6

Axial Plane Imaging

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Levator Ani Complex

It is only very recently that imaging of the levator ani has become feasible using translabial ultrasound. The inferior aspects of the levator ani were identified in early studies using transvaginal techniques[1] and translabial freehand volume acquisition[2] as well as on translabial ultrasound using a Voluson system,[3] but the focus of these reports was on the urethra and paraurethral tissues. With translabial acquisition, the whole levator hiatus and surrounding muscle (pubococcygeus and puborectalis) can be visualized, provided acquisition angles are at or above 70°. As with magnetic resonance imaging (MRI), it is currently impossible to distinguish the different components of the pubovisceral or puborectalis/pubococcygeus complex. Several studies in nulliparous women have found no major asymmetries of the pubovisceral muscle, both on MRI[4] and on ultrasound,[5,6] supporting the hypothesis that significant morphologic abnormalities of the levator are likely to be evidence of delivery-related trauma. Contrary to MRI data,[7] no significant side differences were found on ultrasound biometry, neither for thickness nor for area.

Regarding biometric parameters of the puborectalis/pubococcygeus complex and the levator hiatus, there has been good agreement between three-dimensional ultrasound and MRI, both for dimensions of the levator hiatus[5,7] and levator thickness.[5,8] In general, it is to be expected that ultrasound measurements should be more reproducible because of 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. Figure 6.1 demonstrates the process of obtaining the plane of minimal dimensions.

On MRI, the plane of minimal dimensions is virtually impossible to image reproducibly because of slow acquisition speeds, even of single predefined planes. The latest software developments available for 3D/4D ultrasound such as volume contrast imaging and speckle reduction imaging should result in a further improvement in resolution and therefore reproducibility of ultrasound measurements. Diameter and area measurements of the pubococcygeus–puborectalis complex may not be sufficiently repro-

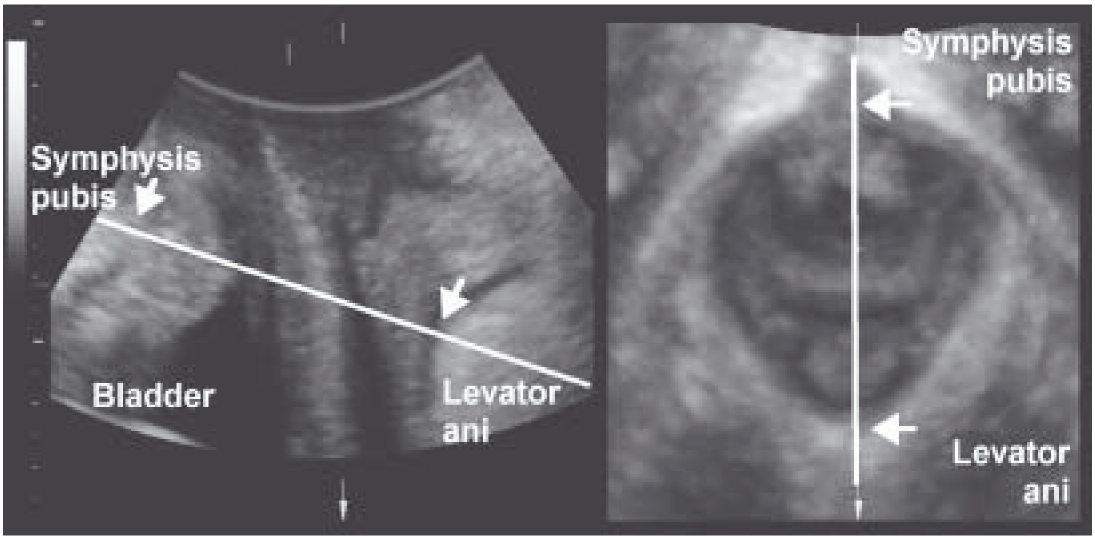

Figure 6.1. Determination of hiatal dimensions. The left-hand image shows the location of the plane of minimal dimensions as seen on the midsagittal view. This plane is tilted in a ventrocaudal to dorsocranial direction as evidenced by the line transecting the image running from the posterior surface of the symphysis to the anterior margin of the most central aspect of the puborectalis loop (white 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.

ducible for clinical or research use, but this is not the case for hiatal diameters and area measurements (see Figure 6.2).[5] They seem highly reproducible (Intraclass correlation coefficients of 0.70–0.82) and correlate strongly with pelvic organ descent, both at rest and on Valsalva.[5] Whereas this is not surprising for the correlation between hiatal area on Valsalva

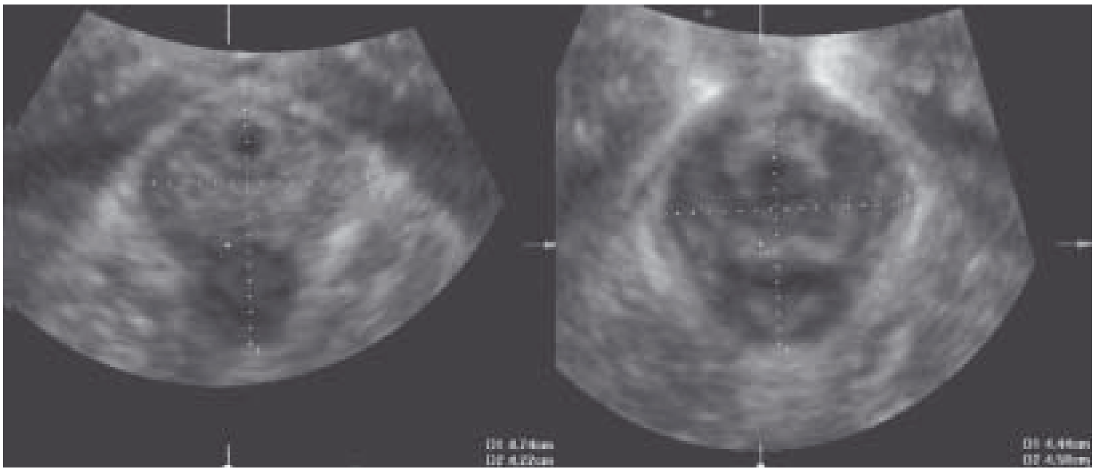

Figure 6.2. Area and diameter measurements of the levator hiatus [plane of minimal dimensions at rest (left) and on Valsalva (right)] in a nulliparous volunteer. (From Dietz HP, Shek C, Clarke B. Biometry of the pubovisceral muscle and levator hiatus by 3D pelvic floor ultrasound. Ultrasound Obstet Gynaecol 2005;25(6):580–585 , with permission.)

and descent (because downward displacement of organs may displace the levator laterally), it is much more interesting that hiatal area at rest is associated with pelvic organ descent on Valsalva. These data constitute the first real evidence for the hypothesis that the state of the levator ani is important for pelvic organ support,[9] even in the absence of levator trauma.

As a rule of thumb, a hiatal area of less than 25 cm^2 on Valsalva is unlikely to be associated with significant prolapse. We classify an area of 30–34.9 cm^2 as mild, 35–39.9 cm^2 as moderate, and 40+ cm^2 as severe ballooning, with extreme cases reaching 50 cm^2 and above. Interestingly, there are nulliparous women who show moderate to marked ballooning on Valsalva. Whereas the highest measurement in a series of 52 young women[5] was 35 cm^2 the author has recently documented ballooning to more than 50 cm^2 in a nulliparous professional athlete with an asymptomatic three-compartment prolapse and enterocele, without there being any evidence of an abnormal connective tissue phenotype. To put this in perspective, the area required by a term-sized fetal head is in the order of 70–90 cm^2.

Apart from static dimensions, relative enlargement of the hiatus on Valsalva may be a measure of compliance or elasticity which may influence the progress of labor, pelvic floor trauma, and future prolapse. However, childbirth obviously has an effect on width and distensibility of the hiatus (see Figure 6.3). And finally, hiatal dimensions are likely to affect treatment outcome if (or when) treatment for pelvic floor dysfunction becomes

Figure 6.3. Increase in hiatal dimensions on Valsalva after vaginal delivery (rendered volumes, axial plane).

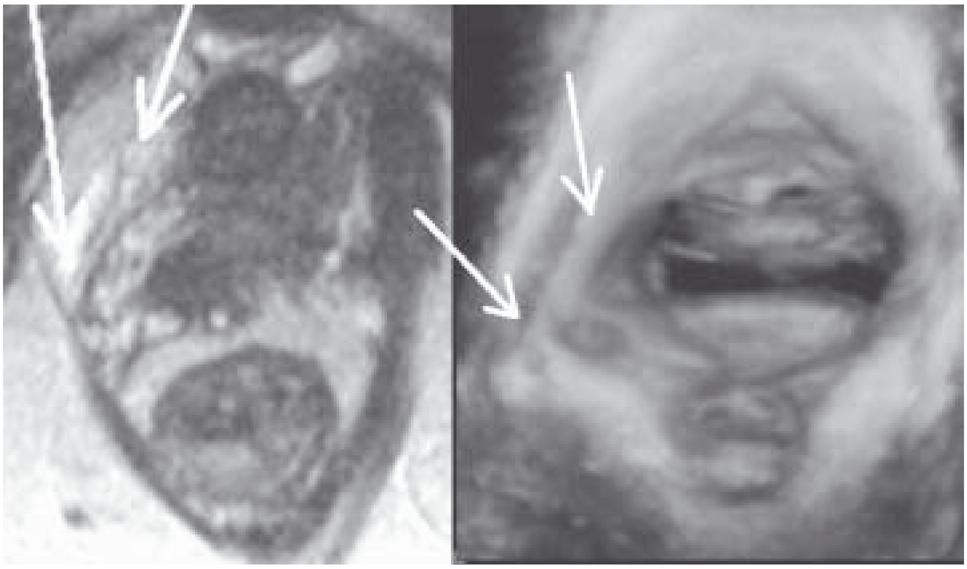

Figure 6.4. Avulsion injury of the right pubovisceral muscle, on MRI (left) and 3D ultrasound (right). Although the images were obtained in different patients, they illustrate the most common pattern of delivery-related levator trauma. The arrows indicate vaginal detachment (top arrows) and detachment of the levator ani (bottom arrows). (MRI courtesy of Dr. Ben Adekanmi, York, UK.)

necessary. The author believes that marked enlargement of the levator hiatus on Valsalva reduces the likelihood of successful pessary management and probably makes successful surgical prolapse correction less likely.[10] In women that show a hiatal area on Valsalva of more than 40 cm^2 one would expect a high likelihood of posterior compartment prolapse after a colposuspension procedure – or a large cystocele after sacrospinous colpopexy, because neither procedure would be expected to address the issue of excessive distensibility of the levator hiatus. Clearly, much work will have to be done in this field over the next decade, and pelvic floor imaging is likely to have a significant impact on the development of prolapse surgery.

The most common morphologic abnormality of the levator ani, an avulsion of the pubovisceral muscle off the pelvic sidewall, is clearly related to childbirth (see Figures 6.4–6.6 and Cases 5, 10, 12, and 13 of the Appendix) and is often palpable as an asymmetric loss of substance in the inferomedial or ventrocaudal portion of the muscle. The digital detection of morphologic abnormality seems to require significant training however, even if palpation of such trauma was described more than 60 years ago.[11] In a recently completed blinded study, the author found poor agreement between palpation by a trained physiotherapist and ultrasound imaging.[12] Technical issues also help explain the poor agreement found in this study. In women with poor resting tone and minimal or absent voluntary function, defects may be impossible to detect by digital examination. However, a recent study using MR detection of levator defects demonstrated much better agreement between imaging and vaginal palpation, provided the operators were trained specifically for this task.[13]

Figure 6.5. Axial plane rendered volumes. The right image shows a left-sided minor defect of the pubovisceral muscle 4 months after vaginal delivery.

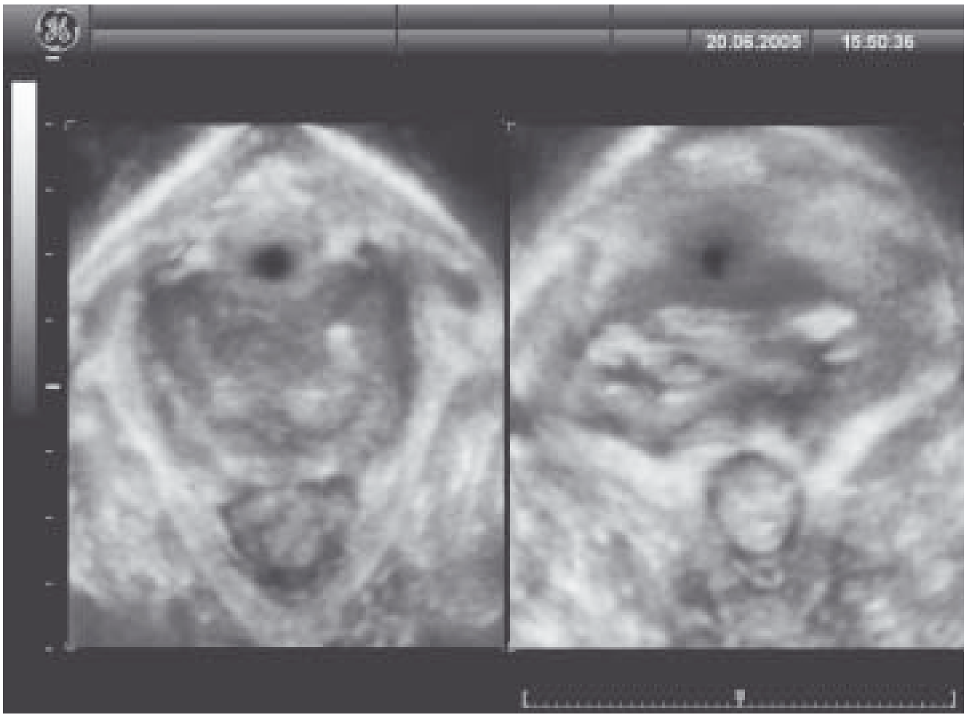

Figure 6.6. Bilateral avulsion injury. The left image was obtained at 37 weeks' gestation in a nulliparous patient. The right image shows a bilateral major defect of the pubovisceral muscle 4 months after vaginal delivery in the same patient.

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. Having said that, bilateral defects (see Figure 6.6, also Figures 3.4 and 3.7, and Cases 10 and 13 of the Appendix) may be more difficult to palpate than unilateral avulsion because of the lack of asymmetry, and they are also much less common.

The detection of avulsion defects by translabial 3D/4D ultrasound seems highly reproducible.[14] Both rendered volumes (surface/transparency mode, rendered from caudally to cranially) and single slices in the C or axial plane may be used to help with the identification of defects. The recent development of tomographic ultrasound imaging (TUI) (see Figures 3.6, 3.7, 6.8, and 6.9) is particularly useful in this regard because it allows the screening of one 3D volume at a glance, especially once speckle reduction algorithms have been used to enhance resolutions in the axial plane. Generally, defects seem to be most clearly evident on levator contraction. On Valsalva, defects may open up further, but once full distension of the hiatus is reached the defect is often obscured by flattening of the area of interest against the pelvic sidewall, particularly in women with significant prolapse.

Difficulties may arise in elderly women with marked urogenital atrophy and/or scarring, especially if voluntary function is absent or with very thin or atrophic muscle. When in doubt, the author has found that measurement of the "levator sling muscle gap,"[15] i.e., the distance between the urethral lumen and the most medial aspect of the pubovisceral muscle insertion, is helpful, with a gap of <2.6 mm likely to indicate normal anatomy (unpublished data). 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.

Such defects of the pubovisceral muscle are surprisingly common for a form of childbirth-related trauma that has received virtually no attention to date. In a recently completed study, the author found that more than one third of women delivering vaginally at an average age of 31.6 years had such injuries,[6] an incidence that is unexpectedly high compared with observations in older symptomatic women[14] and previously published rates in women who had their first child at a younger age, both on clinical examination[11] and MRI.[4] This discrepancy may be explained by an association between maternal age at first delivery and the incidence of major levator trauma[14,16] which is worrying given the marked trend toward delayed childbearing in developed countries. It seems likely that women today run a higher risk of sustaining significant trauma to the levator ani muscle, compared with their mothers or grandmothers. This implies that urogynecology—and urogynecologic imaging—is likely to be a growth area for the foreseeable future.

Regarding causation, there seems to be an association with operative delivery,[6] but analogous to the situation with anal sphincter trauma, it seems that precipitate delivery may also cause major levator trauma. This implies that any association with length of second stage and other parameters indicating a difficult delivery may not be linear, making prediction more difficult.

The clinical significance of such defects is becoming clearer. The author's own data suggest that levator avulsion is associated with anterior and central compartment prolapse,[14] but not with urodynamic findings or symptoms of bladder dysfunction in a series of more than 300 primary urogynecologic assessments. Cross-sectional studies of levator anatomy in asymptomatic and symptomatic older women are needed to determine whether such abnormalities are associated with clinical symptoms or conditions in the general population. Another interesting question is whether major morphologic abnormalities of the levator ani affect surgical outcomes. From experience to date and MRI data,[17] it appears that major levator trauma, i.e., avulsion of the puborectalis/pubococcygeus from the pelvic sidewall, seems to be associated with early presentation and recurrent prolapse after surgical repair.

Clearly, there are different degrees of levator trauma. In the future we should be able to distinguish not just unilateral and bilateral trauma, but also isolated defects of the pubococcygeus or muscle, partial (Figure 6.5) and/or complete avulsions puborectalis (Figure 6.6), and global deficiencies of the whole levator (Figure 6.7) which are probably more likely to be caused by neuropathy rather than direct trauma. In the meantime, we may be able to quantify the extent of trauma by using TUI which allows both scoring according to the number of slices showing defects (see Figure 6.8), and quantification of cranioventral and ventrodorsal defect dimensions. Both defect score and maximal width seem associated with symptoms and signs of prolapse.[18]

Figure 6.7. Virtually complete absence of the pubovisceral muscle on the right side after Forceps delivery.

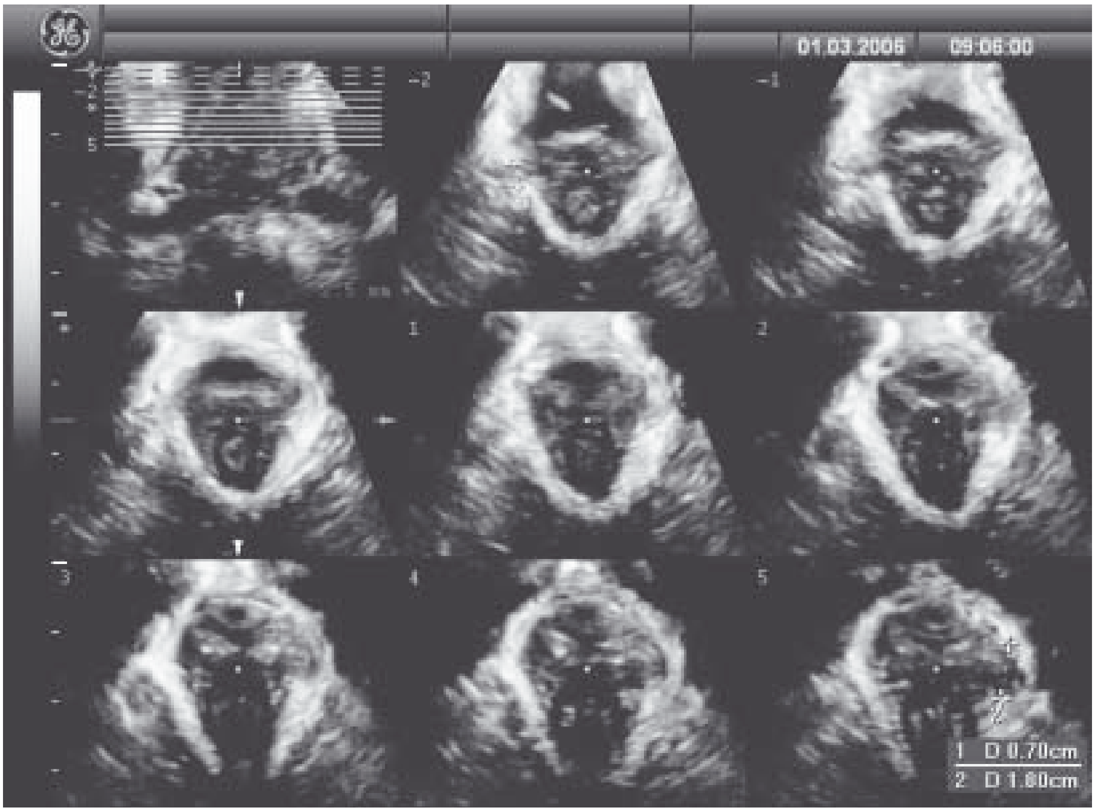

Figure 6.8. TUI of limited bilateral levator trauma, affecting the lowermost aspects of the right pubovisceral muscle and more cranial aspects on the left. The defect score is 6 (2 on right, 4 on left).

On a final note, it appears that the literature to date contains no reports of attempts at surgical correction. This is nothing short of amazing when one considers that such defects may in fact be visible in the delivery suite. Most avulsion injuries are occult, but some become visible due to vaginal tears, resulting in a typical appearance with the vagina detached from the pelvic sidewall, the inferior public ramus and obturator fascia denuded of muscle, and the muscle retracted pararectally. We may have to learn how to reattach the levator, a task that may require us to acquire some of the skills of orthopedic surgeons. Imaging will of course be instrumental in documenting the success of failure of such attempts.

Paravaginal Supports

It has long been speculated that anterior vaginal wall prolapse and stress urinary incontinence are at least partly attributable to disruption of paravaginal and/or paraurethral support structures, i.e., the endopelvic fascia and pubourethral ligaments, at the time of vaginal delivery.[19] In a pilot study using the now obsolete technology of freehand acquisition of 3D volumes, alterations in paravaginal supports were observed in 5 of 21 women seen both ante- and postpartum, and the interobserver variability of the qualitative assessment of paravaginal supports was shown to be good.[2] In light of current knowledge, however, the loss of tenting documented in this study was probably at least partly attributable to levator avulsion.

Structures supporting urethra and bladder can also be assessed by transrectal or transvaginal 3D ultrasound using probes designed for pelvic or prostatic imaging.[1,20] In a recent small series, researchers from Austria have claimed that the endopelvic fascia may be evaluated directly by transrectal 3D ultrasound, describing defects in an echogenic structure underlying the bladder neck and proximal urethra. Such defects almost exclusively occurred in vaginally parous women and were unexpectedly complex.[21]

It remains to be shown whether loss of paravaginal tenting or defects in suburethral/paraurethral echogenic structures are in fact equivalent to what is clinically described as a "paravaginal defect," a concept that is controversial in clinical urogynecology.[22–24] In a recent study on 62 women presenting with pelvic floor disorders, only weak correlations were found between a blinded clinical assessment for paravaginal defects and the presence or absence of tenting in single planes or rendered volumes obtained by 3D translabial ultrasound, and even this weak correlation was only seen on Valsalva.[25] This may be attributable to inadequate clinical assessment techniques or possibly an insufficiently sensitive imaging method. Recent evidence suggests that the clinical assessment for paravaginal defects has poor repeatability.[26,27] However, another (if less likely) explanation may be that true paravaginal defects are either not common and/or irrelevant for anterior vaginal wall support.

Urethra and Urethral Supports

The first use of 3D pelvic floor ultrasound, albeit with a transvaginal probe, was in investigating urethral structure.[28,29] Although there seems to be disagreement as to what has actually been measured in some of the studies of urethral sonoanatomy,[20,28,30] it seems that the volume of the hypoechoic structures surrounding the urethra (smooth muscle, vascular plexus, and mucosa) is associated with closure pressure.[28] On 3D ultrasound in the axial plane, one is generally able to detect a circular hyperechogenic structure surrounding the mid urethra (see Figure 6.9) which, judging from intraurethral ultrasound and axial plane MRI, corresponds to the striated urethral sphincter.

It is less clear, however, whether observation of static urethral anatomy is of any clinical relevance. 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. This may change with the advent of small parts 4D and matrix probes which will likely allow much more detailed insights into urethral anatomy, without distortion and in a noninvasive manner. This probably also applies to urethral supports which are starting to be studied in more detail on MRI and ultrasound.[21]

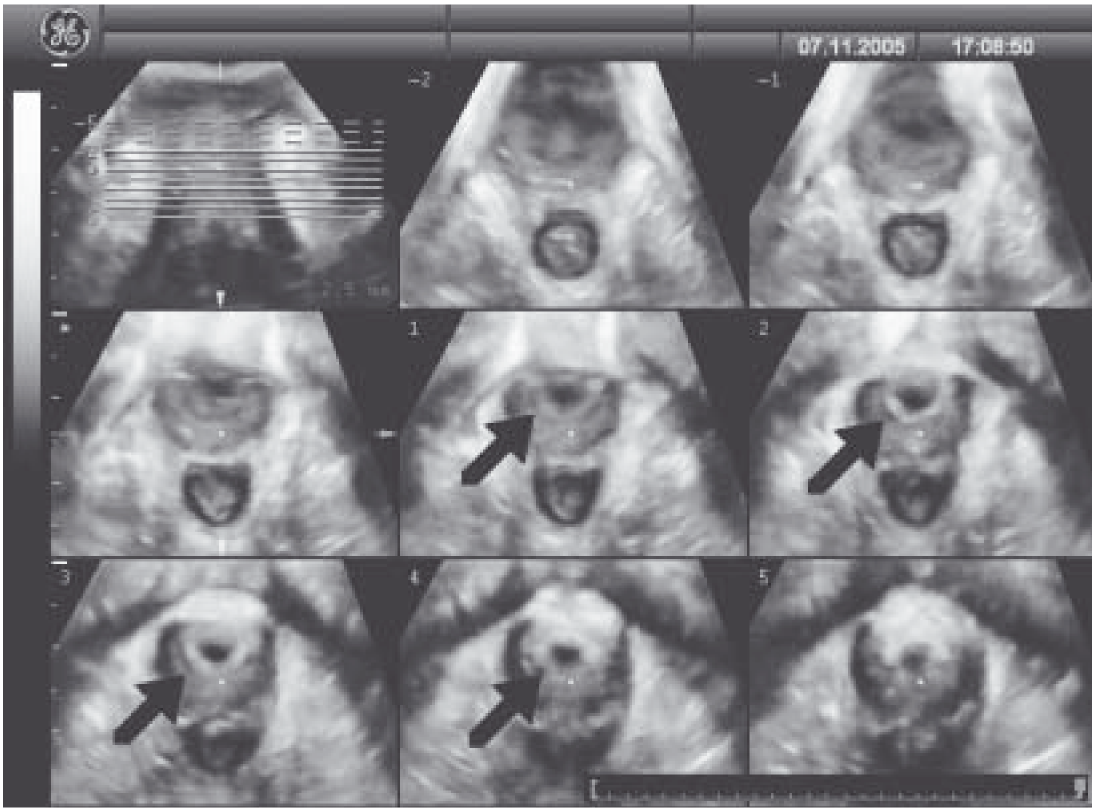

Figure 6.9. TUI in a parous patient without bladder symptoms and normal pelvic floor anatomy. There is a hyperechogenic ring structure (arrows) surrounding the midportion of the urethra in slices 1–4, i.e., extending over at least 10 mm, which represents the urethral rhabdosphincter.

Other Findings

At times, imaging in the axial plane can help clarify anatomic relationships in more complex prolapse cases, especially if there is significant asymmetry. The extent of a cystocele may become more obvious (see Figure 6.10), and side differences, e.g., caused by major levator trauma or neuropathy, can be detected in the coronal plane (see Figure 6.11). Rectoceles are usually clearly apparent because of their hyperechoic nature (see Figure 6.12 and Case 6 of the Appendix).

Cystic structures in the vagina are more easily assessed on 3D ultrasound, especially regarding their relationship with the urethra (see Figure 6.13 and Case 9 of the Appendix for Gartner cysts, Case 15 for a urethral diverticulum). The exact location of a pessary can also be determined more easily on 3D imaging, although Figure 6.14 is mainly given to acquaint readers with the very distinct appearances of a ring pessary. These appear virtually completely anechoic because of total reflection of incoming acoustic waves. Implants and suburethral slings will be discussed in Chapter 7.

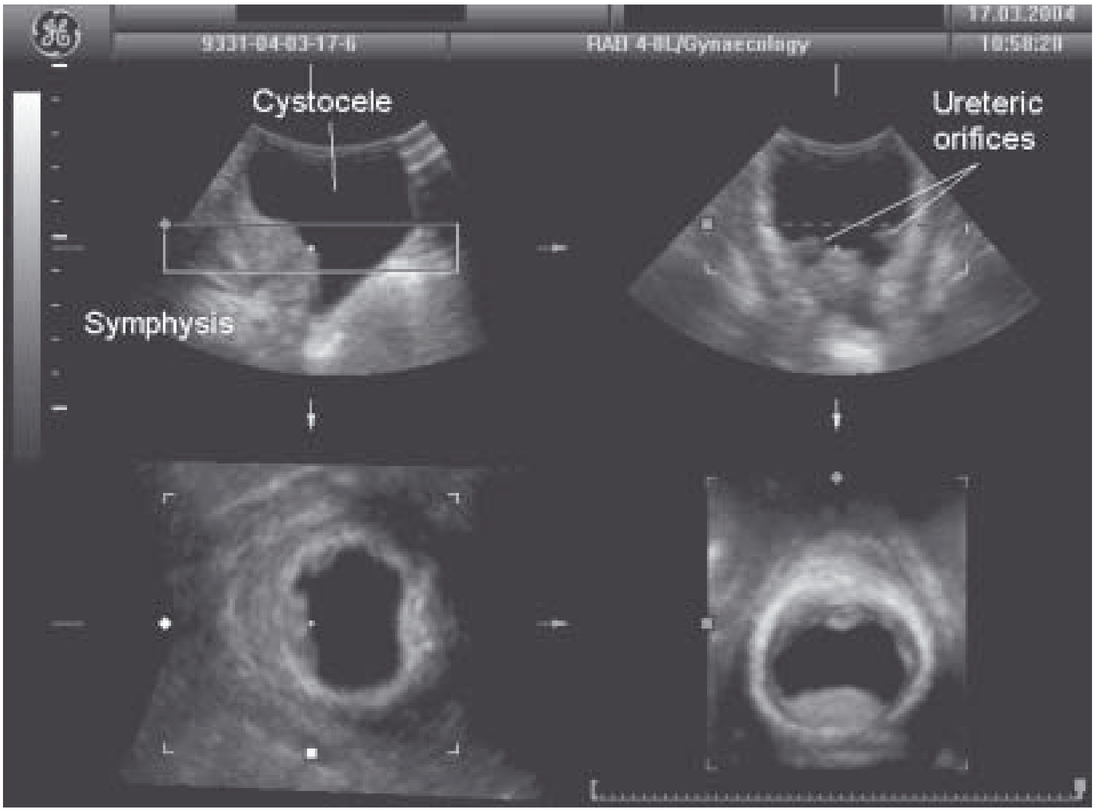

Figure 6.10. Large cystocele with intact retrovesical angle as seen on 3D ultrasound in the midsagittal plane (top left), coronal plane (top right), axial plane (bottom left), and in a rendered volume (axial plane) (bottom right). In the coronal plane, the ureteric orifices are clearly visible and well outside the pelvis. The axial plane and rendered volume do not show the levator ani because they are situated well below the hiatus. (Dietz HP. Pelvic Floor Ultrasound. Current Medical Imaging Reviews 2006; 2: in print, Bentham Publishers.)

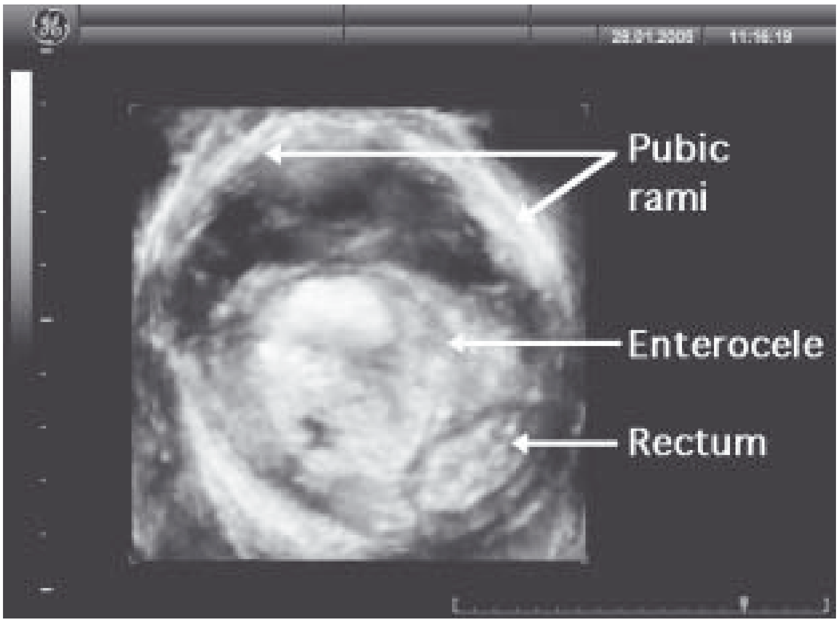

Figure 6.11. Marked asymmetry of prolapse as seen in the axial plane. The left pubovisceral muscle is globally impaired, likely because of neuropathy, with asymmetric development of recto- and enterocele on Valsalva.

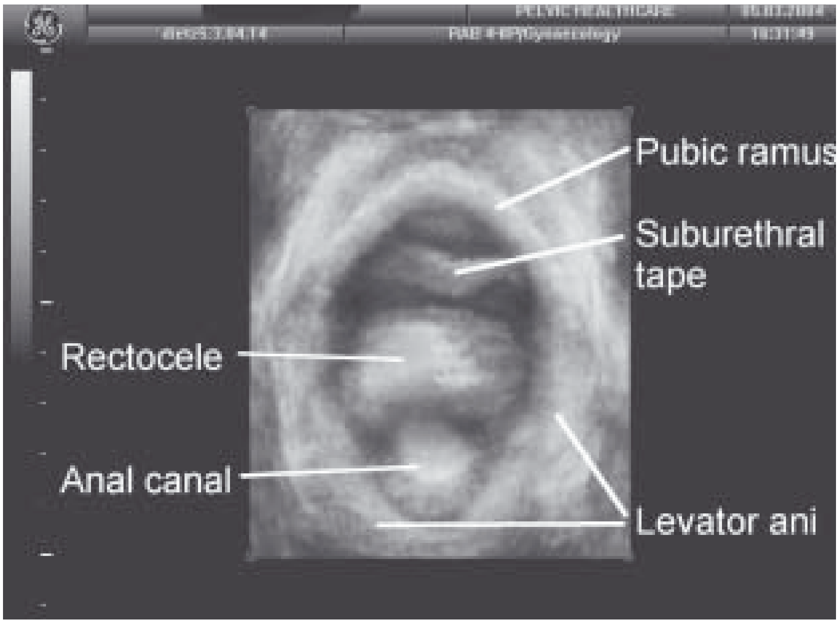

Figure 6.12. A rendered volume of a patient with a second-degree rectocele. The hyperechoic structure of the rectocele is seen to fill a large part of the hiatus. There also is a suburethral tape. (Dietz HP. Pelvic Floor Ultrasound. Current Medical Imaging Reviews 2006; 2: in print, Bentham Publishers, with permission.)

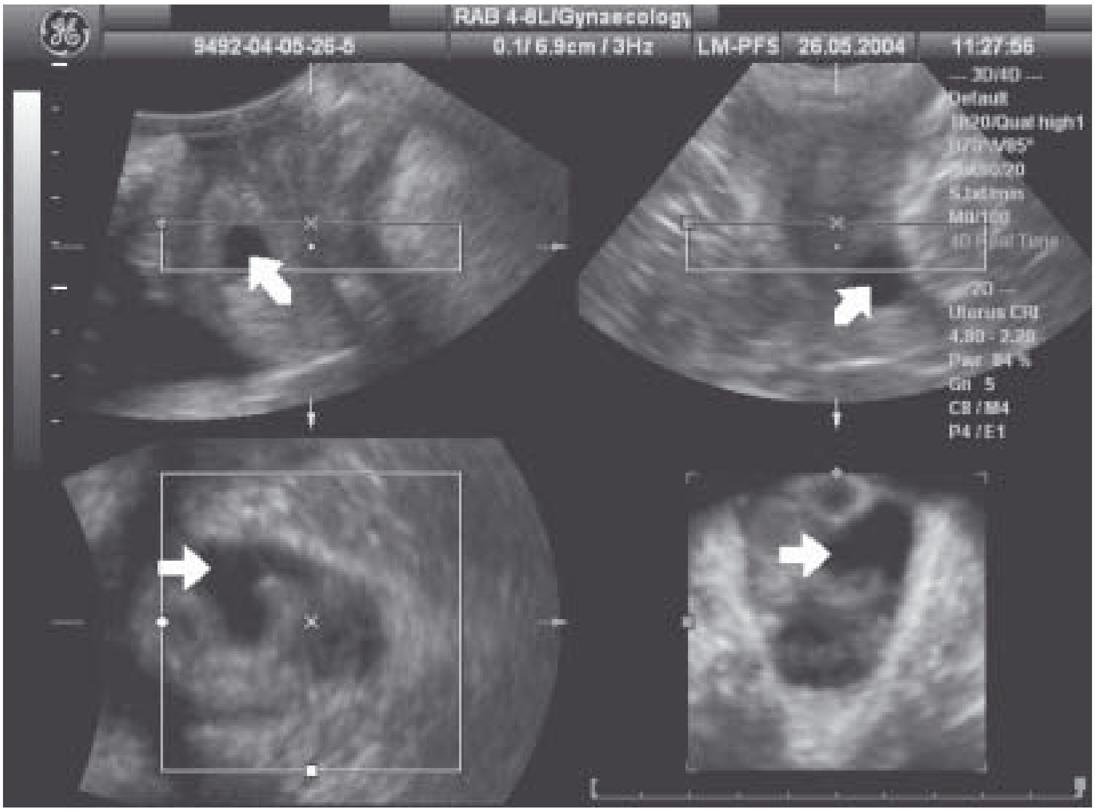

Figure 6.13. The complex appearance of a Gartner cyst on 3D ultrasound, mimicking a cystocele on clinical examination.

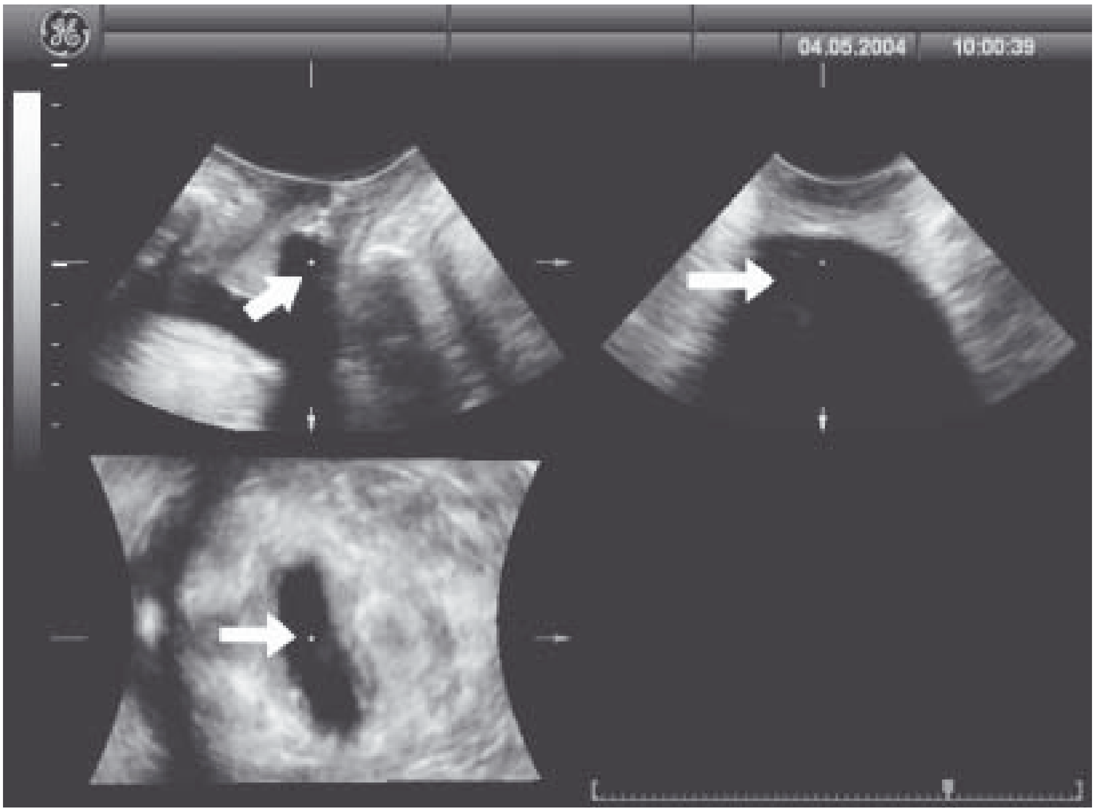

Figure 6.14. Prolapse pessaries may cause unusual and distinct sonographic patterns. In this case, a silicone ring pessary results in complete reflection (and refraction) of incoming soundwaves, resulting in anechoic areas encompassing the pessary and an acoustic shadow which is evident in the midsagittal and the coronal plane.

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