Ultrasound imaging of the pelvic floor. 
Part I: two-dimensional aspects

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KEYWORDS: incontinence; pelvic floor; perineal ultrasound; prolapse; translabial ultrasound; urogynecology

ABSTRACT
Ultrasound imaging is rapidly replacing radiological methods in the investigation of pelvic floor disorders. Transrectal, transvaginal/introital and translabial/transperineal methods are being employed, with the latter probably the most widespread due to ease of use and availability of equipment. Position and mobility of the bladder neck, bladder wall thickness, pelvic floor muscle activity and uterovaginal prolapse can be quantified, and color Doppler may be used to document stress urinary incontinence. Ultrasound imaging has simplified audit activities and enhanced our understanding of the effects of incontinence and prolapse surgery, such as the new synthetic suburethral slings. In recent years, imaging methods have contributed significantly to our understanding of the traumatic effects of childbirth on the pelvic floor. Finally, the assessment of pelvic floor biomechanics may have implications for clinical obstetrics and ultimately for the prevention of delivery-related pelvic floor trauma. Copyright © 2003 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION
For several decades, clinicians working in the field of urogynecology and female urology have focused almost exclusively on urodynamic parameters obtained by filling cystometry and urethral pressure profilometry. Imaging data ceased to be of relevance in the investigation of disorders of the female pelvic floor. This was at least partly due to the poor quality of imaging obtained with static cystourethrography; the high cost of state-of-the-art fluoroscopy equipment may also have contributed. Since quantification of findings was difficult with radiological methods, clinicians limited their assessment to qualitative statements regarding bladder contour, bladder neck descent and funneling.

The increasing availability of ultrasound and magnetic resonance imaging (MRI) equipment has now triggered a renewed interest in diagnostic imaging in urogynecology and female urology, with a growing number of studies being presented every year. For the most part, MRI has been of limited clinical use in the evaluation of pelvic floor disorders due to cost and access problems, and slow acquisition speeds have until very recently precluded dynamic imaging. For these reasons this review will be limited to discussing ultrasound imaging in urogynecology and female urology, providing a summary of developments to date and suggesting areas for future research.

HISTORY
Contrast X-ray techniques were first used in the diagnosis of lower urinary tract abnormalities in the late 1920s. In the 1950s and 1960s, the technique was standardized for use in incontinence diagnostics and the most common diagnostic criteria described and categorized. Contrast radiographic techniques were also evaluated for documentation of prolapse of the vagina and rectum; however, the complexity of this technique precluded widespread use.

During the 1980s, the increasing availability of real-time ultrasound equipment resulted in transabdominal, perineal, transrectal and transvaginal ultrasound being investigated for use in women suffering from urinary incontinence. Due to its non-invasive nature, ready availability and the absence of distortion, perineal or translabial ultrasound is currently used most widely and therefore will be the main focus of this review.

BASIC METHODOLOGY
A mid-sagittal view is obtained by placing a transducer (usually a 3.5–7-MHz curved array) on the perineum.
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(Figure 1), after covering the transducer with a glove or Gladwrap® or similar for hygienic reasons. Imaging can be performed in dorsal lithotomy, with the hips flexed and slightly abducted, or in the standing position. 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 defecation. Parting of the labia may be necessary to improve image quality. The transducer can be placed against the symphysis pubis without causing significant discomfort. The resulting image includes the symphysis anteriorly, the urethra and bladder neck, the vagina, cervix, rectum and anal canal (Figure 1). Posterior to the anorectal junction a hyperechogenic area indicates the central portion of the levator plate, i.e. the puborectalis muscle. The cul de sac may also be seen, filled with a small amount of fluid, echogenic fat or peristalsing small bowel. Parasagittal or transverse views may yield additional information, e.g. enabling direct assessment of the puborectalis muscle, but have not been investigated so far.

There has been disagreement regarding the optimal orientation of images obtained in the mid-sagittal plane. Some prefer image orientation as in the standing patient facing right¹³, 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). Since any image reproduced in one of the above orientations can be converted to the other by simple rotation through 180°, formal standardization may not be necessary.

Perineal imaging of the lower urinary tract yields information equivalent or superior to the lateral view.

![Figure 1](image1.png)

**Figure 1** Field of vision for translabial/perineal ultrasound in the mid-sagittal plane.

![Figure 2](image2.png)

**Figure 2** Lateral urethrocystogram with bead chain outlining the urethra. The images are rotated by 180° to allow comparison with standard translabial ultrasound views. The images are at rest (a) and during Valsalva maneuver (b).
urethrocystogram (shown in Figure 2, rotated by 180° for ease of comparison) or fluoroscopic imaging. Comparative studies have mostly shown good correlations between radiological and ultrasound data. The one remaining advantage of X-ray 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. The next paragraphs will outline the more promising current and potential future uses of the method, both clinical and in a research context.

CURRENT USES IN GYNECOLOGY

Position and mobility of bladder neck and proximal urethra

Bladder neck position and mobility can reliably be assessed by perineal ultrasound. Points of reference are the central axis of the symphysis pubis or its inferoposterior margin. The former may potentially be more accurate as measurements are independent of transducer position or movement; however, due to calcification of the symphyseal disc the central axis is often difficult to obtain in older women. Imaging can be undertaken supine or erect, and with a full or empty bladder. The full bladder is less mobile than the empty organ 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.

Measurements are generally performed at rest and on Valsalva maneuver. The difference between these two measurements 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 (Figure 3). Some investigators measure the retrovesical (or posterior urethrovesical) angle between proximal urethra and trigone and others determine the angle between the central axis of the symphysis pubis and a line from the inferior symphyseal margin to the bladder neck. Of all those ultrasound parameters of hypermobility, bladder neck descent probably has the strongest association with urodynamic stress incontinence (USI). The reproducibility of this dynamic measurement has recently been assessed, with a coefficient of variation (CV) of 0.16 between multiple effective Valsalva maneuvers, a CV of 0.21 for interobserver variability and a CV of 0.219 for a test–retest series at an average interval of 46 days. Intraclass correlations were between 0.75 and 0.98, indicating excellent agreement.

There is no definition of ‘normal’ for bladder neck descent although a cut-off of 2.5 cm has been proposed to define hypermobility. Figure 4 shows an immobilized bladder neck after colposuspension and Figure 5 demonstrates ultrasound findings in a patient with cystourethrocele. Bladder filling, patient position and catheterization all have been shown to influence measurements and it can occasionally be quite difficult to obtain an effective Valsalva maneuver, especially in nulliparous women. Perhaps not surprisingly, publications to date have presented widely differing reference measurements in nulliparous women. While two recently published series showed mean or median bladder neck descent of only 5.1 mm and 5.3 mm in continent nulliparous women, another study on 39 continent nulliparous volunteers measured an average of 15 mm of bladder neck descent. The author has obtained bladder neck descent measurements of 1.2–40.2 mm in a group of 106 stress-continent nulligravid young women aged 18–23 years. It is likely that methodological differences such as patient
position, bladder filling and quality of Valsalva maneuver (i.e. controlling for confounders such as concomitant levator activation) account for the above discrepancies. Attempts at standardizing Valsalva maneuvers\(^\text{35,36}\) have not found widespread application since this requires intra-abdominal pressure measurement, i.e. a rectal balloon catheter. Other methods, such as the use of a spirometer, are likely to lead to suboptimal Valsalva maneuvers; the pressures used in the one study describing the use of such a device\(^\text{35}\) were clearly insufficient to achieve maximal or even near-maximal descent\(^\text{36}\).

In patients with stress incontinence, but also in asymptomatic women\(^\text{37}\), funneling of the internal urethral meatus may be observed on Valsalva (Figure 5) and sometimes also at rest. Funneling is often associated with leakage and occasionally weak gray-scale echoes may be observed in the proximal urethra, suggesting urine flow and therefore incontinence on Valsalva. However, funneling may also be observed in urge incontinence and cannot be used to prove USI. Marked funneling has been shown to be associated with poor urethral closure pressures\(^\text{38,39}\).

Classifications developed for the evaluation of radiological imaging\(^\text{40}\) can be employed with ultrasound data; however, this approach is not generally accepted. The commonest finding in cases of bladder neck hypermobility

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Figure 4 Measurement of bladder neck position at rest (a) and on Valsalva (b). The point of reference is the inferoposterior margin of the symphysis pubis (arrow).

Figure 5 A typical finding in a patient with stress incontinence and anterior vaginal wall descent (cystourethrocele Grade I): postero-inferior rotation of the urethra, opening of the retrovesical angle and funneling of the proximal urethra (arrow).
Figure 6 A cystocele with intact retrovesical angle. Note the absence of funneling (arrow).

is the so-called rotational descent of the internal meatus, i.e. the proximal urethra and trigone rotate in a postero-inferior direction. Usually the retrovesical angle opens to up to 160–180° from a normal value of 90–120°, and such a change in the retrovesical angle is often (but not always) associated with funneling. A cystocele with intact retrovesical angle (90–120°) is frequently seen in continent prolapse patients (Figure 6), and it has been surmised that this configuration distinguishes a central from a lateral defect of the endopelvic fascia although proof for this hypothesis is lacking at present. Marked urethral kinking in such cases can lead to voiding dysfunction and urinary retention. Occult stress incontinence may be unmasked once a successful prolapse repair prevents this kinking.

The etiology 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 in fact confirmed a high degree of heritability for anterior vaginal wall mobility. Conversely, imaging work in this field has confirmed the role of vaginal childbirth with a long second stage of labor and vaginal operative delivery being associated with increased postpartum descent. This association between increased bladder descent and vaginal parity is also evident in older women with symptoms of pelvic floor dysfunction. In another interesting development, the suspicion that progress in labor is not independent of pelvic floor biomechanics has been confirmed: anterior vaginal wall mobility on Valsalva was found to be a potential predictor of progress in labor in two independent studies.

It remains to be mentioned that increased bladder neck mobility antepartum has been claimed as a predictor of postpartum stress incontinence and has already been used as an entry criterion for a randomized controlled intervention trial. However, the author has been unable to confirm these claims in a series of 200 nulliparous women, which may partly be due to different methodology (see above). In this last series, increased antenatal bladder neck mobility was shown to be associated with less peripartum change in this parameter, which would imply a reduced risk of trauma to fascial structures and therefore possibly a reduced risk of stress incontinence in the long term. Clearly, further work is needed in this field.

Documentation of stress incontinence

Contrast media

The main disadvantage of B-mode ultrasound imaging in urogynecology has been the fact that actual leakage may be difficult to detect. Funneling, i.e. opening of the proximal urethra, is easily observed on translabial or transvaginal imaging; however, as mentioned above, funneling also occurs in asymptomatic women and cannot be taken as proof of USI. One solution to this problem is to use ultrasound contrast media, e.g. microbubbles such as Echovist. Such preparations are injected into the bladder before imaging, filling the region of the bladder neck. This technique outlines the bladder neck very clearly but involves considerable expense and catheterization.

Color Doppler

As an alternative to ultrasound contrast media, color Doppler ultrasound has recently been used to demonstrate urine leakage through the urethra on Valsalva maneuver or coughing. The method yielded satisfactory results with or without indwelling catheter. Agreement between color Doppler and fluoroscopy was very high in a controlled group with indwelling catheters and identical bladder volumes. Both velocity (color Doppler velocity (CDV), Figure 7) and energy mapping (color Doppler energy (CDE) or ‘power Doppler’, Figure 8) were able
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Figure 7 Color Doppler velocity (CDV) ultrasound demonstrating urine leakage (arrow) through the urethra on Valsalva maneuver.

Figure 8 Color Doppler energy (CDE) imaging in genuine stress incontinence. The Doppler signal outlines most of the proximal urethra.

to document leakage. CDV was slightly more likely to show a positive result, probably due to its better motion discrimination. This results in less flash artifact and better orientation, particularly on coughing, although imaging quality will depend on the systems used and selected color Doppler settings. As a result, routine sonographic documentation of stress incontinence during urodynamic testing has become feasible. Color Doppler imaging may also facilitate the documentation of leak point pressures. Whether this is in fact desired will depend on the clinician and his/her preferences.

Bladder wall thickness

There has recently been considerable interest in the quantification of bladder wall thickness by transvaginal and/or translabial ultrasound. Measurements are obtained after bladder emptying and perpendicular to the mucosa (Figure 9). Usually three sites are assessed: anterior wall, trigone and dome of the bladder, and the mean of all three is calculated. A bladder wall thickness of >5 mm seems to be associated with detrusor instability. Increased bladder wall thickness likely signifies hypertrophy of the detrusor muscle; this may be the cause of symptoms or simply the effect of an underlying abnormality. While bladder wall thickness on its own seems only moderately predictive of detrusor instability, the method may be clinically highly useful when combined with symptoms of the overactive bladder. It remains to be seen whether determination of this parameter can add any useful clinical information to the work-up of a patient with pelvic floor and bladder dysfunction.

Levator activity

Perineal ultrasound has been used for the quantification of pelvic floor muscle activity, both in women with stress incontinence and continent controls, as well as before and after childbirth. A cranioventral shift of pelvic organs imaged in a sagittal midline orientation is taken as evidence of a levator contraction. The resulting displacement of the internal urethral meatus is measured relative to the inferoposterior symphyseal margin (Figure 10). In this way pelvic floor activity is assessed at the bladder neck where its effect as part of the continence mechanism is most likely to be relevant. It can also be utilized for pelvic floor muscle exercise teaching and provide visual biofeedback. The technique has helped validate the concept of ‘the knack’, i.e. of a reflex levator contraction immediately prior to increases in intra-abdominal pressure such as those resulting from coughing. 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.

Prolapse quantification

Translabial ultrasound can demonstrate uterovaginal prolapse. The inferior margin of the symphysis pubis serves as a line of reference against which the maximal descent of bladder, uterus, cul de sac and rectal ampulla on Valsalva maneuver can be measured (Figure 11).
Figure 10 Quantification of levator contraction: cranioventral displacement of the bladder neck is measured relative to the inferoposterior symphyseal margin. The measurements indicate 4.5 (31.9 – 27.4) mm of cranial displacement and 16.2 (17.9 – 1.7) mm of ventral displacement of the bladder neck.

Figure 12 shows a first-degree uterine prolapse after Burch colposuspension. In a recent study, ultrasound findings were compared to clinical staging and the results of a standardized assessment according to criteria developed by the International Continence Society, with good correlations shown for the anterior and central compartments. While there is poorer correlation between posterior compartment clinical assessment and ultrasound, it is possible to distinguish between 'true' and 'false' rectocele, i.e. a true fascial defect of the rectovaginal septum (Figure 11) and perineal hypermobility without fascial defects. True fascial defects of the rectovaginal septum are in fact found in about 10% of young nulliparous women (Figure 13), but are more common in parous, older women. From imaging experience to date, fascial defects seem to almost always arise in the same area, i.e. very close to the anorectal junction, and most commonly are transverse. Many are asymptomatic. Hopefully the identification of such posterior compartment fascial defects will allow better surgical management in the future, not least because enterocoele (Figure 14) can be distinguished from rectocele. Most recently, it appears that colorectal surgeons are starting to use the technique to complement or replace defecography.

Disadvantages of the method include incomplete imaging of cervix and vault with large rectoceles and the possible underestimation of severe prolapse due to transducer pressure. Needless to say, procidentia or complete vaginal eversion preclude translabial imaging. Occasionally, apparent anterior vaginal wall prolapse will turn out to be due to a urethral diverticulum (Figure 15).

The main use of this technique may prove to be in outcome assessment after prolapse and incontinence surgery, a field that is rapidly developing at present. The elevation and distortion of the bladder neck arising from a colposuspension is easily documented (Figure 12). Fascial and synthetic slings are visible posterior to the trigone or the urethra (Figure 16), and bulking agents such as Macroplastique® (Figure 17) show up anterior, lateral and posterior to the proximal urethra. It has been demonstrated that overelevation of the bladder neck on colposuspension is unnecessary for cure of USI, and elevation may also have a bearing on postoperative symptoms of voiding dysfunction and *de novo* detrusor overactivity.
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Figure 12 First-degree uterine descent in a patient after Burch colposuspension. The latter is evident as a ridge-like deformation of the trigone, posterior to the internal urethral meatus (arrow). The images are at rest (a) and on Valsalva (b).

Figure 13 First-degree rectocele in a 23-year-old nulliparous asymptomatic volunteer both at rest (a) and on Valsalva (b). The anal canal is seen to the right in both images, with a small rectocele (large arrow) clearly visible on Valsalva (b). Midline imaging shows a transverse fascial defect (arrows) of the lower rectovaginal septum, at the level of the anorectal junction.

Ultrasound has contributed significantly to the investigation of new surgical procedures such as the recently developed suburethral slings. It has helped to clarify the mode of action of these procedures, i.e. urethral kinking or ‘dynamic compression’ against the posterior surface of the symphysis pubis, and may well provide us with the means of performing in vivo biomechanical assessment of implants in the future. The method seems superior even to MRI in this context since the currently available synthetic slings are easily visualized posterior to the urethra (Figure 16). Wide-weave monofilament mesh such as the tension-free vaginal tape (TVT) or suprapubic arc (SPARC) tape are more echogenic than more tightly woven multifilament implants such as the intravaginal slingplasty (IVS) tape, but all can usually be identified and followed in their course from the pubic rami laterally to the urethra centrally. Ultrasound has demonstrated the wide margin of safety and efficacy of such tapes as regards placement, which explains their extraordinary success and allayed concerns regarding tape shrinkage and tightening due to scar formation. The assessment of bladder neck mobility before implantation of a suburethral sling may predict success or failure, an observation that makes perfect sense when one considers that dynamic compression relies on relative movement of implant and native tissues. Finally, sonographic imaging...
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Figure 14 Recto-enterocele after Burch colposuspension at rest (a) and on Valsalva maneuver (b). Usually, enteroceles (filled by peristalsing small bowel, epiploic fat or omentum) appear more homogeneous and nearly isoechogenic whereas the rectocele is filled by a stool bolus, resulting in hyperechogenicity with distal shadowing.

Figure 15 Urethral diverticulum (arrow) herniating downwards and clinically simulating a cystourethrocele shown at rest (a) and on Valsalva maneuver (b). The neck of the diverticulum is seen close to the bladder neck.

seems similarly useful in evaluating the effect of pessaries and/or bladder neck support prostheses and may be of help in optimizing the design of such devices.

Paravaginal defect imaging

Transabdominal ultrasound has been used to demonstrate lateral defects of the endopelvic fascia, also termed ‘paravaginal’ defects. However, the method has not been conclusively validated, and a recent study showed poor correlation with clinically observed defects. There may be several factors limiting the predictive value of transabdominal ultrasound in the identification of paravaginal defects: the poor definition of an optimal scanning plane, the influence of uterine prolapse or a full rectum, and finally the inability to observe the effect of a Valsalva maneuver (which would dislodge the transducer) by transabdominal imaging. Standard translabial ultrasound has not yet been evaluated for this purpose but does hold some promise. Coronal plane imaging may enable us to identify asymmetries in the downwards development of the bladder on Valsalva. However, it may well be that significant progress in this field will have to await the more widespread application of three-dimensional ultrasound and MRI.
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Figure 16 Synthetic implants such as tension-free vaginal tape (TVT) or suprapubic arc (SPARC) tape are easily visualized as highly echogenic structures posterior to the urethra. The images illustrate tape position relative to the symphysis pubis and urethra at rest (a) and on Valsalva (b).

Figure 17 Macroplastique® silicone macroparticles used in incontinence surgery are very echogenic and located surrounding the urethra both anteriorly and posteriorly.

Other findings

A range of other abnormalities, incidental or expected, may at times be detected on translabial ultrasound, although a full pelvic ultrasound assessment does of course require a transvaginal approach. Urethral diverticula73,74 (Figure 15), Gartner duct cysts (Figure 18) or bladder tumors (Figure 19) may be identified, and intravesical stents and bladder diverticulae can also be visualized13. Postoperative hematomata may be visible after vaginal surgery or TVT and at times explain clinical symptoms such as voiding dysfunction or persistent pain (Figure 20).

OUTLOOK

Ultrasound imaging, and in particular translabial or transperineal ultrasound, is in the process of becoming a new diagnostic standard in urogynecology. Several factors are contributing to its increasing acceptance, the most important being the availability of suitable equipment. Recent developments such as the assessment of levator activity and prolapse, but also the use of color Doppler to document urine leakage, enhance the clinical usefulness of the method. It is to be hoped that increasing standardization of parameters will make it easier for clinicians and researchers to compare data.

The convenience with which pre- and post-treatment imaging data can now be obtained will simplify outcome studies after prolapse and incontinence surgery. Ultrasound imaging may be able to significantly enhance our understanding of the different mechanisms by which conservative methods, colposuspension or urethropexy procedures, slings and (most recently) the TVT achieve – or
fail to achieve – continent. It may even be possible to identify distinct fascial defects (such as defects of the rectovaginal septum in true rectoceles), which should open up new surgical possibilities.

Regardless of which methodology is used to determine descent of pelvic organs, it is evident that there is a wide variation in pelvic organ mobility even in young nulliparous women. This variation is likely to be at least partly genetic in origin. Ultrasound imaging now allows quantification of the phenotype of pelvic organ prolapse, which will facilitate molecular and population genetic approaches to evaluating the etiology of pelvic floor and bladder dysfunction.

Conversely, there is no doubt that childbirth causes significant alterations of pelvic organ support and levator function, and that there is some relationship between the prior state of pelvic organ supports and labor outcome. It is highly likely that pelvic floor ultrasound will help us identify women at high risk of operative delivery and/or significant pelvic floor damage. It remains to be seen, however, whether such information can have a positive effect on clinical outcomes in what is no doubt a highly politicized environment.

The second part of this review will cover three-dimensional imaging aspects of pelvic floor ultrasound.

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