface area and friction. In the end, pelvic reconstructive surgery is largely about creating load-resistant structures to stop herniation of organs through the levator hiatus. Such endeavours may fail if the implant itself is mechanically weak[26]. However, from experience to date the mechanical integrity of anchoring is likely to be more important.

Midvaginal or DeLancey Level II [27] anchoring is clearly required for effective cystocele reduction, and the only effective method to date seems to be the use of transobturator arms. Transobturator mesh techniques may be particularly useful in women with avulsion who seem prone to recurrence after anterior repair [28], see Chapter 7. Unfortunately, effective anchoring may result in irritation of nearby nerves, whether this is to the sacrospinous ligament or the pelvic sidewall, and chronic pain resulting from mesh arms may well be a complication that is inherent to this particular technology.



*Figure 8.22: Asymmetrical anterior compartment transobturator mesh (arrows), resulting in appearances suggestive of bladder perforation (A) in an asymptomatic patient. On cystoscopy there was no perforation. Rather, the right lateral bladder base was insufficiently supported, resulting in a shallow diverticulum between the mesh arms on Valsalva. The asymmetrical nature of the mesh is evident in the coronal (B) and axial planes (C).*

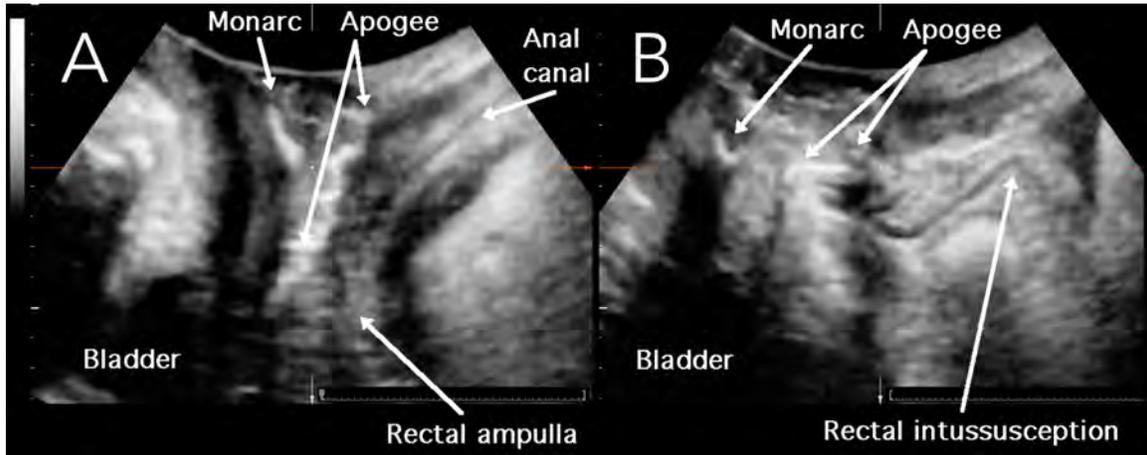
Posterior compartment mesh is less commonly used, and at the time of printing there is little evidence as to its utility. Figures 8.17 and 8.18 show an Apogee- type posterior compartment mesh implant that seems to bridge the hiatus at its widest portion. Initially, it was hoped that such pararectal techniques, by virtue of the anchoring arms perforating the levator ani muscle, may effect a minimally invasive levatorplasty. If true, one would expect a marked reduction in levator ballooning after Apogee. Unfortunately, this is not the case as shown in Figure 8.18, probably because the lateral extensions of an Apogee- type repair traverse the iliococcygeus muscle, not the more substantial lower aspects of the levator ani.

Erosion, one of the commonest complications after mesh use, is not usually apparent on ultrasound, nor is it useful in women with chronic pelvic pain, unless there is evidence of perforation into hollow organs. One should be careful in the interpretation of sonographic findings however. Figure 8.22 may easily be interpreted as a perforation of an anterior compartment mesh arm, but cystoscopy was normal, and appearances were explained on observing a Valsalva maneuver cystoscopically. The mesh was placed more cranial than normal, ie., above the trigone, and parts of the bladder base were not sufficiently supported due to asymmetrical placement of the mesh body, making them herniate between mesh arms.

Just as anterior mesh implants, posterior mesh can also give rise to unusual, iatrogenic forms of prolapse recurrence that are difficult, if not impossible to assess without imaging. Posterior mesh used in women with a true radiological rectocele commonly does not obliterate the ‘pocket’ of a true rectocele as demonstrated in Chapter 5. It is not uncommon to find a rectocele, if somewhat reduced in size, to be still present after posterior compartment mesh, even if the posterior compartment prolapse is fully and permanently reduced. In such cases a rectocele may however still be symptomatic, especially if it develops into the perineum as in Figure 5.6.

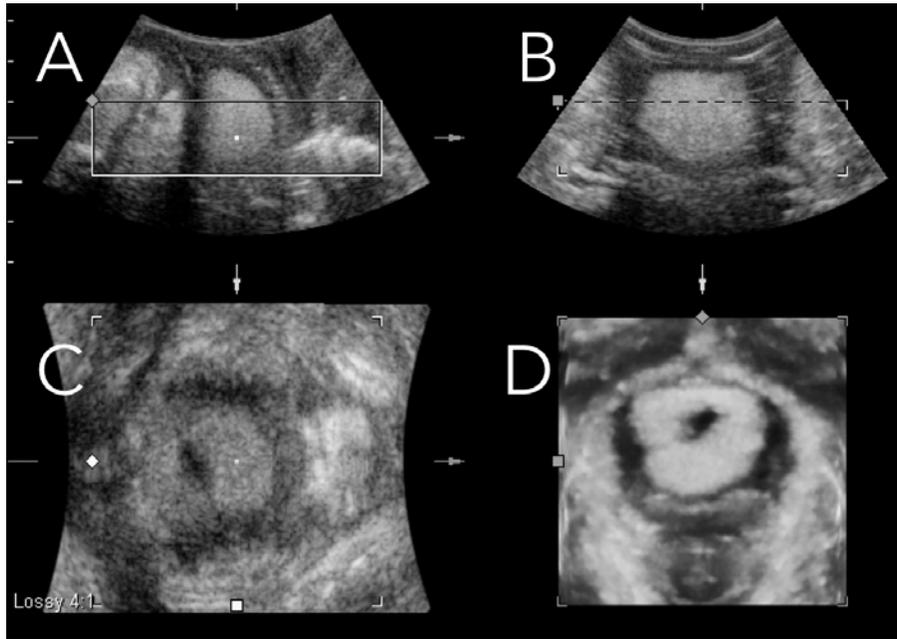
There remains another alternative route for prolapse to develop in women predisposed to this condition- via the anal canal. This seems particularly likely in women with substantial hiatal overdistensibility or ‘ballooning’ (see Chapter 7). Figures 5.12 and 8.23 show an intususception after posterior compartment mesh placement. In this case an enterocele is invaginating the rectal wall after ‘gynaecologically successful’ posterior vaginal wall mesh repair for post-hysterectomy vault prolapse. The patient in

Figure 8.23 had de novo symptoms of dyschezia and obstructed defaecation 4 months after the procedure and was found to have an internal rectal prolapse on colorectal assessment. This rectal prolapse had not been apparent on preoperative imaging.

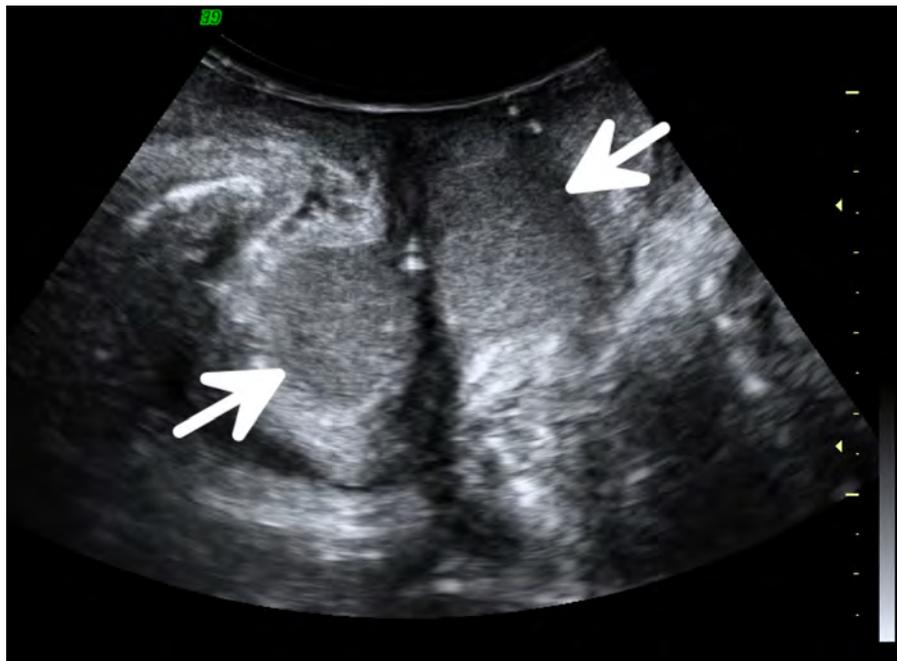


*Figure 8.23: Enterocele developing posterior to an Apogee mesh as seen in the midsagittal plane, causing a rectal intussusception or internal rectal prolapse (left image at rest, right image on Maximal Valsalva). Clearly, the vaginal prolapse has been cured, only to be replaced by an incipient (and, so far, occult) rectal prolapse due to a very large hiatus and levator damage.*

Finally, it should be mentioned that some of the injectables used in anti-incontinence surgery are also highly echogenic. Macroplastique for example can be visualized as a hyperechoic donut shape surrounding the urethra (see Figure 8.24). Unfortunately, there seems to be little correlation between imaging findings and treatment success; hence, imaging is probably of little utility in those cases. An exception may be the identification of rare complications such as sterile abscesses after Zuidex TM injections (Figure 8.25).



*Figure 8.24: Findings 6 months after Macroplastique injection for recurrent stress incontinence. The silicone macroparticles are evident as a highly echogenic area surrounding the urethra in the shape of a doughnut.*



*Figure 8.25: Sterile Zuidex abscess surrounding the urethra (arrows) in a donut shape. Image courtesy of Dr Stefan Albrich, Mainz.*

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