CHAPTER 13

Committee 9

Imaging and other Investigations

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A. INTRODUCTION

The committee evaluated the current evidence regarding imaging techniques and clinical indications in patients with urinary or faecal incontinence, pelvic floor dysfunction and pelvic organ prolapse. Additional related issues such as pad testing were also reviewed. The present chapter is based upon the outcome of the 2nd International Consultation on Incontinence which was held in Paris in 2001 [1].

The 2001 chapter was reviewed in the light of the publications which appeared in the peer-review literature from 2001 until today. Modifications to the previous chapter were proposed by the committee members who were allocated the different topics included in the new chapter and then jointly reviewed until a consensus was reached. The chapter structure has been modified as it now includes also imaging issues in patients with faecal incontinence.

The various imaging issues were considered and analysed also regarding the particular questions which may arise when dealing with different clinical and pathophysiological conditions so that the neurogenic or non-neurogenic origin of incontinence was considered beyond the more obvious distinction deriving from age and gender. Imaging of the central nervous system in the incontinent patient was also included as this is a very dynamic field which is highly instrumental in understanding the physiology and pathophysiology of lower urinary tract dysfunction in neurogenic and non-neurogenic patients.

Imaging and other investigations were evaluated with reference to the techniques and their clinical value taking into consideration what is the possible impact of the diagnosis on patient management. It is important in fact to consider that some imaging modalities may provide evidence regarding the severity of the disease, indications for treatment, prognostic values as treatment outcome or patient prognosis, but they can also be used to monitor patient conditions over time and in treatment follow-up. Imaging can also be used to evaluate treatment outcome as well as for research purposes. At the end of each paragraph, recommendations for the clinical use of a certain imaging modality are provided and the relative level of evidence is stated. Areas of interest for further research are identified.

The application of standard levels of evidence and grade of recommendations as proposed by the Oxford Centre for Evidence Based Medicine and endorsed by the International Consultation on Urological Diseases (ICUD) to the field of diagnostic imaging is not without problems. The Authors of this chapter have tried to apply the proposed ICUD system whenever possible, all diagnostic techniques have been at lest evaluated with reference to their technical performance, accuracy and impact of clinical management.

I. LEVEL OF EVIDENCE

- **Level 1** evidence (incorporates Oxford 1a, 1b) usually involves meta-anaylsis of trials (RCTs) or a **good quality** randomised controlled trial, or 'all or none' studies in which no treatment is not an option, for example in vesicovaginal fistula.
- **Level 2** evidence (incorporates Oxford 2a, 2b and 2c) includes "low" quality RCT (e.g. < 80% follow up) or meta-analysis (with homogeneity) of **good quality** prospective 'cohort studies'. These may include a single group when individuals who develop the condition are compared with others from within the original cohort group. There can be parallel cohorts, where those with the condition

in the first group are compared with those in the second group.

- **Level 3** evidence (incorporates Oxford 3a, 3b and 4) includes:

  good quality retrospective 'case-control studies' where a group of patients who have a condition are matched appropriately (e.g. for age, sex etc) with control individuals who do not have the condition.

  good quality 'case series' where a complete group of patients all, with the same condition/ disease/ therapeutic intervention, are described, without a comparison control group.

- **Level 4** evidence (incorporates Oxford 4) includes expert opinion were the opinion is based not on evidence but on 'first principles' (e.g. physiological or anatomical) or bench research. The Delphi process can be used to give 'expert opinion' greater authority. In the Delphi process a series of questions are posed to a panel; the answers are collected into a series of 'options'; the options are serially ranked; if a 75% agreement is reached then a Delphi consensus statement can be made.

II. GRADE OF RECOMMENDATION

- **Grade A** recommendation usually depends on consistent level 1 evidence and often means that the recommendation is effectively mandatory and placed within a clinical care pathway. However, there will be occasions where excellent evidence (level 1) does not lead to a Grade A recommendation, for example, if the therapy is prohibitively expensive, dangerous or unethical. Grade **A** recommendation can follow from Level 2 evidence. However, a Grade **A** recommendation needs a greater body of evidence if based on anything except Level 1 evidence
- **Grade B** recommendation usually depends on consistent level 2 and or 3 studies, or 'majority evidence' from RCT's.
- **Grade C** recommendation usually depends on level 4 studies or 'majority evidence' from level 2/3 studies or Dephi processed expert opinion. Grade **C** recommendation is given when expert opinion is delivered without a formal analytical process, such as by Dephi.
- **Grade D "No recommendation possible"** would be used where the evidence is inadequate or conflicting.

B. IMAGING IN URINARY INCONTINENCE AND PELVIC FLOOR DYSFUNCTION

B1. IMAGING OF THE UPPER URINARY TRACT

Urinary incontinence is defined as the complaint of any involuntary leakage of urine, it can be urethral or extraurethral. This latter condition either results from congenital anomalies such as ectopic ureters (inserting in the female distal urethra or vagina), iatrogenic or traumatic conditions such as fistula. In some patients, lower urinary tract dysfunction causing urinary incontinence, might compromise the transport of urine from the kidneys to the bladder resulting in hydronephrosis and renal failure. The relationship between high bladder storage pressure and renal deterioration has been well established in neuropathic patients [1]. In male patients, chronic retention of urine can be associated with urinary incontinence and lead to chronic renal failure. In females, severe urogenital prolapse may cause angulation of the pelvic ureter by the uterine arteries leading to hydronephrosis in up to 30-40% of patients [2] (**Figure. 1 a,b**).

I. INDICATIONS

Generally speaking, there is no need for upper tract imaging in cases of urinary incontinence unless any of the previously described conditions is suspected or diagnosed. Patients with extraurethral incontinence may also benefit from upper urinary tract imaging.

The objectives used for upper tract imaging in the incontinent patient are as follows:

1. Evaluation of the upper urinary tract when the presence of an ectopic ureter or ureterovaginal fistula are suspected.
2. Evaluation of the kidneys whenever urinary incontinence is related to bladder dysfunction with high storage pressures (e.g. in neurogenic voiding dysfunction, chronic retention with overflow or low compliance bladders)
3. Exclusion of hydronephrosis in cases of urinary incontinence associated with severe uterine prolapse (**Figure 2 a,b,c,d**).

Figure 1a. Procidentia uteri.

Figure 1 b. IVU: bilateral hydronephrosis. Left kidney is in sacral ectopia.

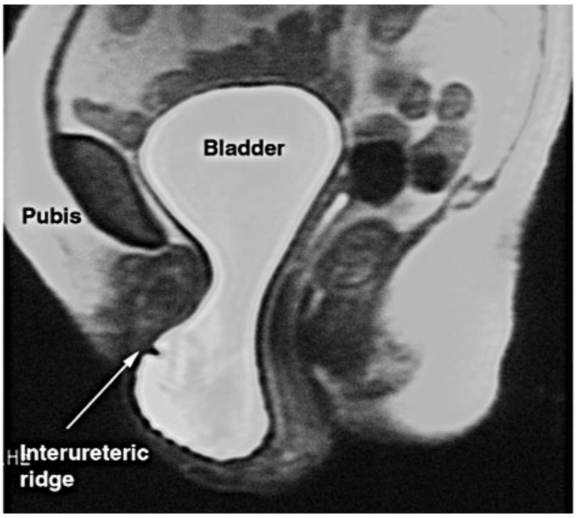


Figure 2 a. MRI: complete urogenital prolapse.

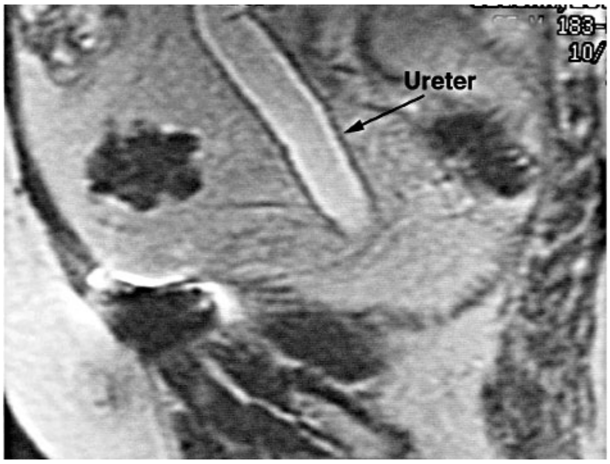


Figure 2-b. MRI: ureteral dilation

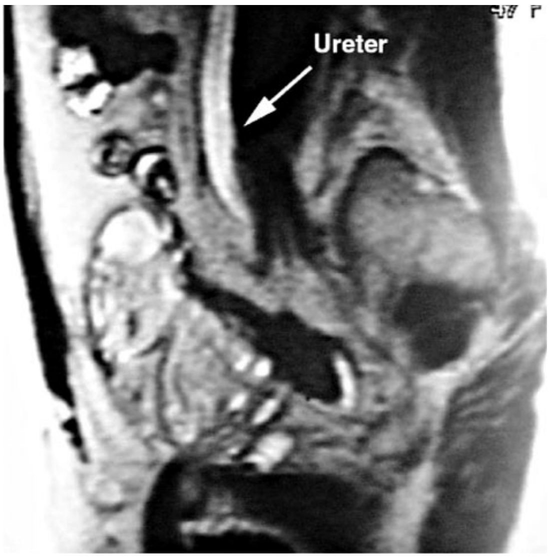


Figure 2-c. MRI: ureteral dilation

Figure 2-d. MRI bilateral hydronephrosis

II. TECHNIQUES

Upper tract imaging modalities include intravenous ultrasonography (USS), urogram (IVU), computerized tomography (CT scan), magnetic resonance imaging (MRI), and isotope scanning. No data as to specificity, sensitivity, predictive value or reproducibility in connection with the diagnosis and management of urinary incontinence are available. The use of the different imaging modalities also depend on availability, expertise, and local management policies. Generally speaking, low cost and low risk techniques such as USS should be preferred. Unless otherwise described, the following considerations regarding the different imaging modalities are based on expert opinion.

1. Ultrasonography

Ultrasonography is the gold standard technique for primary imaging of the upper urinary tract because of the relatively low cost of the equipment and therefore of the examination, its large availability, the lack of any exposure to ionising radiation. Renal USS is independent on kidney function, provides a good evaluation of renal anatomy including malformations, kidney size, cortex/medulla index, hydronephrosis. Concurrent kidney disorders such as urinary lithiasis and neoplasms can also be diagnosed. In patients with lower urinary tract dysfunction (LUTD), the detection of hydronephrosis is of importance and it can be related to either vesico-ureteral reflux or obstruction. However, no correlation exists between the degree of dilatation and the severity of obstruction. Measurement of the resistive index in the interlobar and arciform arteries of the kidney has been proposed for the diagnosis of urinary obstruction but this is rarely used in the evaluation of the incontinent patient [3]. Whenever hydronephrosis is diagnosed on USS, other imaging modalities are often used to evaluate renal function, the degree of obstruction or vesico-urethral reflux. USS is an ideal technique to follow the degree of hydronephrosis over time or the response to treatment.

2. Intravenous Urography

Intravenous urography (IVU) or intravenous pyelography (IVP) is the original radiographic examination of the upper urinary tract which allows evaluation of upper urinary tract anatomy and function. Successful examination is dependent upon adequate renal capacity to concentrate urine and the exam is currently contraindicate when creatinine levels exceed 2.0 mg/dL. A number of different conditions such as renal dysfunction, obstruction, congenital anomalies, fistula, stones and tumors may be detected.

IVU is the appropriate first study in cases of extraurethral incontinence. When ectopic ureter is suspected (although this condition can also be responsible of urethral incontinence), delayed films and tomography are important because the renal unit or moiety associated with an ectopic ureter is often poorly functioning. In fact, IVU is sometimes unable to detect a small, malfunctioning moiety associated with a duplication and ectopic ureter or a poorly functioning or abnormally located kidney with a single ectopic system [4-6]. In such cases where the diagnosis of ectopia is still suspected after IVU, another imaging modality such as CT, MRI (**Figure 3 a,b**) or isotope scanning [7-9] should be considered. IVU is the appropriate first imaging study when uretero-vaginal fistula is suspected, usually after pelvic surgery. Typically, one sees ureteropyelocaliectasis proximal to the level of the fistula. This finding has been reported in 84-92% of cases [10,11]. Sometimes extravasation can be seen. Confirmation of the presence of the fistula, its size and exact location is often obtained with retrograde ureteropyelography.

3. Computerized tomography

High quality information of the upper urinary tract anatomy can be obtained using multislice Computerized Tomography (CT) scan and 3D reconstruction software. Differently from IVU which only acquires images in the coronal plane, CT acquires images in the transverse plane. Pictures can then be reconstructed in 2D along any plane or in 3D whenever required. CT scan can be used irrespective of renal function when no iodinated contrast media are used. Whenever hydronephrosis is found, urine can be used to delineate the collecting system avoiding the use of contrast medium. Intravenous contrast medium can be required to highlight specific anatomic characteristics. CT scan is often used after a first line evaluation is performed using USS and constitutes a valid if no better alternative to IVU and it is usually no more expensive. Several authors have reported the use of CT scan to detect ectopic ureter, in cases where the diagnosis is suspected, despite a normal IVU and ultrasound [12]. In these cases the small size and poor function of the ectopic moiety made diagnosis difficult by IVU.

Figure 3 a. MRI diagnosis of ureteral ectopia

Figure 3 b. MRI diagnosis of ureteral ectopia: sagittal view

4. Magnetic resonance imaging

Magnetic Resonance Imaging (MRI) shares some of the advantages of CT over IVU in the evaluation of the upper urinary tracts. Furthermore acquisition can be performed along any plane and pictures can then be presented in a 2D or 3D fashion. The paramagnetic contrast medium is free of allergic reaction risk although its use in the upper urinary tract remains dependent upon renal function. The development of the uro-MR technique has gained an increasing role for the technology in the evaluation of hydronephrosis and urinary tract anomalies in alternative to IVU. MR usefulness in the diagnosis of ectopic ureter has recently been described [13,14].

5. Isotopes

Isotopes are used primarily to examine morphological and functional characteristics of the upper urinary tract. Isotope scanning can be used to identify the location of a small kidney which is otherwise difficult to image with radiological techniques.

Renography is used to examine the differential function of the two kidneys, to identify disorders of urine transit and to quantify obstruction of the upper urinary tract. There are many physiological factors and technical pitfalls that can influence the outcome including the choice of radionucleotide, timing of diuretic injection, state of hydration and diuresis, fullness or back pressure from the bladder, variable renal function and compliance of the collecting system [15-17]. Diuresis renography with bladder drainage is recommended when obstructive uropathy is suspected [18]. Renal scintigraphy may be useful in the evaluation of ectopic ureters associated with hypoplastic kidneys [19].

III. CONCLUSIONS AND RECOMMENDATIONS

Imaging of the upper urinary tract is NOT indicated in the evaluation of non-neurogenic stress, urge or mixed urinary incontinence. **[*Level of Evidence 3, Grade of Recommendation C*]**

Imaging of the upper urinary tract is indicated in cases of:

- a neurogenic urinary incontinence with high risk of renal damage (due to high detrusor pressure, e.g. myelodysplasia, spinal cord injury, and low compliance bladders) **[*Level of Evidence 3, Grade of Recommendation C*]**
- b chronic retention with incontinence **[*Level of Evidence 3, Grade of Recommendation C*]**
- c untreated severe urogenital prolapse **[*Level of Evidence 3, Grade of Recommendation C*]**
- d suspicion of extra-urethral urinary incontinence by upper tract anomaly **[*Level of Evidence 3, Grade of Recommendation C*]**

The choice of the imaging techniques and their sequence depend on the clinical question and their availability. The least invasive techniques should be preferred and should precede the more invasive, also taking into consideration cost effectiveness. [*Level of Evidence 3, Grade of Recommendation C*]

IV. SUGGESTED RESEARCH AREAS

- Prevalence of upper tract deterioration in various urinary incontinence populations
- Natural history of upper tract damage
- Relation between upper tract dilation, renal damage and bladder function

B2. LOWER URINARY TRACT (LUT) IMAGING

Imaging of the lower urinary tract has a long tradition in the management of urinary incontinence, particularly in female patients. The hype has moved, over the decades from static to dynamic imaging, from qualitative to quantitative information. Although some of the techniques are now more than 50 years old, their standardisation is insufficient and their clinical value often unclear. Most of the possible imaging modalities remain "investigational" as their impact on the management of urinary incontinence has not been established yet. Nevertheless there are encouraging signs of change in this field and analysis of the peer-review literature of the last three years revealed a number of interest papers which were instrumental in preparing this chapter.

Voiding cystourethrogram (VUCG) was the mainstay of imaging studies in urinary incontinence until recently when USS evaluation of the lower urinary tract through the pelvic window became prevalent because of its immediacy, low cost and availability. While CT never gained acceptance because of the exposure of ionising radiations, MRI took the lead as the most promising imaging modality and a number of papers have been published over the years riding the horse of technological development.

In males the purpose of voiding cystourethrography has been mainly to locate infravesical obstruction [1,2] although it may play a role in the management of post-prostatectomy incontinence. In children the diagnosis and classification of reflux and diagnosis of posterior urethral valves have been the primary goals [3]. MRI may be an alternative [4].

Positive-pressure urethrography has been designed only for the diagnosis of female urethral diverticula, it was shown to be more sensitive than voiding cystourethrography [5-7] although it was surpassed by MR.

I. RADIOLOGICAL IMAGING IN FEMALE URINARY INCONTINENCE AND PELVIC FLOOR DYSFUNCTION

The rationale for imaging studies of the lower urinary tract in this field derives from the supposed relation of morphology and function and particularly the causative role of urethral hypermobility in stress urinary incontinence. Investigation into cohorts of continent and incontinent patients failed to provide evidence to support the hypothesis and some imaging techniques became almost abandoned. The same applied to outcome research in urinary incontinence where restoration of normal anatomy did not necessarily lead to cure of the condition. A renewed interest derived from the availability of USS which took imaging out of the radiology suites and moved it into the urological and gynaecological outpatient clinics opening new opportunities for clinical research in this field. The hype on MRI derives from the specific characteristics of this imaging modality which allowed both fast acquisition in the dynamic range and accurate evaluation of tissue characteristics together with the possibility to investigate the whole pelvis as one functional unit.

1. Female Cystourethrography

X-ray imaging of the urinary bladder and urethra has been used to assess the female urinary tract in women suffering urinary incontinence to evaluate urethral/bladder neck hypermobility and to assess associated conditions such as urethral obstruction, vesico-urethral reflux, diverticula, fistula, stones and tumours. In males the purpose of voiding cystourethrography has been mainly to locate infravesical obstruction [1,2].

a) Background

History and methodology of cystourethrography in females had been reviewed by Olesen [8]. The technique is now over 70 years old. Voiding cystourethrography with lateral projection was first done by Mikulicz-Radecki in 1931 [8]. The use of a metallic bead to identify the urethra was introduced by Stevens and Smith in 1937 [9], and in 1956 Ardran, Simmons and Stewart [10] reported on a cinematographic technique with contrast media also in the vagina and rectum. In an attempt to combine qualitative and quantitative information as to the function of the lower urinary tract, the combined used of fluoroscopy and pressure-flow recordings was proposed during the the sixties and seventies [11-15].

b) Methodology (projection, positioning and exposures)

Bladder neck displacement is best viewed and quantified in true lateral projection although image quality is sometimes poor because of the increased body mass and the overlap of bony structures with the bladder neck area. Consequently, oblique projections are sometimes used notwithstanding no quantitative information can be obtained. Achieving a quasi-physiological voiding in a radiology suite is difficult because of the inevitable impact of the environment. The use of a sitting position is recommended for micturition studies as voiding while standing or lying will increase the embarrassment and thereby the bias of the examination [8]. Especially in patients with large body mass index, imaging of female urethra in a true lateral projection is difficult, it necessitates high radiation doses as the central x-ray beam must penetrate the trocanteric regions and further because the urethrovesical junction sometimes is overshadowed by the lateral parts of the bladder. A significant improvement in this area has been brought about by digital imaging which allows the subtraction of the bony structures (**Figure 4**). The position and mobility of the urethrovesical junction as well as urine leakage are supposed to be influenced by the filling volume as has been demonstrated on ultrasonography [16] and leak point pressure measurements [17].

However, in voiding cystourethrography the bladder is filled to capacity. Addition of a urethral bead chain or catheter and vaginal contrast to improve the visualisation of the urethra, bladder neck and trigone has been abandoned. Contrast in the rectum is not necessary for urinary incontinence purposes. Exposures at rest should be supplemented with provocative manoeuvres to test bladder neck mobility by contracting and relaxing the pelvic floor (e.g.: coughing, straining, and squeezing). Whenever possible, pictures while the patient is voiding the bladder should be obtained. It is important to consider that coughing

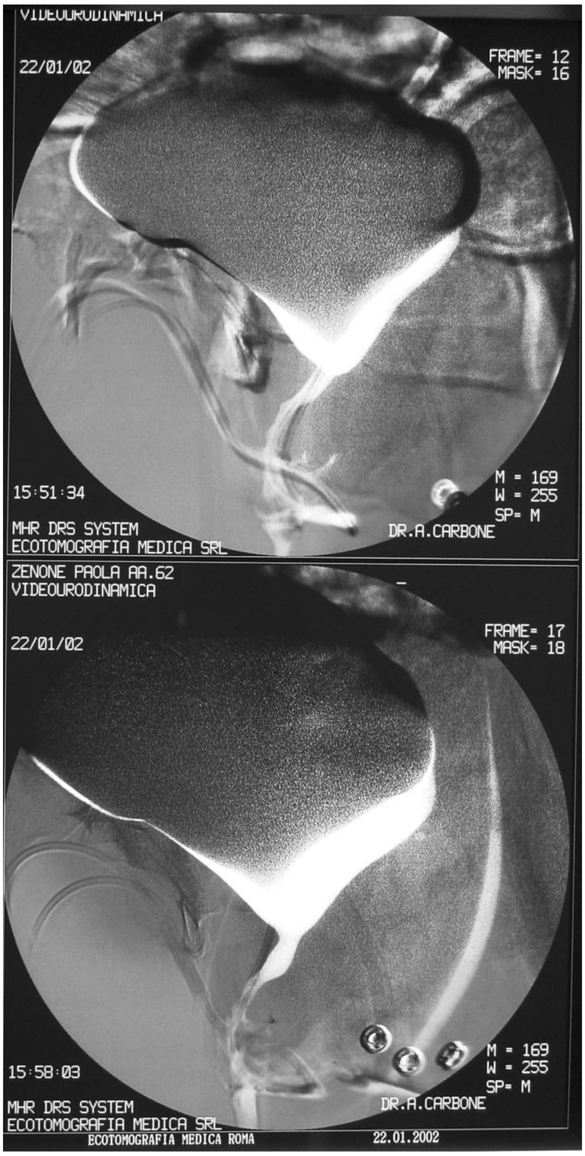


Figure 4. VCUG with digital substraction

and straining result in a different effect on the pelvic floor. Straining might be associated with relaxation or contraction of the pelvic floor, and the imaging can change accordingly.

During coughing there is a reflex contraction of the pelvic floor, but coughs are of short duration and difficult to catch on spot films. Bladder suspension defects were diagnosed at rest in 49% of 420 examinations, while coughing and micturition disclosed a further number of 20% and 4% respectively [8]. Squeezing can demonstrate pelvic floor awareness and contraction [18].

c) Combined imaging and urodynamics

Videourodynamics has been by some regarded as the “gold standard” in the evaluation of lower urinary tract dysfunction [18]. Reproducibility of the combined examination has not been assessed and the radiation dose has to be considered [10, 15, 19-21]. One study has attempted to compare videourodynamics with saline cystometry [18]. Independent observers carried out the two procedures with 75 women having the saline cystometry first and a further 75 women had videourodynamics first. The degree of bladder descent noted on screening was greater than on clinical examination. Nineteen women had trabeculation and a further 11 women had bladder (9) or urethral (2) diverticula, urethral stenosis (1) and vesicoureteric reflux (2). Only seven of the eleven women could have been predicted by a selective imaging policy based on history alone which would image 43% of the 150 women. This suggests that a selective policy of screening will unnecessarily expose patients to radiation while not using the optimal technique for investigation for all patients who need the test. Nevertheless simultaneous videomonitoring along with tracings of pressure and urine flow rate are important means to be sure that the exposures are made at appropriate moments so that the radiographs can be representative of the various functional states [8, 13, 22, 23].

Patients with Parkinson’s disease and multiple system atrophy are best evaluated by videourodynamics and sphincter motor unit potential analyses to identify characteristic features of these conditions including: external sphincter denervation, neurogenic sphincter motor unit potentials, open bladder neck at rest and detrusor-external sphincter dyssinergia [24]. Neurologic patients show severe bladder trabeculation with diverticula and pseudodiverticula, pelviureteric reflux, widening bladder neck and proximal urethra, and narrowing at the level of the membranous urethra can suggest, the presence of neurogenic dysfunction of the lower urinary tract (occult spinal dysraphism, non-neurogenic neurogenic bladder) even in the absence of neurogenic symptoms and signs [25-27]. Urodynamic parameters in children do not discriminate between those with or without vesicoureteral reflux thus videourodynamics have been considered essential [28] additionally children with non-neurogenic voiding dysfunction are found to have a number of abnormalities with videourodynamics [29]. Indications for videourodynamics include previous continence and vaginal surgery, neurological disorders and suspicion of urethral diverticula.

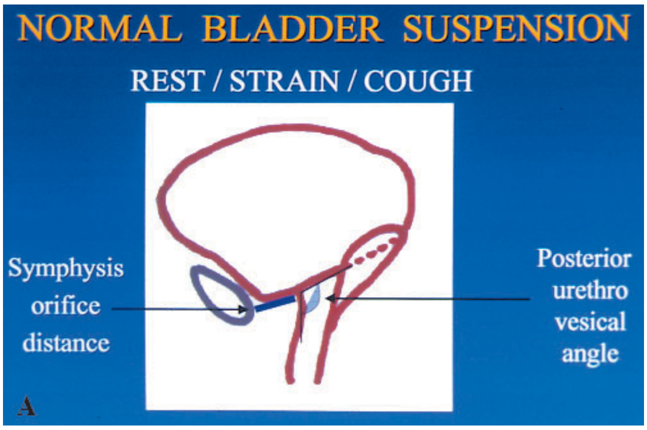
Normal and defective bladder support

The whole issue about the clinical value of cystourethrogram is about the pathophysiology of defective bladder support in the pathophysiology of stress urinary incontinence in female patients and the relation between the surgical correction of such a defect and cure. The concept of urethral hypermobility was inherent to the classification of stress urinary incontinence and the concept that an impaired transmission of abdominal pressure to female urethra could be responsible for the observed leakage. Little remain about the concept of urethra hypermobility in a modern view of female stress urinary incontinence and this contributed to the gradual abandonning of cystourethrogram in the evaluation of a standard patient.

The normal resting bladder has a smooth surface although bladder trabeculation is often seen in elderly female patients and not necessarily related to any pathological condition. The internal urethral orifice is located just above a horizontal line through the lowermost part of the symphysis in a coronal projection. The urethra is straight and runs anteriorly and caudally toward the external meatus.

On coughing and straining, relaxation of the pelvic floor results in downward movement of the bladder neck which can be associated with a backward movement of the bladder neck resulting in a change in urethral axis. Squeezing (and sometimes also straining) results in contraction of the pelvic floor muscle with a cranial movement of the bladder neck **Figure 5a**. During voiding (**Figure 5b**) the bladder base is usually lowered about 1 cm, the angle between the urethra and the trigone is straightened, making a funnelled appearance of the proximal urethra and the bladder base, the bladder contour is rounded and a fine sawtooth irregularity of the mucosa becomes visible above the trigone. Angles and distances between the urethra, bladder base and symphysis pubis have been assessed radiologically. The following parameters have been assessed for reliability:

1. The posterior urethrovesical angle (PUV) is defined by lines along the posterior urethra and the trigone [30]. Cut off values were usually 115° or more [31, 32].
2. The urethral inclination is between the proximal urethral axis and the vertical plane, which is a plane outside the patient and, therefore, the angle also varies with pelvic inclination. In Green type I and type II descent the angle is less or more than 45° respectively [33].



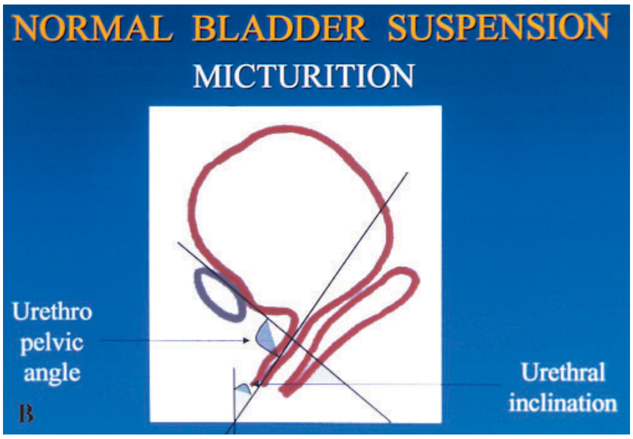


Figure 5 . Female Cysto-urethrography 1a: normal appearance on coughing, straining and squeezing b: normal appearance on voiding

3. The urethropelvic angle (UP) is measured during voiding as the anterior angle between a line through the middle of the internal urethral orifice and the urethral knee and a line through the posterior surface of the symphysis through the lowermost part of the obturator foramen closest to the film. In normals the mean UP is about 95° and the cut off point for bladder descent are values below 70° [8]
4. Symphysis orifice distance (SO) is measured at rest as the distance on a horizontal line from the symphysis to the internal urethral orifice. Normal values are 31 +- 6 mm (mean +- SD) and values less than 20 mm are the cut off points for descent [8]
5. The urethral axis at rest (UAR) and during straining (UAS) (**Figure 6**)

Funneling of the proximal urethra and flatness of the bladder base (both anterior and posterior to the internal urethral orifice) and the most dependent portion of the bladder base (the urethrovesical junction or a point posterior to that) are important qualitative parameters estimated on straining films [31].

Anterior bladder suspension defects or bladder base insufficiency (BBI) (**Figure 7**) is defined as SO < 20 mm with a normally positioned vagina at rest, during coughing or micturition and/or funneling of the bladder base at rest or with coughing. The insufficiency can be graded 1-3 [8] which corresponds to Green's type I descent [33]. The supportive defect is supposed to be in the fascial and ligamentous system and their abnormal detachments (eg., paravaginal defects).

Posterior bladder suspension defects [8] (**Figure 8**) are defined as a posterior-inferior bladder displacement and a UP of less than 70°. It corresponds to Green's type II [34]. Sometimes (**Figure 9**) only the trigone and posterior part of the bladder is involved. The supportive defect is supposed to be in the muscular pelvic floor, that is, the pubo-vesical part of the pubococcygeus muscle or in paravaginal detachment.

Interestingly, when UAR and UAS were examined in a group of 76 continent women and correlated with age, a perfect linear regression was noted between UAR and age (R^2= 0.28). Patients with stress urinary incontinence were found to have an average UAR value of 25° with a mean UAS of 43° leading to a threshold value of hypermobility of about 20°. When standing cystourethrograms were repeated 3 to 6 months after surgery for stress urinary incontinence, UAR and UAS values were found to close to normal suggesting a relation between the correction of the defective bladder support and cure [34]. A more structured definition of cystocele (ranked by height in centimeters) was also obtained, adding to the emerging data that the reliability of the pelvic organ prolapse quantification system (POP-Q) increases when measurements are performed in a more upright position [34].

d) Reproducibility

The observer variation has been evaluated in four university uro-gynecological units [18, 31, 35, 36]. (**Table 1**). The inter-observer agreement was 43-79%

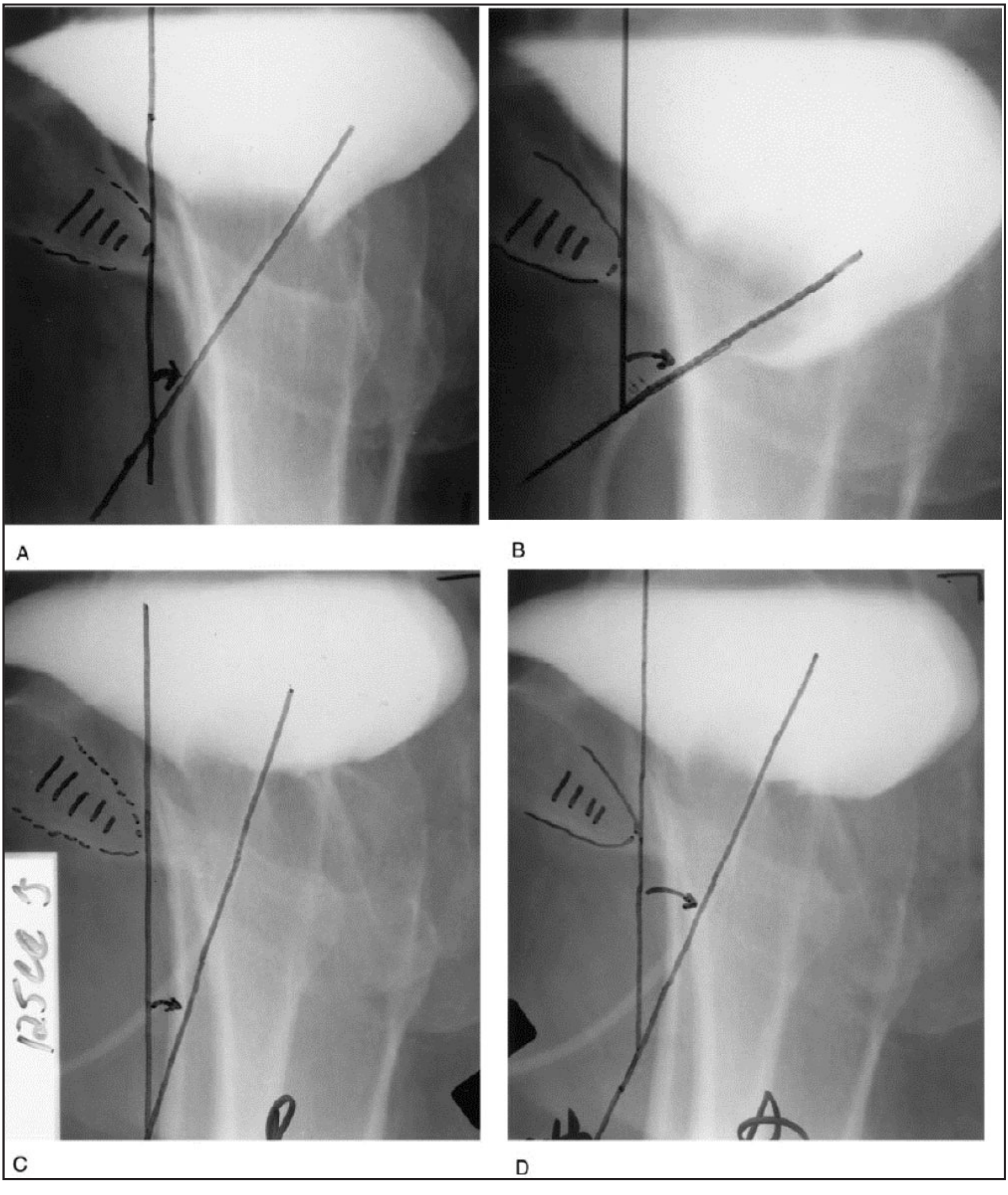


Figure 6. Example of standing, lateral views on VCUG with 125 mL of contrast within the bladder. (A) Preoperative UAR. (B) Preoperative UAS. (C) Postoperative UAR. (D) Postoperative UAS. The urethral angle is calculated from a reference line drawn through the inferior portion of the pubic symphysis.

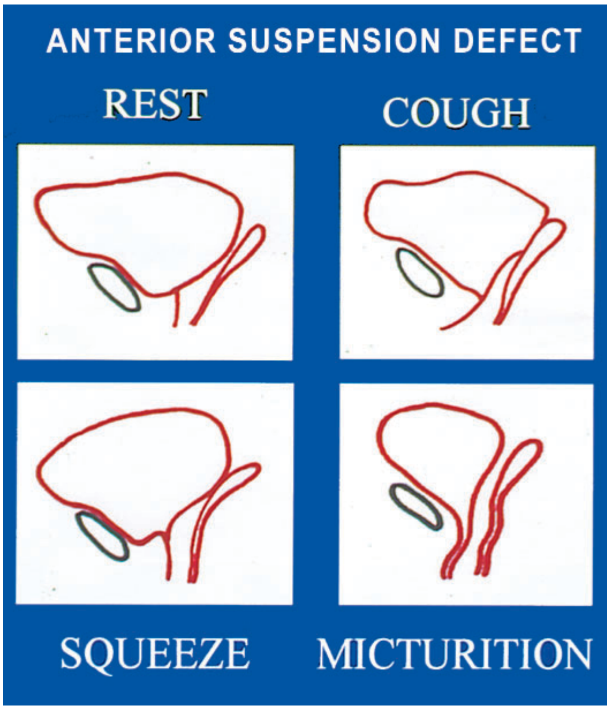


Figure 7. Female Cysto-urethrography. Anterior bladder suspension defect

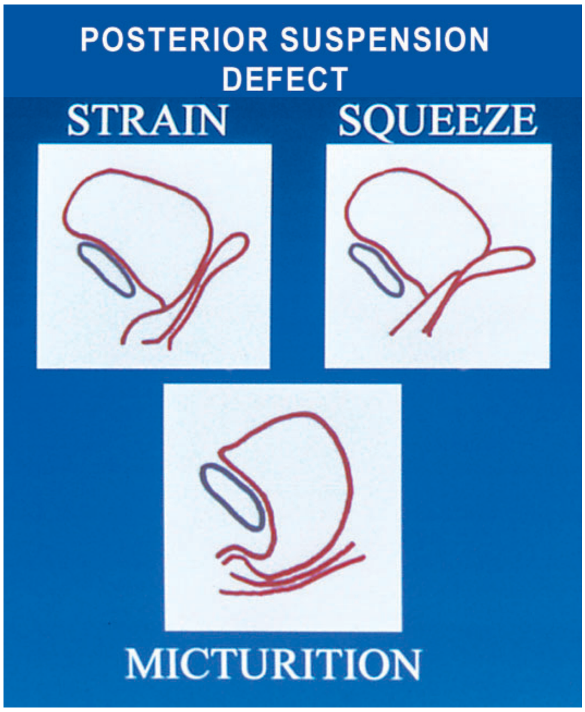


Figure 8. Female Cysto-urethrography. Posterior bladder suspension defect

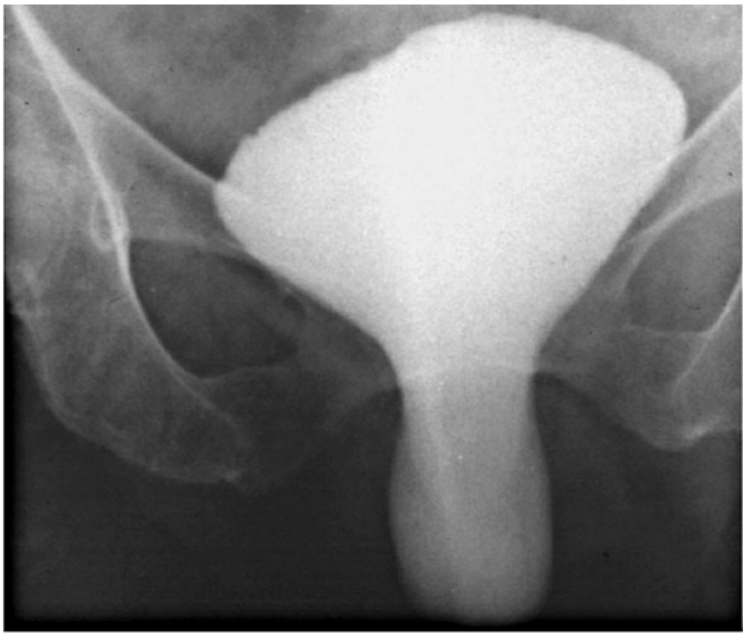


Figure 9. Female cystourethrography: the trigone herniates through the anterior vaginal wall

Table 1. Inter- and intra-observer variation (agreement) on cystourethrography in females with urinary incontinence.

Type of examination, patients and observers	Inter-observer variation	Intra-observer variation
Bead-chain 1 stress & urge incontinence n°92 3 observers on 5 landmarks	45.8-80.7 %	
VCCU 2 stress incontinence n° 52 1 observer on type of descent	79% 95% c.l. 65-89	
VCCU 3 stress incontinence n° 29 2 observers on type of descent	70% 95% c.l. 75-89	53% 95% c.l. 27-78
VCCU 4 n° 93 stress & urge incontinence 6 observers on type of descent	43-60% kappa 20-39%	72-99% kappa 57-98%
VCUG 5 Stress incontinence n° 11 2 observers on urethral angle shift from rest to straining	r = 0.83 (p=0.001) for UAR r = 0.82 (p=0.002) for UAS	

1: static bead-chain cystourethrography with straining [31]. The 5 landmarks were the posterior urethrovesical angle, urethral inclination, funnelling of the proximal urethra, flatness of the bladder base and most dependent position of the bladder base.

2: voiding colpo-cystourethrography (VCCU) at rest and with coughing, straining, micturition and squeezing; one observer against original diagnosis (that is, normal appearance or anterior, posterior or combined suspension defects) made by a few senior radiologists [17]

3: voiding colpo-cystourethrography at rest and with coughing, straining, squeezing and micturition. Possible diagnoses were: normal appearance or anterior, posterior or combined descent respectively [36].

4: voiding colpo-cystourethrography at rest, coughing, with holding and voiding. Possible diagnoses were: normal appearance and anterior or posterior descent respectively [35].

5: standing voiding cystourethrography, urethral angle was measured ate rest (UAR) and during straining (UAS) [34]

and the intra-observer agreement was 53-99%. These figures are in the same range as has been found for other diagnostic tests [37]

Accuracy for the diagnosis of stress incontinence and post-operative results

Evaluation of accuracy is the mainstay in the evaluation of a diagnostic technique. One has to consider that sensitivity and specificity depend on intrinsic factors such as reproducibility (as measured by intraobserver and interobserver variation) and extrinsic one such as the characteristic of the patient cohort used for to assess accuracy.

The accuracy of the previously mentioned radiological criteria have been measured by comparing imaging data with the ‘so called’ index-test which in this case was a clinical diagnosis of urodynamic stress incontinence and expressed as specificity and sensitivity or as predictive values. The crux of the matter is that the diagnosis of stress urinary incontinence is controversial and might be based on subjective criteria, urodynamic tests, or measurement of leakage. Even radiological criteria have been included in the diagnosis.

Reproducibility (e.g. test-re-test agreement) has not been measured, but intra- and inter-observer variation has been calculated and also adjusted for expected chance agreement (kappa coefficient). The predictive values and the kappa coefficient are supposed to depend on the prevalence [37], and therefore, comparison between different materials are difficult.

No consensus has been reached in the peer-review literature as to the lack of discriminant value of cystourethrography between stress incontinence and continence, the majority of published papers are consistently negative [32, 38-40] although new promising data have recently been published [34]. The specificity of 5 radiological parameters on static bead chain cystourethrography was 44-76% and the sensitivity 53-100% [40, 41]. Neither was the degree of stress incontinence correlated to the type or degree of suspension defects [18, 42, 43]. The positive and negative predictive values for a bladder suspension defect were 0.70 (95% C.l.: 0.62-0.78) and 0.52 (95% C.l. 0.41-0.63) respectively on voiding colpo-cystourethrography [33, 44]. In a later publication on 159 women, positive and negative predictive values of 0.56 and 0.74 were obtained [40]. Evaluation of urethral angle at rest and during stress in controls and in patients with stress urinary incontinence and various grades of anterior vaginal prolapse show a significant relation between UAR and aging (from 2.4° ± 14.9° in the third decade to 29° ± 9.2° in the 9th decade; r^2= 0.28). In patients with SUI, UAR and UAS decreased from 25.7° ± 13.6 ° and 42.6° ± 15.9° to 16.6° ± 14.7° and 23.8° ± 17.5°, respectively; the observed change were found to be statistically significant. A similarly significant difference was found in patients with moderate to grade 3 cystocele and urethral hypermobility (at least 5 cm descent of bladder base below the inferior ramus of the pubic symphysis on the lateral view of a standing VUCG): UAR and UAS decreased from 48.1° ± 16.5 ° and 64.4° ± 16.8° to 22.3° ± 26.9° and 29.8° ± 22.8°, respectively

Comparison of a randomly selected control cohort (aged-mached) with patients suffering SUI showed a significant difference of UAR and UAS at diagnosis while similar values were found after surgery (**Figure 10**). Similarly occurred in patients with grade 3 cystocele in whom both UAR and UAS were significantly different from controls at baseline while showed similar values in the postoperative follow-up.

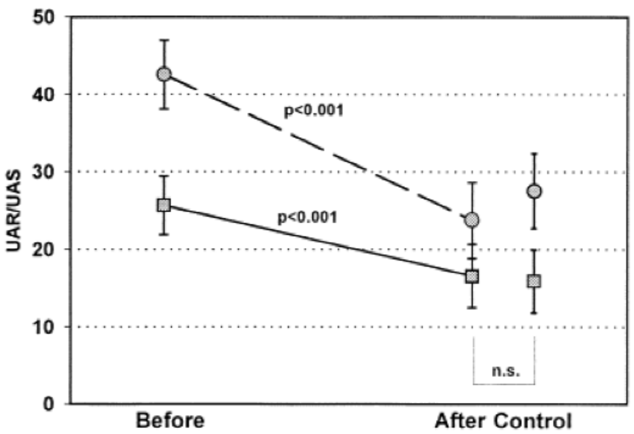


Figure 10. Mean 6 95% confidence interval for UAR (squares) and UAS (circles) before and after surgical correction compared with age-matched controls. Difference from "before" to "after" was significant for both surgical groups; difference between "after" and "control" was not significant.

Measurement of the cystocele height (LATH), obtained as the distance between the inferior border of the pubic symphysis and the inferior edge of the cystocele in controls and patients with mild and severe cystocele showed a significant difference between the two cohorts (16.63 ± 10.9 versus 27.4 ± 12.3 mm versus 73.4 ± 15.6 mm, respectively). Following formal cystocele repair, a significant change of LATH values was found in patient with mild and severe cystocele (from 27.4 ± 12.3 mm to 13.9 ± 18.0 mm and from 73.4 ± 15.6 mm to 25.4 ± 24.6 mm, respectively [p<0.001]).

These are the first data supporting the used of standing VCUG as an outcome measured, previous peer-review papers suggested the inability of the technique to distinguish postoperative failures from success [8, 18, 37, 39, 41, 45-48].

e) Comparison of cystourethrography and ultrasonography

The development of USS techniques for the evaluation of the lower urinary tract raised the question of the relation of X-ray versus USS imaging. Static bead chain cystourethrography has been compared with transrectal [41] and perineal ultrasonography [42, 49] and voiding colpo-cystourethrography has been compared with perineal ultrasonography [50]. The findings correlated well regarding bladder neck position and mobility, PUV, urethral inclination, SO distance and rotation angle.

Specificity, sensitivity and interobserver agreement were also comparable for the two methods. All the authors seem to prefer the sonographic modality because the imaging study can be performed at the same time as the physical examination. This has also been the case in men with neuromuscular dysfunction [51]. Simple and extensive funnelling is more easily imaged in upright patients during cystourethrography than in the supine position frequently used for ultrasound studies [25].

f) Comparison of cystourethrography and MRI

The introduction of MR in LUT imaging posed the case for an adequate comparison of this technique with standard X-ray imaging. Cystourethrography was compared in 27 women with urinary incontinence and bladder descent [26] and with colpocystorectography in 12 women or with bead-chain cystourethrography in 20 women in a prospective study [27]. The findings on MRI were equivalent to that obtained with colpocystorectography and superior to cystourethrogaphy in diagnosing rectoceles. Bias produced by difference in study position must also be considered when MRI and cystourethrography is compared.

g) Conclusion

The role of cystourethrography in the evaluation of female urinary incontinence remains to be established although preliminary evidence is now available that the measurement of urethral angle and cystocele height might have some clinical utility in the management of patients with urinary incontinence and genital prolapse who are scheduled for surgery. Defective bladder support can be diagnosed on voiding cystourethrography with a reliability comparable with other diagnostic tests.

Dependent on local facilities the method might be considered if the choice of a surgical procedure is based on type and degree of supporting tissue insufficiency and possibly if new procedures are evaluated for the ability to restore this insufficiency.

The method can not yet be recommended for the diagnosis or classification of urinary incontinence.

h) Recommendations

- Cystourethrography is NOT indicated in primary uncomplicated stress, urge or mixed female urinary incontinence [***Level of Evidence 3, Grade of Recommendation C***].
- Cystourethrography may be a reasonable option in the preoperative evaluation of complicated or recurrent female urinary incontinence [***Level of Evidence 3, Grade of Recommendation C***].

h) Suggested Research Areas

Standardization of technique, parameters and interpretation of cystourethrography.

Possible value of cystourethrography in the evaluation of pelvic floor dysfunction (correlation of imaging to pelvic floor physical examination and to clinical outcome following therapy)

II. ULTRASOUND OF THE LOWER URINARY TRACT AND PELVIC FLOOR IN FEMALE URINARY INCONTINENCE

1. INTRODUCTION

For several decades, clinicians working in the field of urogynaecology 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 cysto- urethrography; 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 equipment has now triggered a renewed interest in diagnostic imaging in urogynaecology and female urology. 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. Ultrasound, on the other hand, is almost universally available and has become useful in a number of clinical and research applications in this field.

Contrast X- ray techniques were first used in the diagnosis of lower urinary tract abnormalities in the late 1920s [1,2]. In the 1950s and 1960s the technique was standardized for use in incontinence diagnostics; diagnostic criteria were described and standardized [3-5]. Contrast radiographic techniques were also evaluated for documentation of prolapse of the vagina and rectum [6] ; however, the complexity of this technique precluded widespread use.

During the 1980's the increasing availability of realtime ultrasound equipment resulted in transabdominal [7, 8], perineal [9, 10], transrectal [11] and transvaginal ultrasound [12] being investigated for use in women suffering from urinary incontinence and prolapse. Due to its noninvasive nature, ready availability and the absence of distortion, perineal or translabial ultrasound is currently used widely.

Most recently, the developent of 3D ultrasound [13, 14] has opened up new diagnostic possibilities. First attempts at producing 3D capable systems go back to the 1970s when the processing of a single volume of data would have required 24 hours of computer time on a system large enough to fill a small room [15]. Due to the phenomenal development of microelectronics, such data processing can now be done on a laptop and in realtime. Both transvaginal and translabial techniques of 3D ultrasound have recently been reported, and it is likely that there will be significant development of this field in the next few years.

2. 2D Pelvic Floor Ultrasound

Two-dimentional ultrasound is the mainstay of this form of imaging is considered the standard technique. The acquisition plane depends upon the probe orientation and it is higly flexible depending upon the probe manoeuvrability and patient anatomy. Review od 2D US images from an independent observer carries the limitation that only the available pictures can be reassessed, a fact that introduces a possible major operator-dependent bias.

a) Basic Methodology

Translabial (or 'transperineal') ultrasound is the most commonly used modality at present and will be the focus of this text. A modification of the translabial technique is introital imaging which usually utilizes either endocavitary transducers or mechanical or electronic sector transducers with smaller footprints that are placed in the introitus [16]. This results in higher resolution of urethra and paraurethral tissues but does not allow imaging of all three compartments and may complicate quantification of findings since the symphysis pubis may not be included in the field of vision. However, most of the following discussion also applies to this technique.

A midsagittal view is obtained by placing a transducer (usually a 3.5- 7 MHz curved array) on the perineum (**Figure 11**), after covering the transducer with a glove or Gladwrap or similar for hygienic reasons. Powdered gloves can markedly impair imaging quality and should be avoided. 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 defaecation. Parting of the labia can improve image quality. The transducer can generally be placed quite firmly

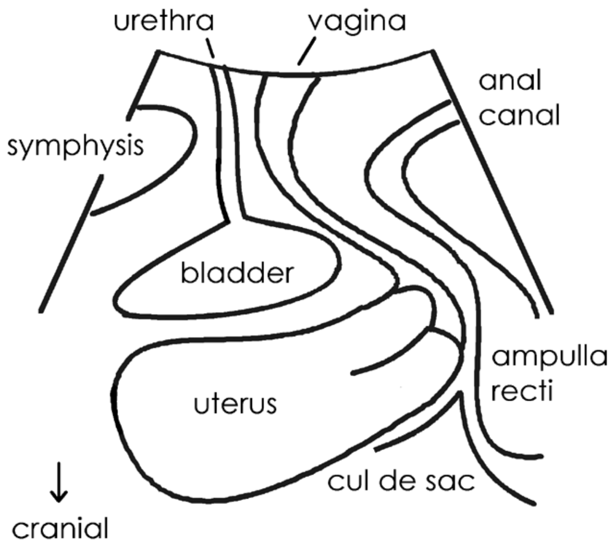


Figure 11. Field of vision for translabial/ perineal ultrasound, midsagittal plane.

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 11**). 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 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 midsagittal plane. Some prefer image orientation as in the standing patient facing right [16] 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^{o}, formal standardization may be necessary.

Perineal imaging of the lower urinary tract yields information equivalent or superior to the lateral urethrocystogram (shown in **Figure 12**, rotated by 180 degrees for ease of comparison) or fluoroscopic imaging. Comparative studies have mostly shown good

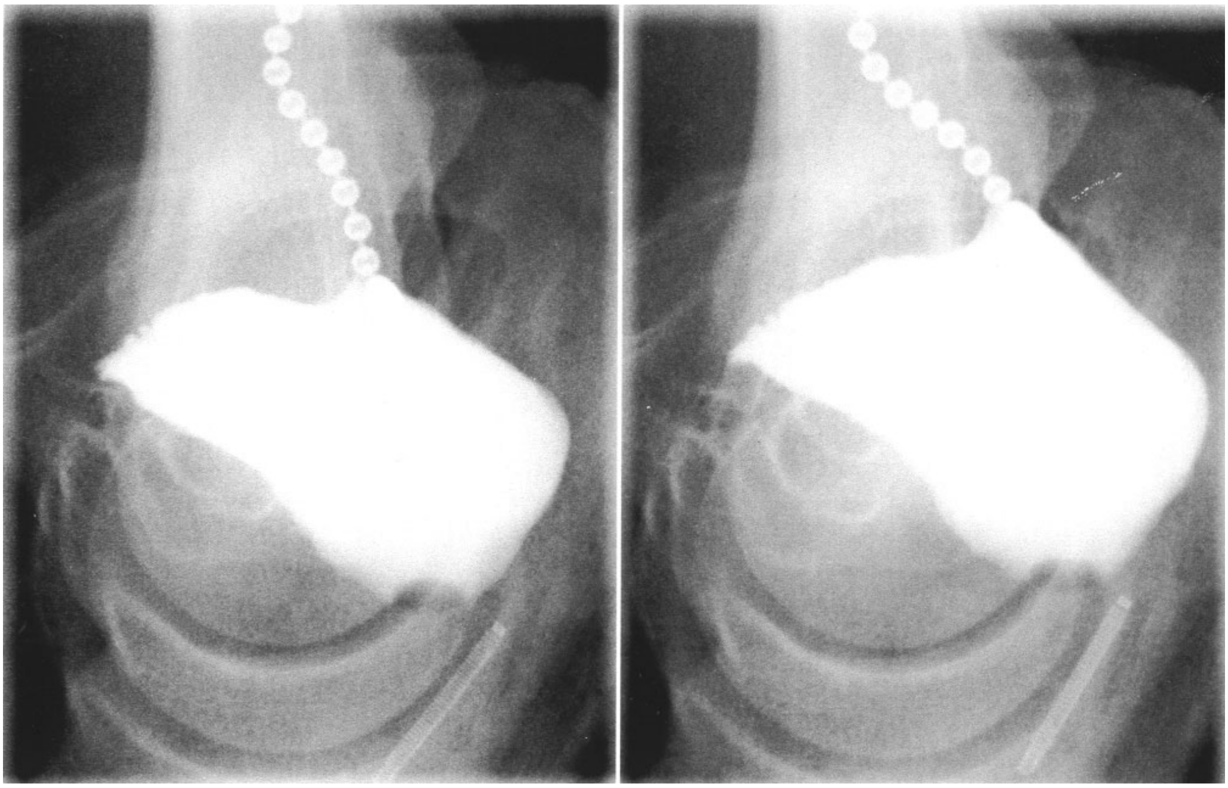


Figure 12. Lateral urethrocystogram with bead chain outlining the urethra. The images are rotated by 180 degrees to allow comparison with standard translabial ultrasound views. Image on left is at rest, on right during Valsalva.

correlations between radiological and ultrasound data [11, 17-22]. 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 [23].

b) Current uses of 2D translabial imaging in Gynaecology

1. POSITION AND MOBILITY OF BLADDER NECK AND PROXIMAL URETHRA

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 [24] or its inferoposterior margin [17]. 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 [25] 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 [26]. In either patient position, it is essential to not exert undue pressure on the perineum so as to allow full development of pelvic organ descent.

Measurements are generally performed at rest and on Valsalva manoeuvre. 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 13**). Some investigators measure the retrovesical (or posterior urethrovesical) angle between proximal urethra and trigone [27] (**Figure 13**), others determine the angle γ between the central axis of the symphysis pubis and a line from the inferior symphyseal margin to the bladder neck [28, 29]. Of all those ultrasound parameters of hypermobility, bladder neck descent probably has the strongest association with Urodynamic Stress Incontinence (USI) [30]. The reproducibility of this dynamic measurement has recently been assessed [30], with a % CV of 0.16 between multiple effective Valsalva manoeuvres, a % CV of 0.21 for interobserver variability and a % CV 0.219 for a test-

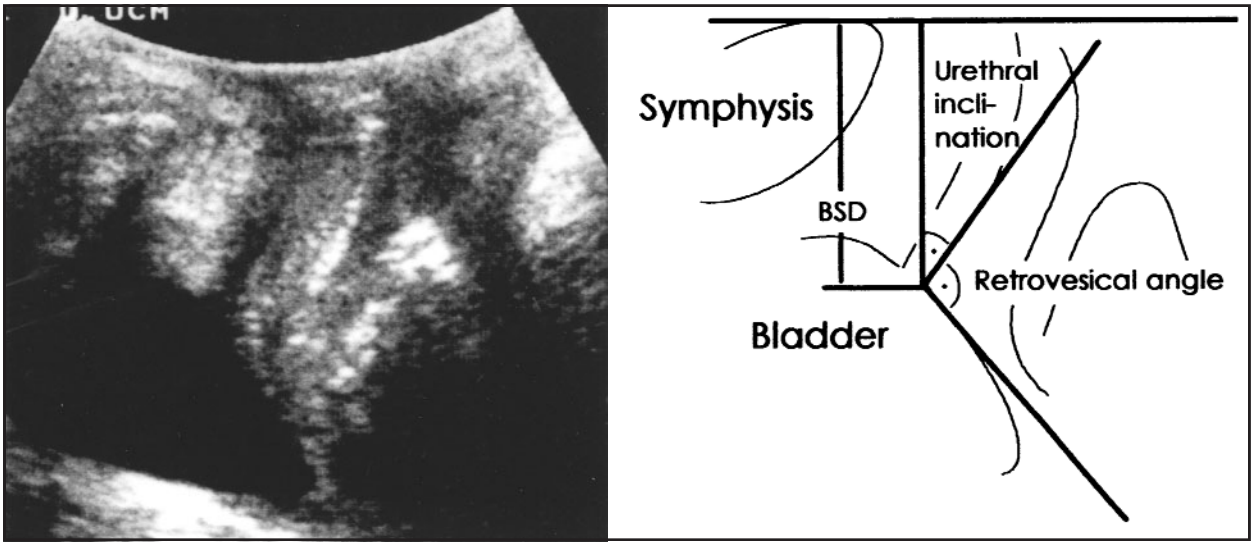


Figure 13. Perineal ultrasound image (left) and line drawing (right), illustrating some of the measured parameters (distance between bladder neck and symphysis pubis BSD, urethral inclination and retrovesical angle).

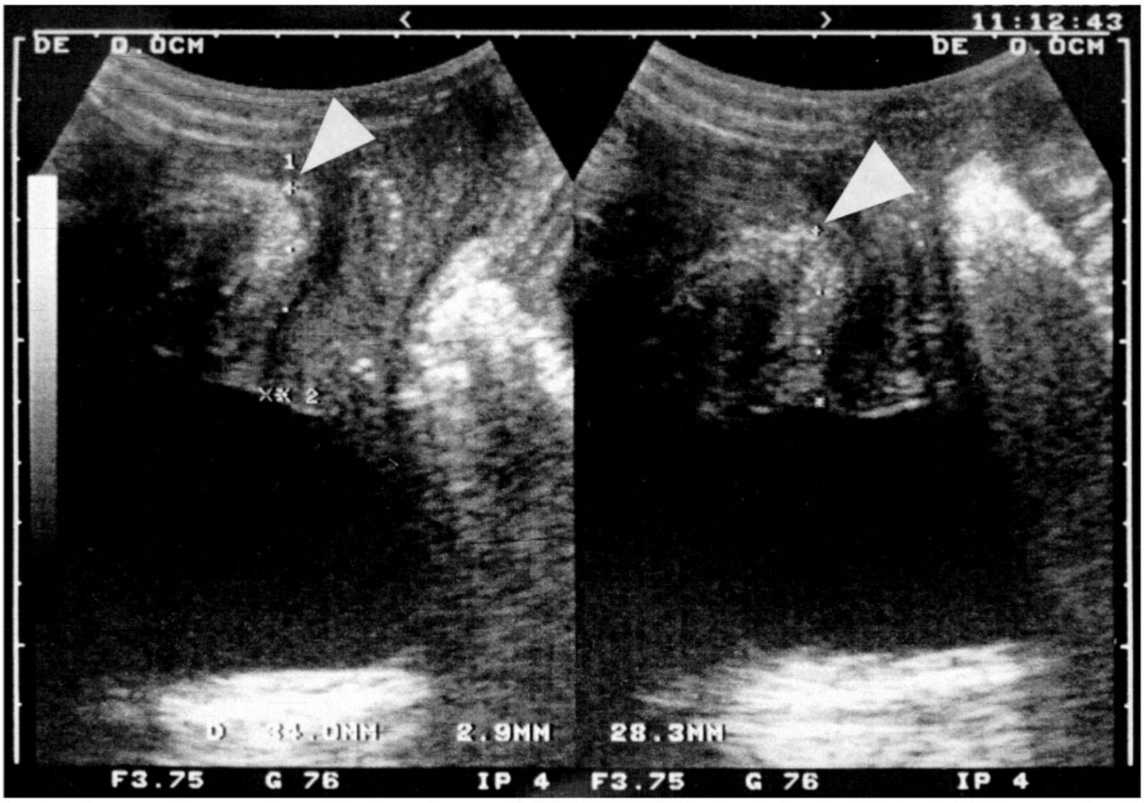


Figure 14. Measurement of bladder neck position at rest (left) and on Valsalva (right). The point of reference is the infero-posterior margin of the symphysis pubis (arrow). No bladder neck displacement occurs after colposuspension.

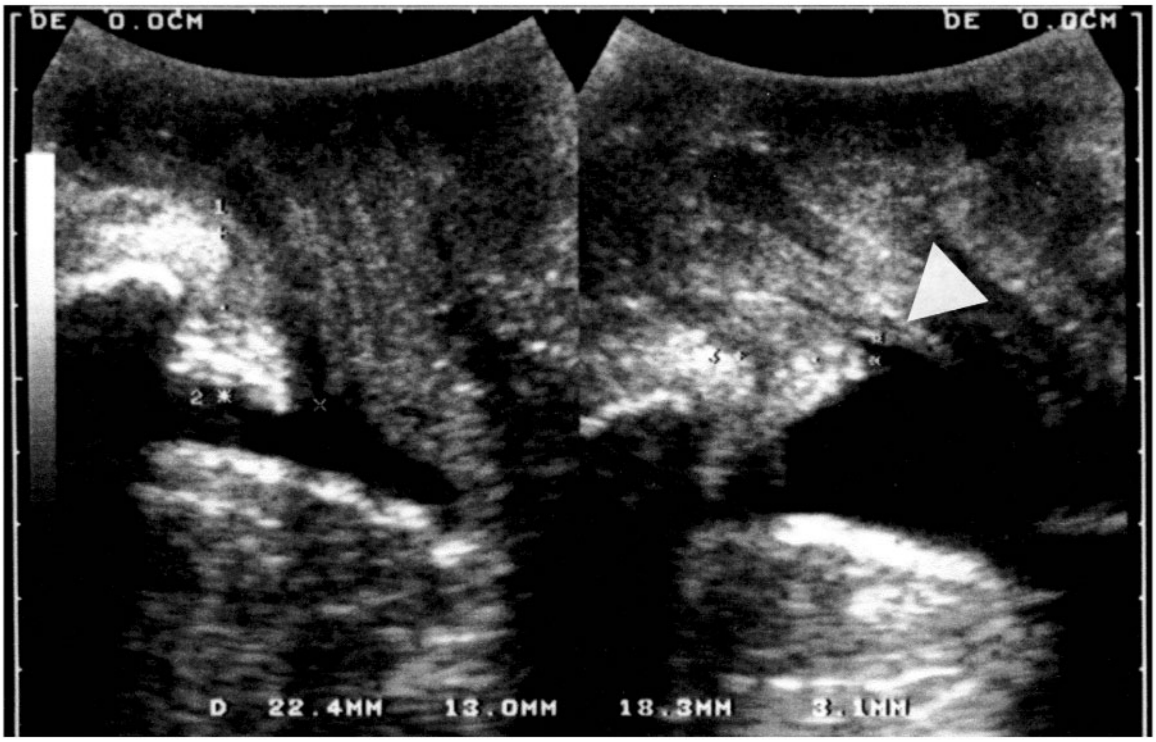


Figure 15. A typical finding in a patient with stress incontinence and anterior vaginal wall descent (cystourethrocele Grade I): postero- inferior rotation of the urethra, opening of the retrovesical angle and funneling of the proximal urethra (arrow).

retest series at an average interval of 46 days Intraclass correlations were between 0.75 and 0.98, indicating 'excellent' agreement [31].

There is no definition of 'normal' for bladder neck descent although cutoffs of 20 and 25 mm have been proposed to define hypermobility. **Figure 14** shows an immobilized bladder neck after colposuspension, **Figure 15** demonstrates ultrasound findings in a patient with cystourethrocele. Bladder filling, patient position and catheterization all have been shown to influence measurements [25, 26, 32, 33], and it can occasionally be quite difficult to obtain an effective Valsalva manoeuvre, 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 [34] and 5.3 mm [35] in continent nulliparous women, another study on 39 continent nulliparous volunteers measured an average of 15 mm of bladder neck descent [36]. 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 [37]. It is likely that methodological differences such as patient position, bladder filling and quality of Valsalva manoeuvre (i.e., controlling for confounders such as concomitant levator activation) account for the above discrepancies. Attempts at standardizing Valsalva manoeuvres [38] 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 manouvres; the pressures used in the one study describing the use of such a device [38] were clearly insufficient to achieve maximal or even near- maximal descent [39].

In patients with stress incontinence, but also in asymptomatic women [40], funneling of the internal urethral meatus may be observed on Valsalva (**Figure 15**) 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 can not be used to prove USI. Marked funneling has been shown to be associated with poor urethral closure pressures [41, 42].

Classifications developed for the evaluation of radio-

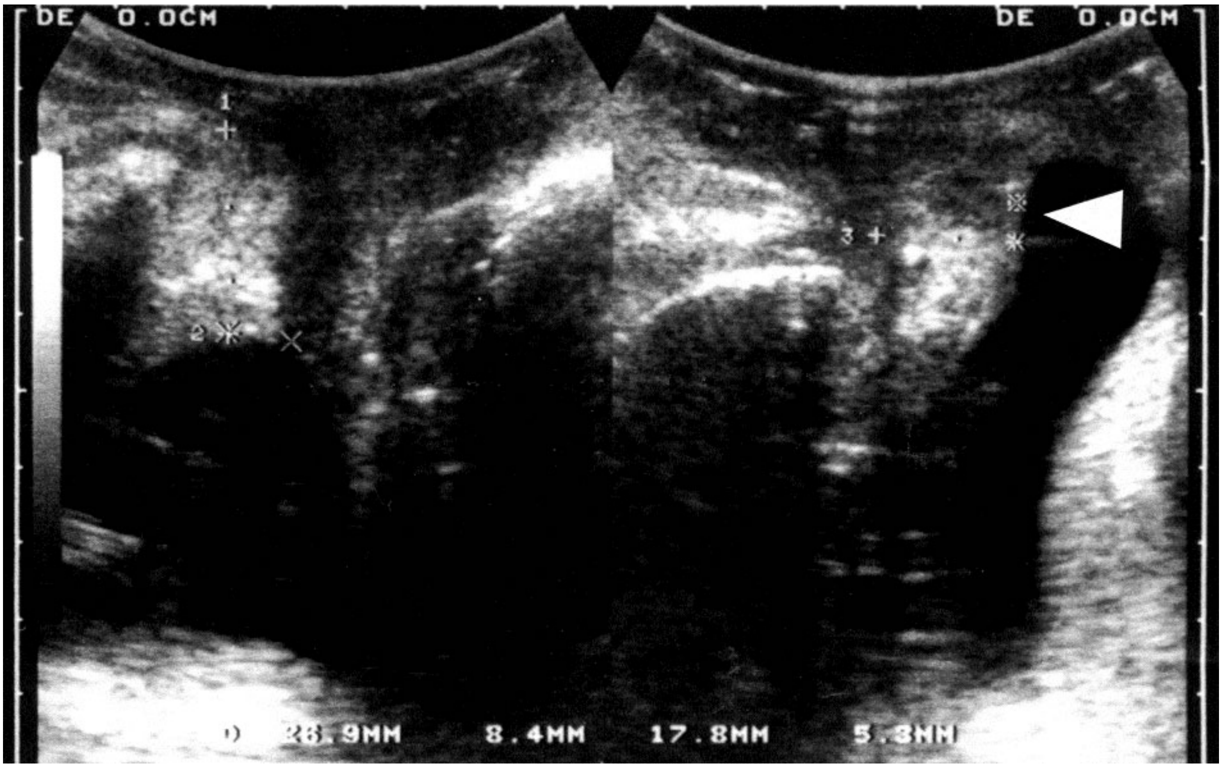


Figure 16. A cystocele with intact retrovesical angle. Note the absence of funneling (arrow).

logical imaging [43] can be used with ultrasound data; however, this approach is not generally accepted. 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 in a postero-inferior direction. Usually 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 often (but not always) associated with funneling. A cystocele with intact retrovesical angle (90- 120 degrees) is frequently seen in continent prolapse patients (see **Figure 16**), and it has been surmised that this configuration distinguishes a central from a lateral defect of the endopelvic fascia [16] although proof for this hypothesis is lacking at present. Marked urethral kinking in such cases can lead to voiding dysfunction (worsened by straining) and urinary retention. Occult stress incontinence may be unmasked once a successful prolapse repair prevents this kinking.

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 [44]. Vaginal childbirth [45-47] is probably the most significant environmental factor, with a long second stage of labour and vaginal operative delivery being associated with increased postpartum descent [47]. This association between increased bladder descent and vaginal parity is also evident in older women with symptoms of pelvic floor dysfunction [48]. In another interesting development, the suspicion that progress in labour is not independent of pelvic floor biomechanics [49] has been confirmed: Anterior vaginal wall mobility on Valsalva was found to be a potential predictor of progress in labour in two independent studies [50, 51].

It remains to be mentioned that increased bladder neck mobility antepartum has been claimed as a predictor of postpartum stress incontinence [38] and has already been used as an entry criterion for a randomized controlled intervention trial [52]. 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 [53] 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.

2. Documentation of Stress Incontinence

US can be used as an alternative to the stress test to demonstrate urine leakage during provocation manoeuvres

- *Contrast media*

The main disadvantage of B– Mode ultrasound imaging in urogynaecology 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 can not be taken as proof of USI [54]. One solution to this problem is to use ultrasound contrast media, e.g., microbubbles such as Echovist [55, 56]. Such preparations are injected into the bladder before imaging, filling the region of the bladder neck. This technique outlines the bladder neck very clearly [57] but involves considerable expense and catheterization. It has therefore not found widespread application.

- *Colour Doppler*

As an alternative to ultrasound contrast media, color Doppler ultrasound has recently been used to demonstrate urine leakage through the urethra on Valsalva maoeuvre or coughing [58]. 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 [59]. Both velocity (CDV, **Fig. 17**) and energy mapping (CDE or 'Power Doppler', **Figure 18**) were able 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 artefact 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 [60]. Whether this is in fact desired will depend on the clinician and his/ her preferences.

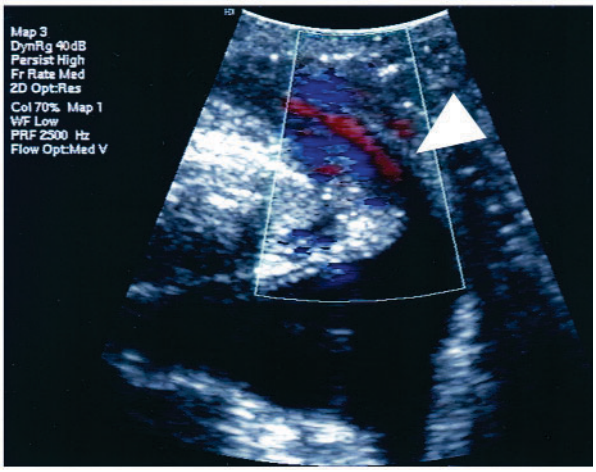


Figure 17. Colour Doppler ultrasound (CDV) demonstrating urine leakage (arrow) through the urethra on Valsalva manoeuvre.

3. Bladder wall thickness

There has recently been renewed interest in the quantification of bladder wall thickness by transvaginal and/ or translabial ultrasound [61, 62]. Measurements are obtained after bladder emptying and perpendicular to the mucosa (**Figure 19**). 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 over 5 mm seem to be associated with detrusor overactivity [61, 63]. 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 overactivity, the method may be clinically highly useful when combined with symptoms of the overactive bladder [64]. It remains to be seen whether determination of this parameter can add any useful clinical information to the workup of a patient with pelvic floor and bladder dysfunction.

4. Levator activity

Perineal ultrasound has been used for the quantification of pelvic floor muscle activity, both in women with stress incontinence and continent controls [65], as well as before and after childbirth [66, 67]. 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 infero-posterior symphyseal margin (**Figure 20**). 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 [68]. Another means of quantifying levator activity would be to measure a reduction of the levator hiatus in the midsagittal plane; this does not seem to have been investigated to date. The method can also be utilized

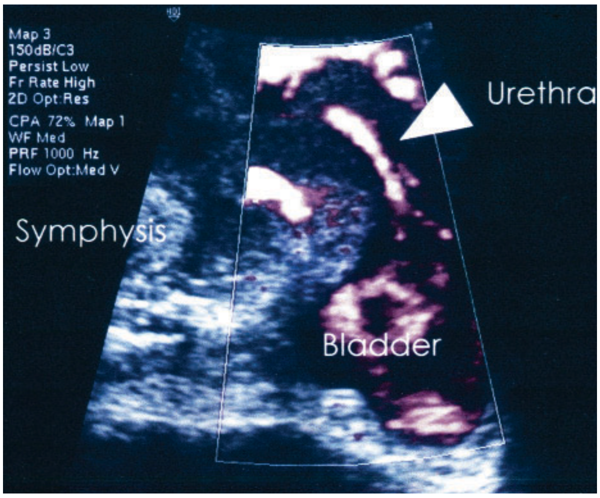


Figure 18. CD Energy (CDE) imaging in Genuine Stress Incontinence. The Doppler signal outlines most of the proximal urethra.

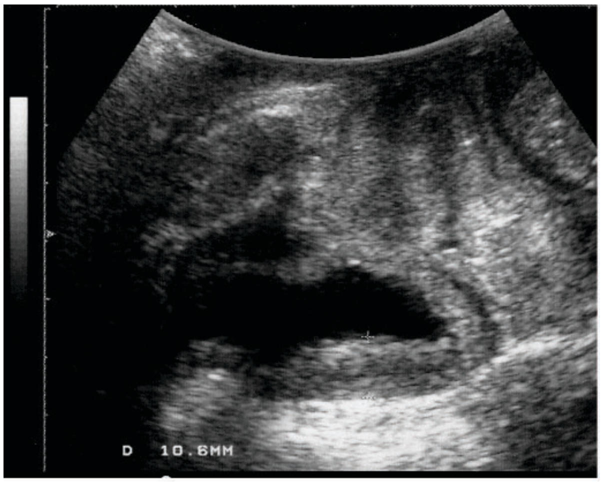


Figure 19. Measurement of bladder wall thickness in a patient with symptoms of an overactive bladder and detrusor instability on urodynamic testing, parasagittal view.

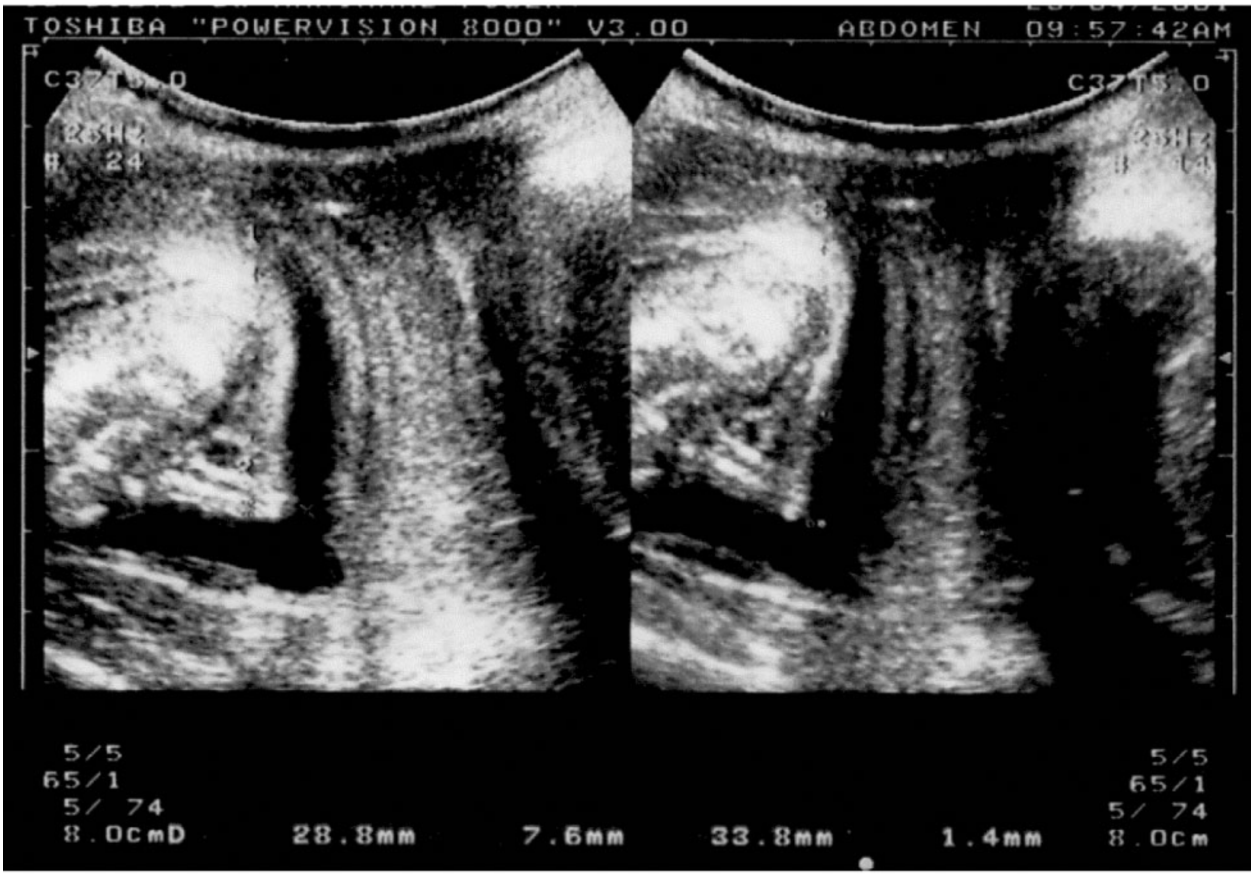


Figure 20. Quantification of levator contraction: Cranioventral displacement of the bladder neck is measured relative to the inferoposterior symphyseal margin. The measurements indicate 4.5 (31.9- 27.4) mm of cranial displacement and 16.2 (17.9 – 1.7) mm of ventral displacement of the bladder neck.

for pelvic floor muscle exercise teaching by providing visual biofeedback [69]. The technique 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 [70]. 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 [71].

5. Prolapse quantification

Translabial ultrasound can demonstrate uterovaginal prolapse [72, 73]. 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 manoeuvre can be measured (**Figure 21**). **Figure 22** 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 [74], with good correlations shown for the anterior and central compartments [75]. 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 and perineal hypermobility without fascial defects. True fascial defects may be present in young nulliparous women (**Figure 23**) but are much more common in the parous. 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 the least because enterocele (**Figure 24**) can easily be distinguished from rectocele. Most recently, it appears that Colorectal surgeons are starting to use the technique to complement or replace defecography [76].

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 25**) [77, 78].

The main research use of this technique may prove to be in outcome assessment after prolapse and incontinence surgery, a field that is rapidly developing at the moment. The elevation and distortion of the bladder neck arising from a colposuspension is easily documented (**Figure 22**). Fascial and synthetic material slings are visible posterior to the trigone or the urethra (**Figure 26**), and bulking agents such as Macroplastique (**Figure 27**) 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 [79].

Ultrasound has contributed significantly to the investigation of new surgical procedures such as the recently developed wide- weave suburethral Prolene 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 [80], 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 [80-84], see **Figure 26**. Wide- weave monofilament mesh such as the TVT or Sparc are more echogenic than more tightly woven multifilament implants such as the IVS (**Figure 28**), but all can 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 [85]. The assessment of bladder neck mobility before implantation of a suburethral sling may predict success or failure [86], an observation that makes perfect sense when one considers that dynamic compression relies on relative movement of implant and native tissues. Finally, sonographic imaging 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 [87].

6. Paravaginal defect imaging

Transabdominal ultrasound has been used to demonstrate lateral defects of the endopelvic fascia, also termed "paravaginal" defects [88, 89]. However, the method has not been conclusively validated, and a recent prospective study showed poor correlation with clinically observed defects [90]. There may be several factors limiting the predictive value of transabdominal ultrasound in the identification of parava-

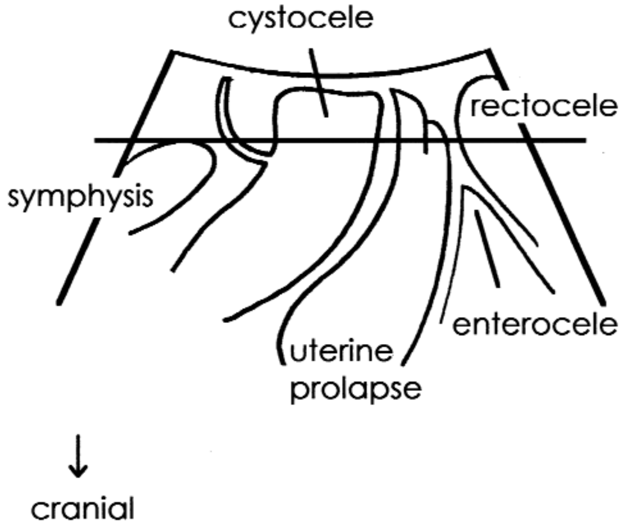


Figure 21. Ultrasound quantification of uterovaginal prolapse. The inferior margin of the symphysis pubis serves as a line of reference against which the maximal descent of bladder, uterus, cul de sac and rectal ampulla on Valsalva manoeuvre can be measured.

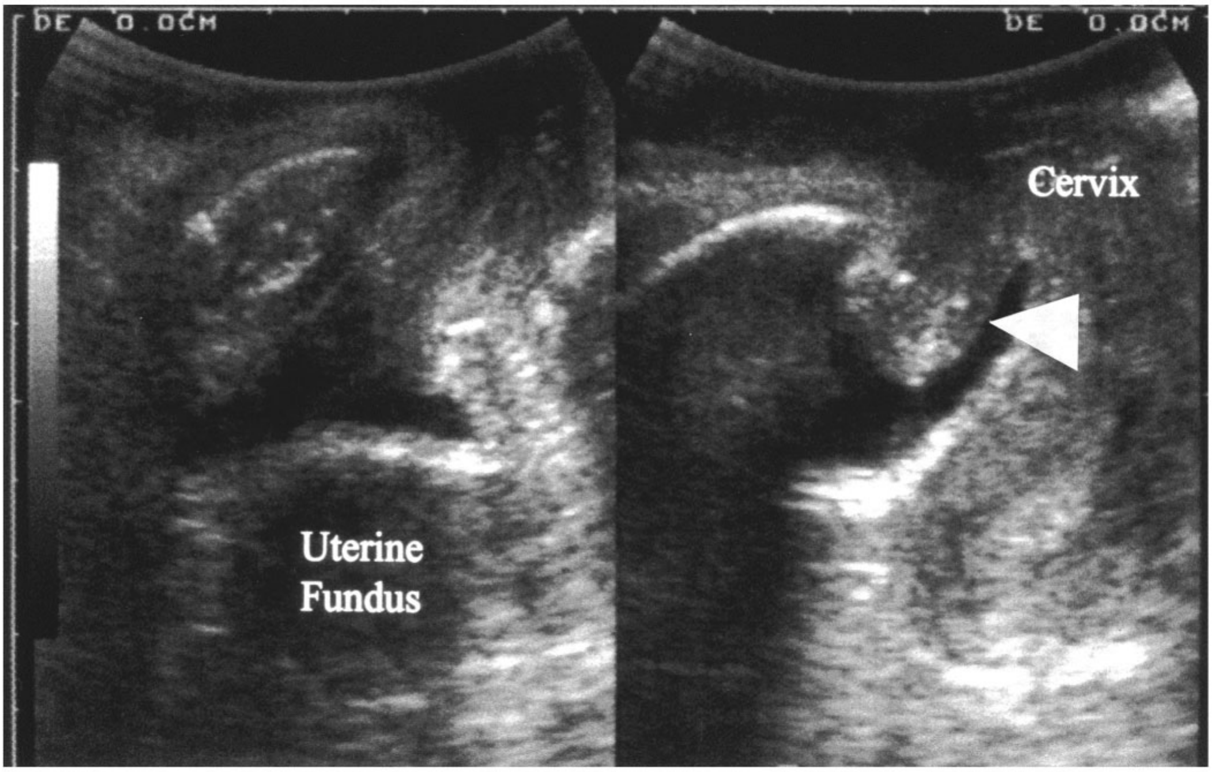


Figure 22. First degree uterine descent in a patient after Burch colposuspension. The latter is evident as a ridge- like deformation of the trigone, posterior to the internal urethral meatus (arrow). Image on left is at rest, right on Valsalva.

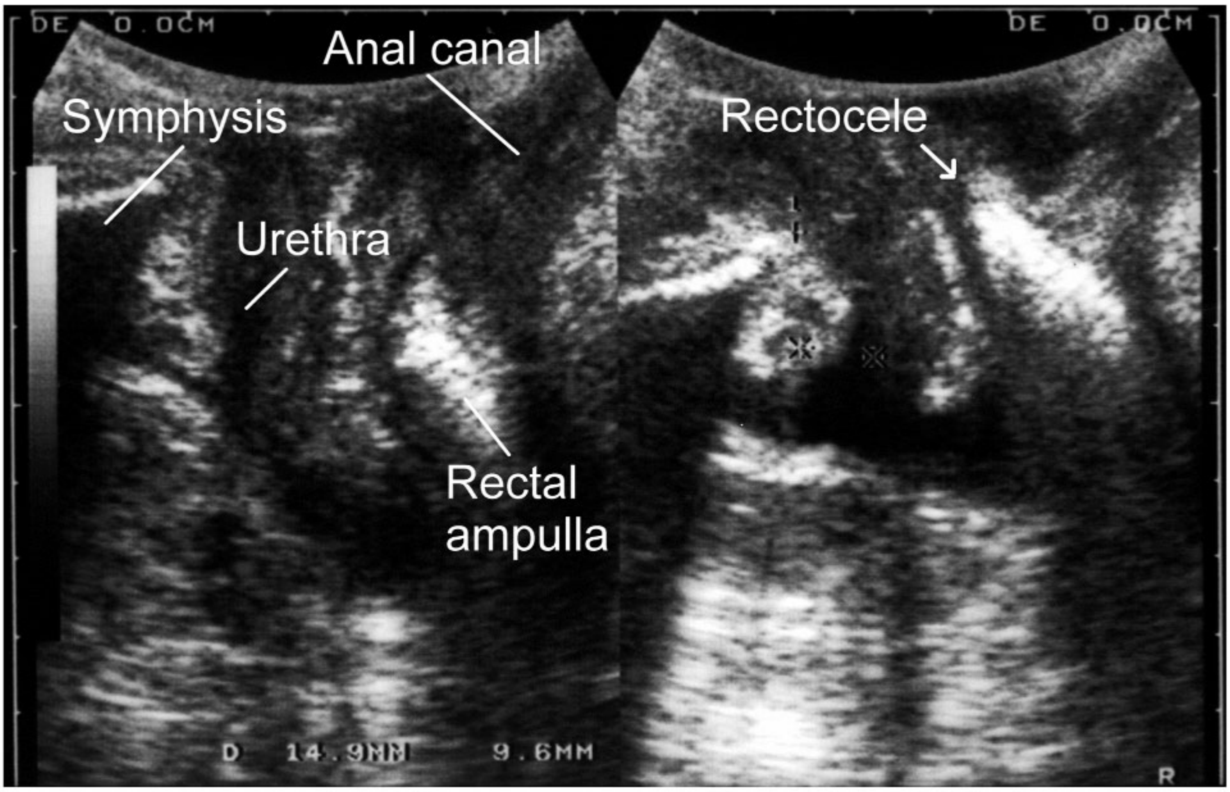


***Figure 23**. First degree rectocele in a 23 year old nulliparous asymptomatic volunteer. The anal canal is seen to the right of both images, with a small rectocele (large arrow) clearly visible on Valsalva (right). Midline imaging shows a transverse fascial defect (arrows) of the lower rectovaginal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

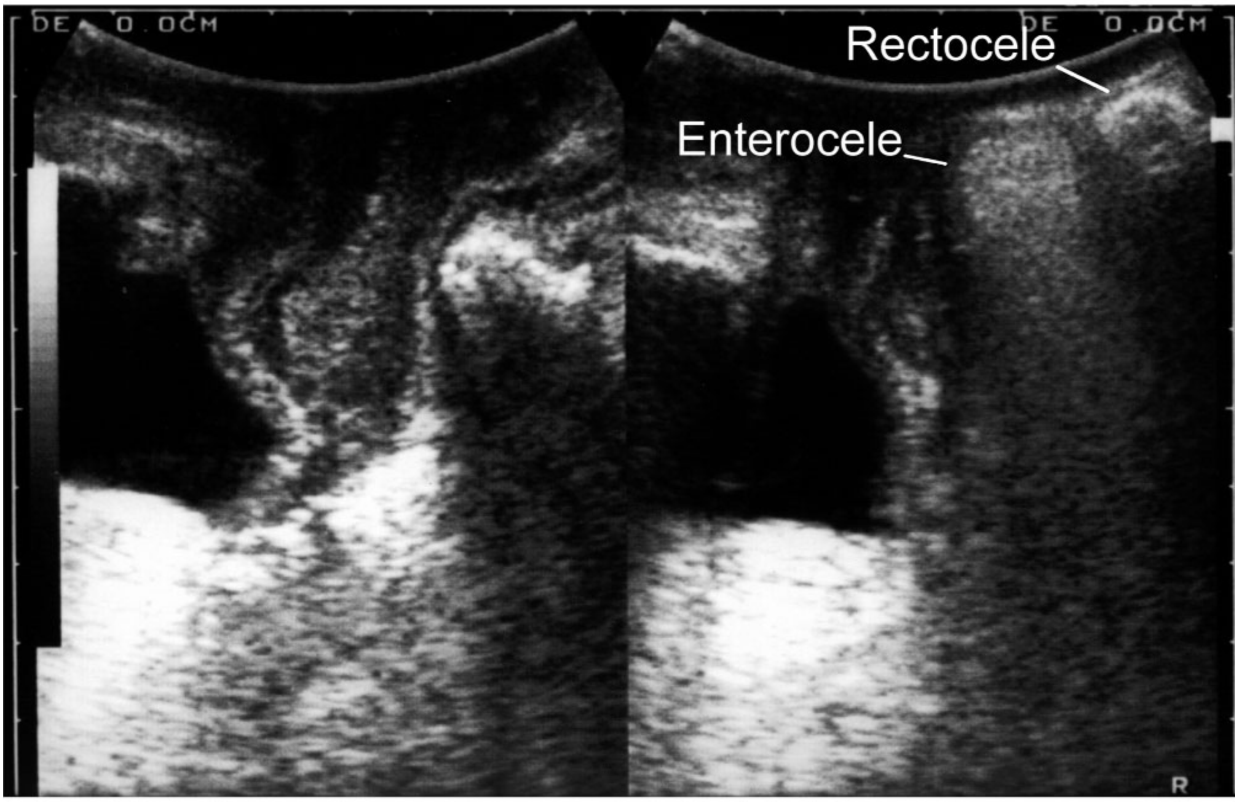


***Figure 24**. Recto- enterocele after Burch colposuspension at rest (left), and on Valsalva manoeuvre (right). Usually, enteroceles (filled by peristalsing small bowel, epiploic fat or omentum) appear more homogeneous and nearly isoechoic whereas the rectocele is filled by a stool bolus, resulting in hyperechogenicity with distal shadowing.*

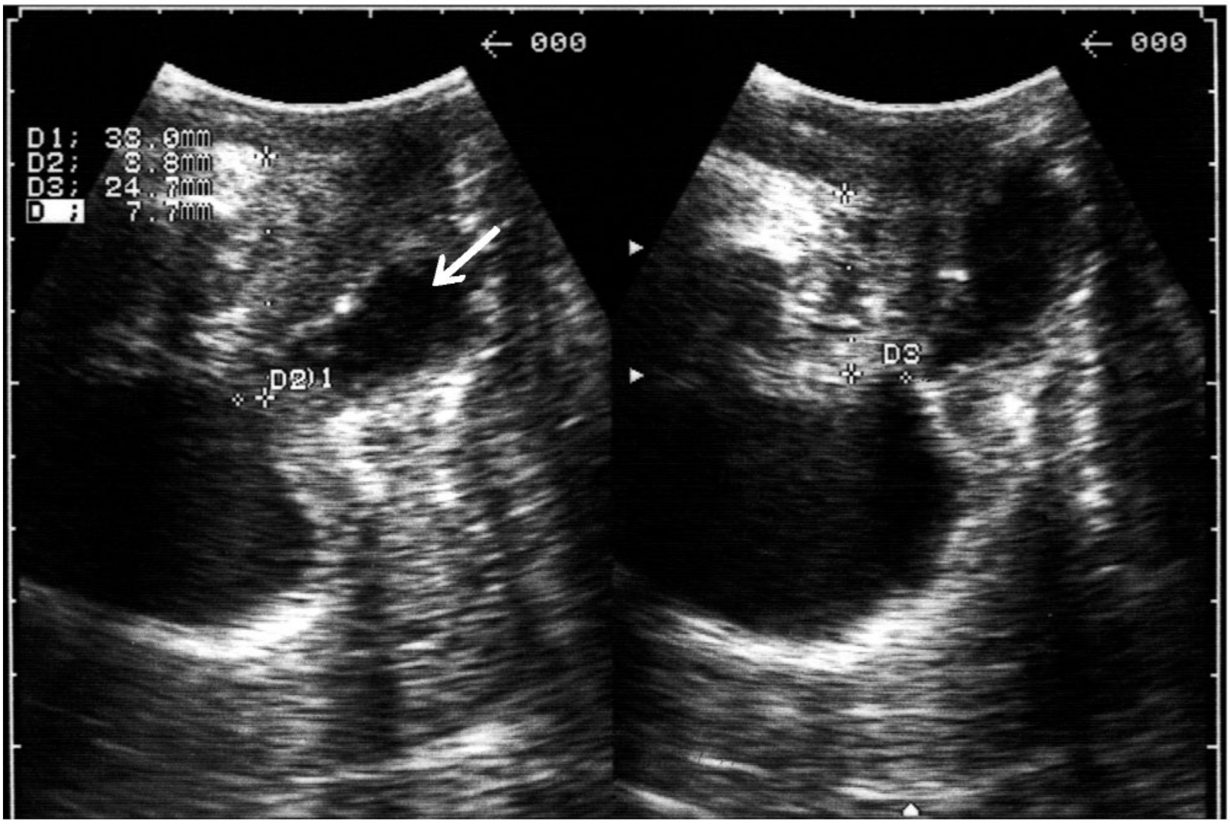


Figure 25. Urethral diverticulum (arrows), herniating downwards and clinically simulating a cystourethrocele on Valsalva manoeuvre. The neck of the diverticulum is seen close to the bladder neck.

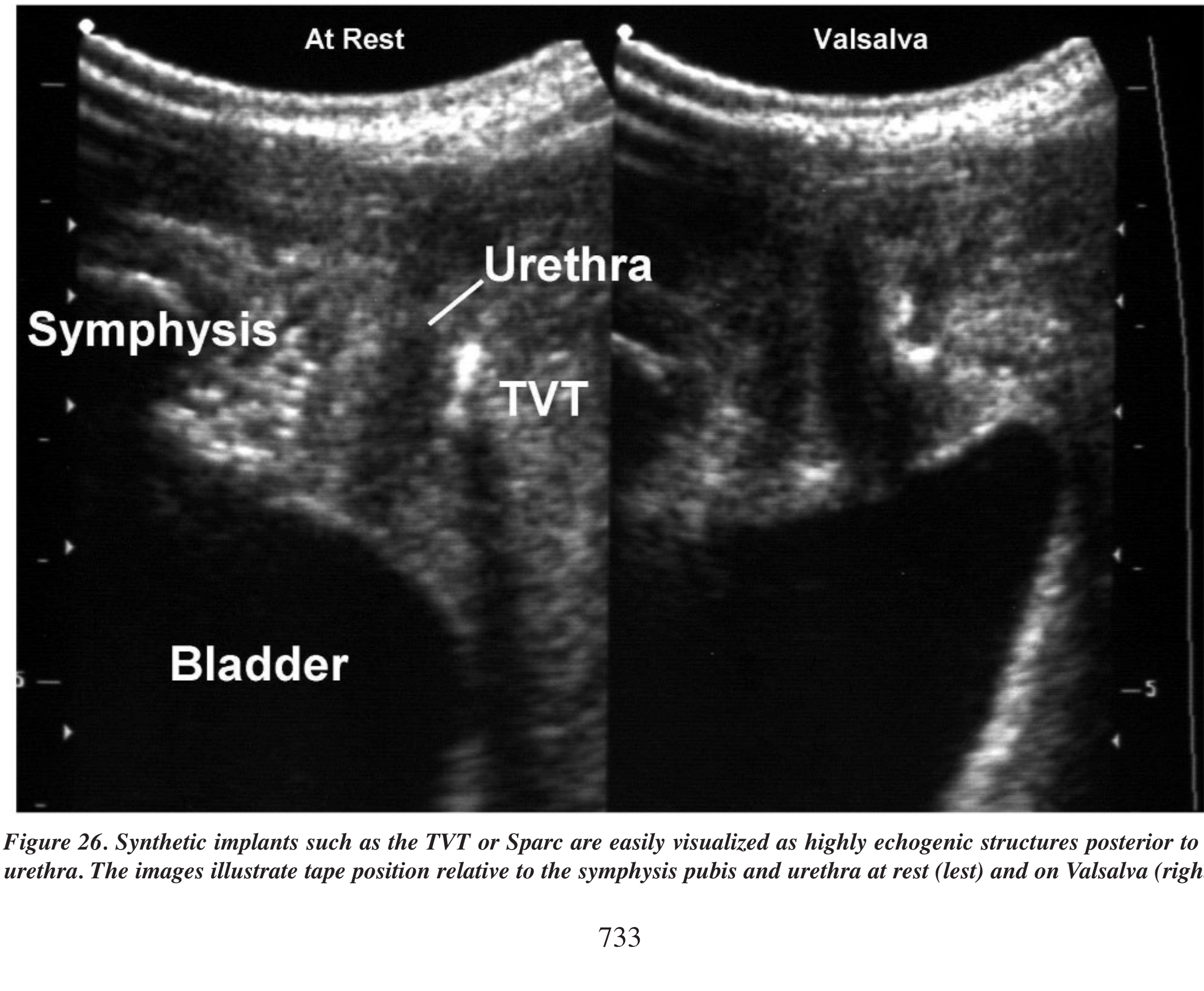


Figure 26. Synthetic implants such as the TVT or Sparc are easily visualized as highly echogenic structures posterior to the urethra. The images illustrate tape position relative to the symphysis pubis and urethra at rest (lest) and on Valsalva (right).

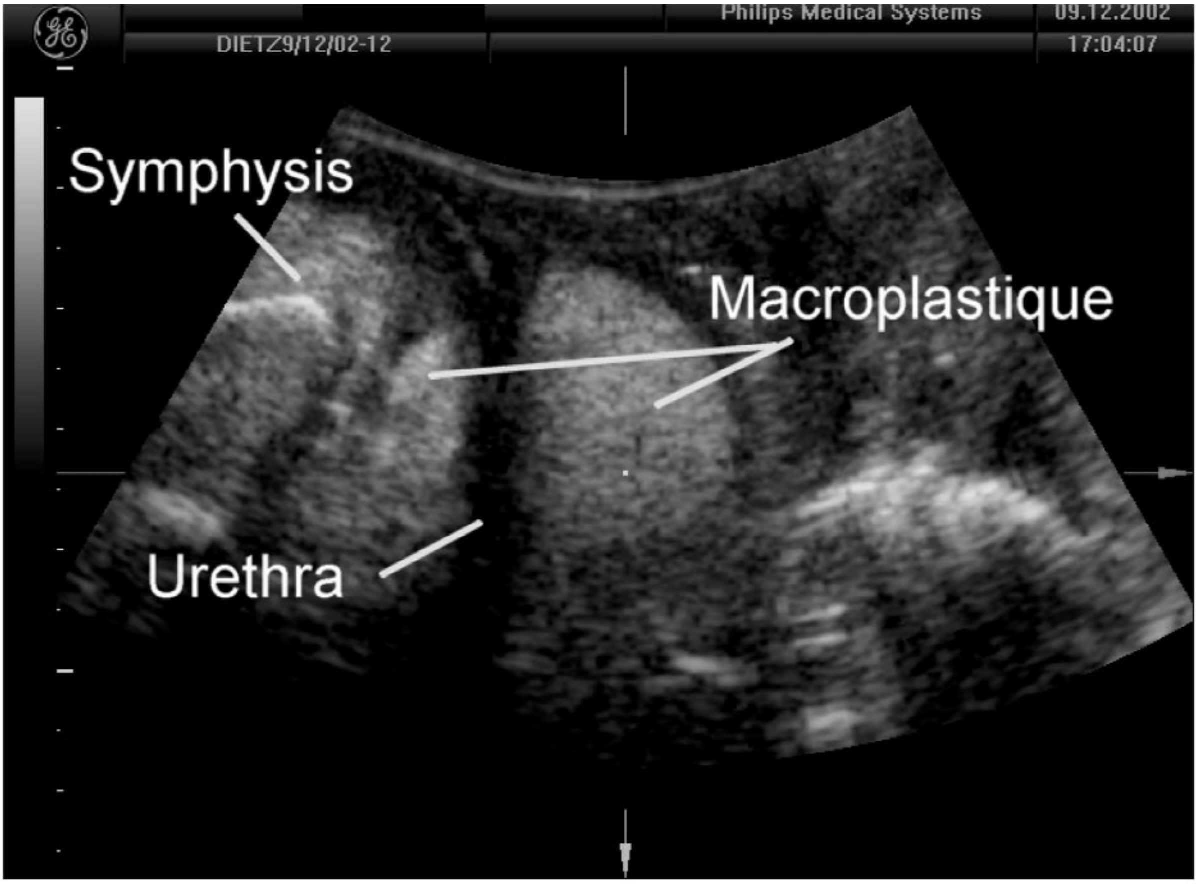


Figure 27. Macroplastique silicone macroparticles used in incontinence surgery are very echogenic and located surrounding the urethra both anteriorly and posteriorly.

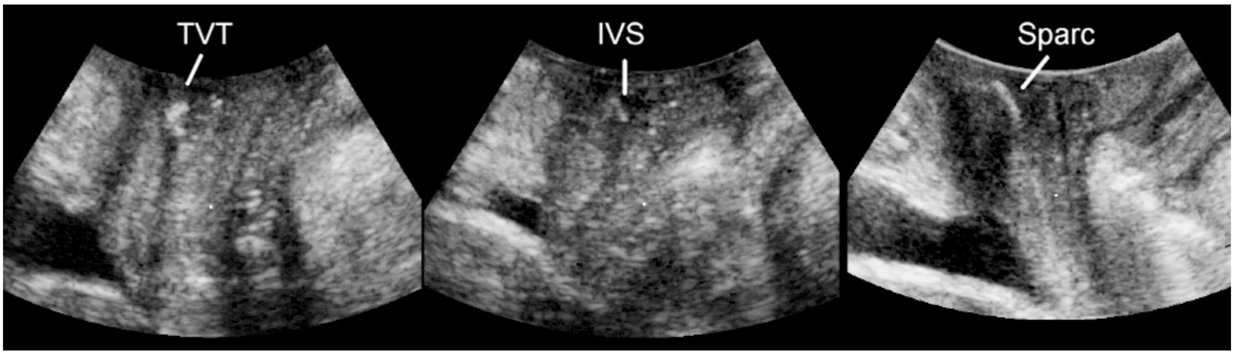


Figure 28. A comparison of TVT, SPARC and IVS (left to right) on midsagittal imaging (top row) and 3D rendered volumes in an oblique axial plane (bottom row).

ginal 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 manoeuvre (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 3D ultrasound and Magnetic Resonance Imaging in this field.

7. 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 diverticulae [77, 91] (**Figure 25**), Gartner duct cysts (**Figure 29**) or bladder tumours (**Figure 30**) may be identified, and intravesical stents and bladder diverticulae can also be visualized [16]. Postoperative haematomata may be visible after vaginal surgery or TVT and at times explain clinical symptoms such as voiding dysfunction or persistent pain (**Figure 31**).

Figure 29. Gartner duct cyst close to bladder neck (arrow).

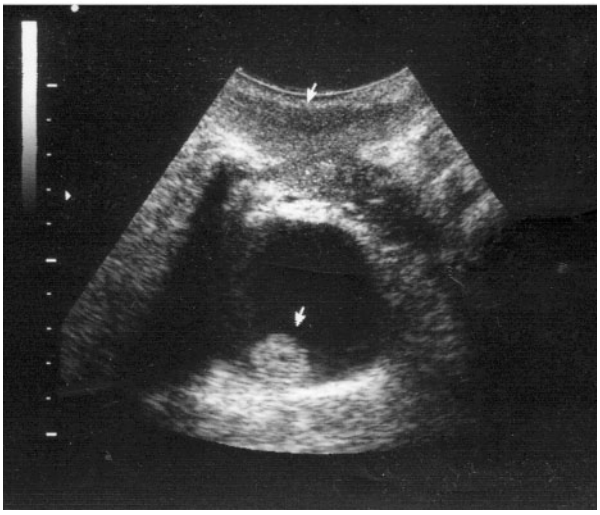


Figure 30. Transitional cell carcinoma of the bladder as seen on parasagittal translabial ultrasound (arrow).

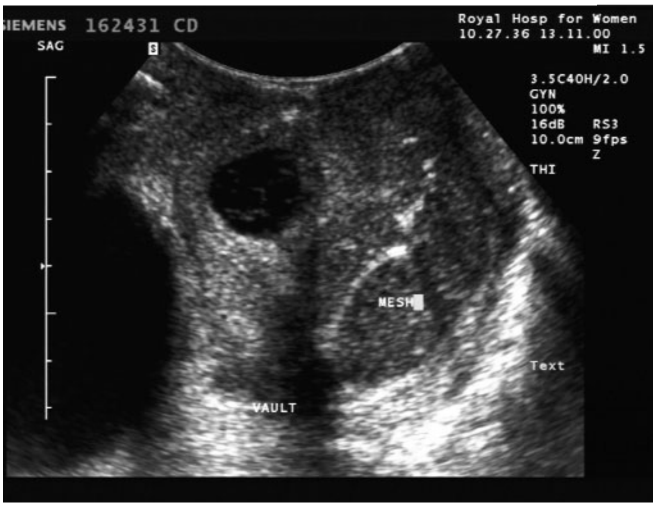


Figure 31. Retroperitoneal haematoma and subcutaneous vaginal haematoma after mesh sacrocolpopexy and posterior repair.

3. 3D Pelvic Floor Imaging

Ultrasound imaging of the pelvic floor developed as an adjunct to physical examination taking advantage of the large availability of the US equipments, of the possibility to repeat the imaging both at rest and during provocation manoeuvres. Modern ultrasound probes provide a large view angle encompassing both then anterior and the posterior compartments of the pelvic floor. The possibility to image not only the pelvic organs but also muscle and fascial components of the pelvis offer a possible advantage over standard X-ray imaging and place US in competition with MRI.

a) Technical overview

Two main engineering solutions have been developed to allow integration of 2D sectional images into 3D volume data- motorized acquisition and external electromagnetic position sensors. A simplified technique is the freehand acquisition of volumes without any reference to transducer position.

Quantitative evaluation of volumes requires information on transducer position at the time of acquisition of a given frame of imaging data, and this can be achieved by using a motor to move the probe. Motorized acquisition may take the shape of automatic withdrawal of an endocavitary probe or motor action within the transducer itself. The first such motorized probe was developed in 1974, and by 1987 transducers for clinical use were developed that allowed motorized acquisition of imaging data [92]. The widespread acceptance of 3D ultrasound in Obstetrics and Gynaecology has been helped considerably by the development of these systems since they do not require any movement relative to the investigated tissue during acquisition.

Fortuitously, transducer characteristics on currently available systems for use in Obstetrics and Gynaecology have been almost perfect for pelvic floor imaging. A single volume obtained at rest with an acquisition angle of 70 degrees or higher will include the entire levator hiatus with symphysis pubis, urethra, paravaginal tissues, the vagina, anorectum and puborectalis loop from the pelvic sidewall in the area of the arcus tendineus of the levator ani (ATLA) to the posterior aspect of the anorectal junction. A Valsalva manœuvre however may result in lateral or posterior parts of the puborectalis being pushed outside the field of vision, especially in women with significant prolapse (see below).

b) Display modes

Figure 32 demonstrates the two basic display modes currently 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), the latter at the level of the levator hiatus.

One of the main advantages of volume ultrasound for pelvic floor imaging is that the method gives access to the axial plane. Up until recently, pelvic floor ultrasound was limited to the midsagittal plane [9, 93, 94]. The axial plane was accessible only on MRI

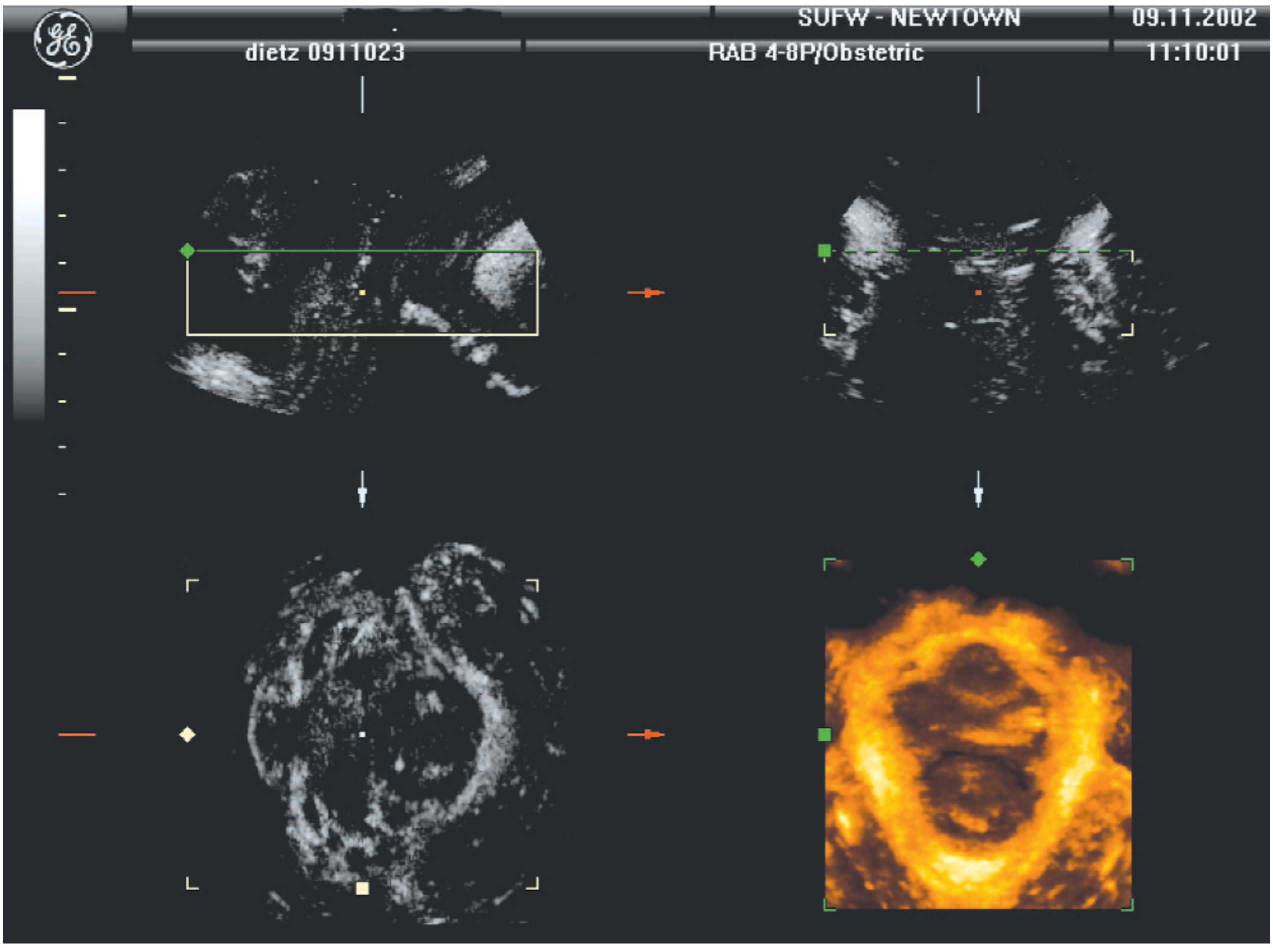


Figure . 32. The usual acquisition/ evaluation screen on Voluson type systems shows the three orthogonal planes: sagittal (top left), coronal (top right) and axial (bottom left); as well as a rendered volume (bottom right) which is a semi- transparent representation of all grayscale data in the rendered volume (arrow).

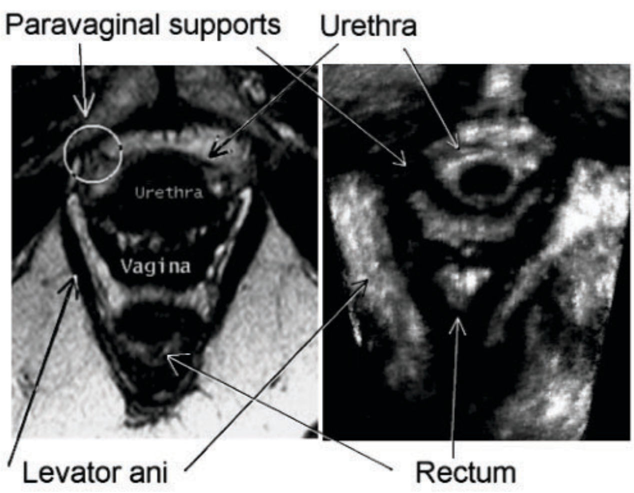


Figure 33. The axial plane on MRI and US (freehand 3D). While these images were obtained in different patients, all significant structures can be identified by both methods. Image courtesy of Dr. Ben Adekamni, Plymouth UK.

[95] (see **Figure 33** for an axial view of the levator hiatus on MRI and 3D ultrasound). As opposed to MRI however, 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 at a later time. The levator ani for example usually requires an axial plane that is tilted in a cranioventral to dorsocaudal direction. The three orthogonal images are complemented by a 'rendered image', i.e., a semitransparent representation of all voxels in an arbitrarily definable 'box'. The bottom right hand image in **Figure 32** shows a standard rendered image of the levator hiatus, with the rendering direction set from caudally to cranially which seems to be most convenient for pelvic floor imaging. The possibilities for postprocessing are restricted only by the software used for this purpose; programmes such as GE Kretz 4D (Kretztechnik Gmbh, Zipf, Austria) view or Philips Sonoview Pro (Philips Australia, Epping Rd, North Ryde NSW 2113, Australia) allow almost unlimited manipulation of image characteristics.

Due to the realtime nature of pelvic floor imaging, functional anatomy can be assessed on Valsalva (which includes the development of prolapse and the opening up of fascial or muscular defects), and the effect of a levator contraction on the levator hiatus. **Figure 34** shows frames representing the levator hiatus at rest and on maximal Valsalva in a nulliparous young woman with minimal pelvic organ descent; in someone with prolapse the levator hiatus often increases markedly in size, even without actual fascial or muscular defects (**Figure 35**).

To date, 3D pelvic floor ultrasound has been used for the evaluation of the urethra and its structures, for imaging of the more inferior aspects of the levator ani complex (pubococcygeus and puborectalis), for the visualization of paravaginal supports, as well as for prolapse and implant imaging. One of the major advantage of 3D US is the possibility to acquire information on a patient "volume", to store it and to have it available for further analysis and review along any plane.

c) 3D Imaging of the Urethra

Technically, 3D pelvic floor ultrasound imaging became feasible in 1988-89 with the advent of the Kretz Voluson 530 systems. However, there are no records of any such use of those first true 3D ultrasound systems; the first publication on 3D ultrasound in Urogynaecology dates to 1994 [96] when Linda Cardozo's group at King's College, London, demonstrated that this technique could be used to assess the urethra. Khullar et al. used transvaginal probes with motorized withdrawal to allow the use of calipers in all three planes. Subsequently, it was shown that urethral volumetry data correlated with urethral pressure profilometry [96], and that urethral volume decreased with parity. More recently, this technique has been used to assess delivery- related changes [97], and 3D ultrasound with intravaginal systems may also aid in identifying paraurethral support structures such as the pubourethral ligaments. Probes designed for prostatic imaging have also been employed for the assessment of the urethra and paraurethral structures by the transrectal route [98].

d) 3D Imaging of the Levator Ani complex

To date, the levator ani has not been comprehensively investigated by 3D volume ultrasound. While it was identified on early studies using transvaginal techniques [14] and translabial freehand volume acquisition [99] as well as on translabial ultrasound using a Voluson system [13], 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 as a highly echogenic structure. Similar to MRI imaging, it is currently impossible to distinguish the different components of the pubovisceral or puborectalis/ pubococcygeus complex [100], and the more cranial aspects of the levator, e.g. iliococcygeus, are impossible to identify. Observation of the muscle during levator contraction and on Valsalva increases the likelihood of detecting abnormalities of levator morphology. In a series of 52 young, nulligravid women no significant

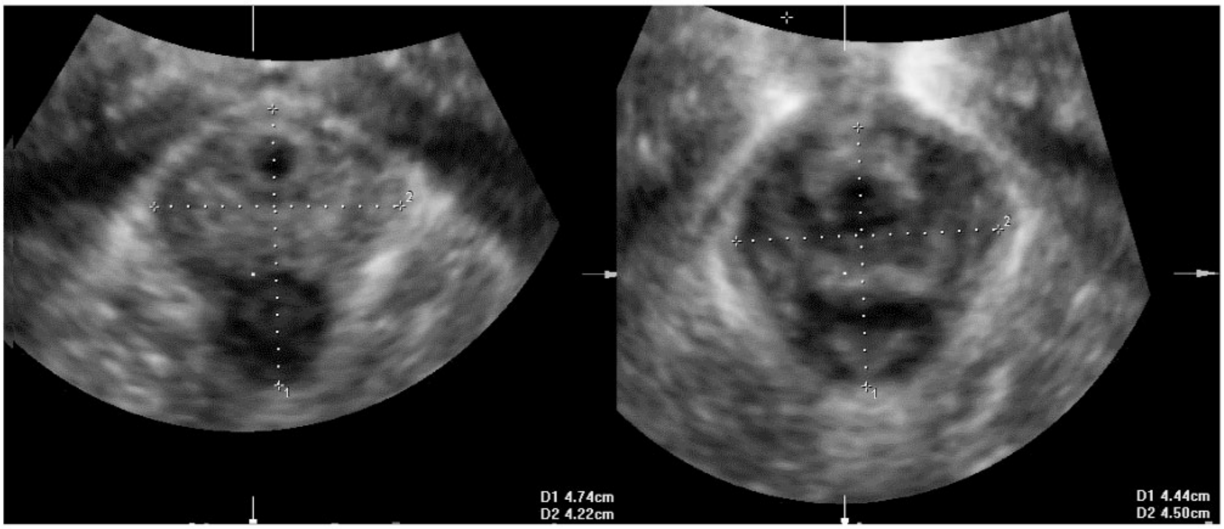


Figure . 34. The effect of a Valsalva manœuvre on the levator hiatus (left, at rest; right, on Valsalva) in a young nulliparous woman without significant pelvic organ descent. The dimensions of the levator hiatus are measured in the sagittal (1) and coronal (2) planes.

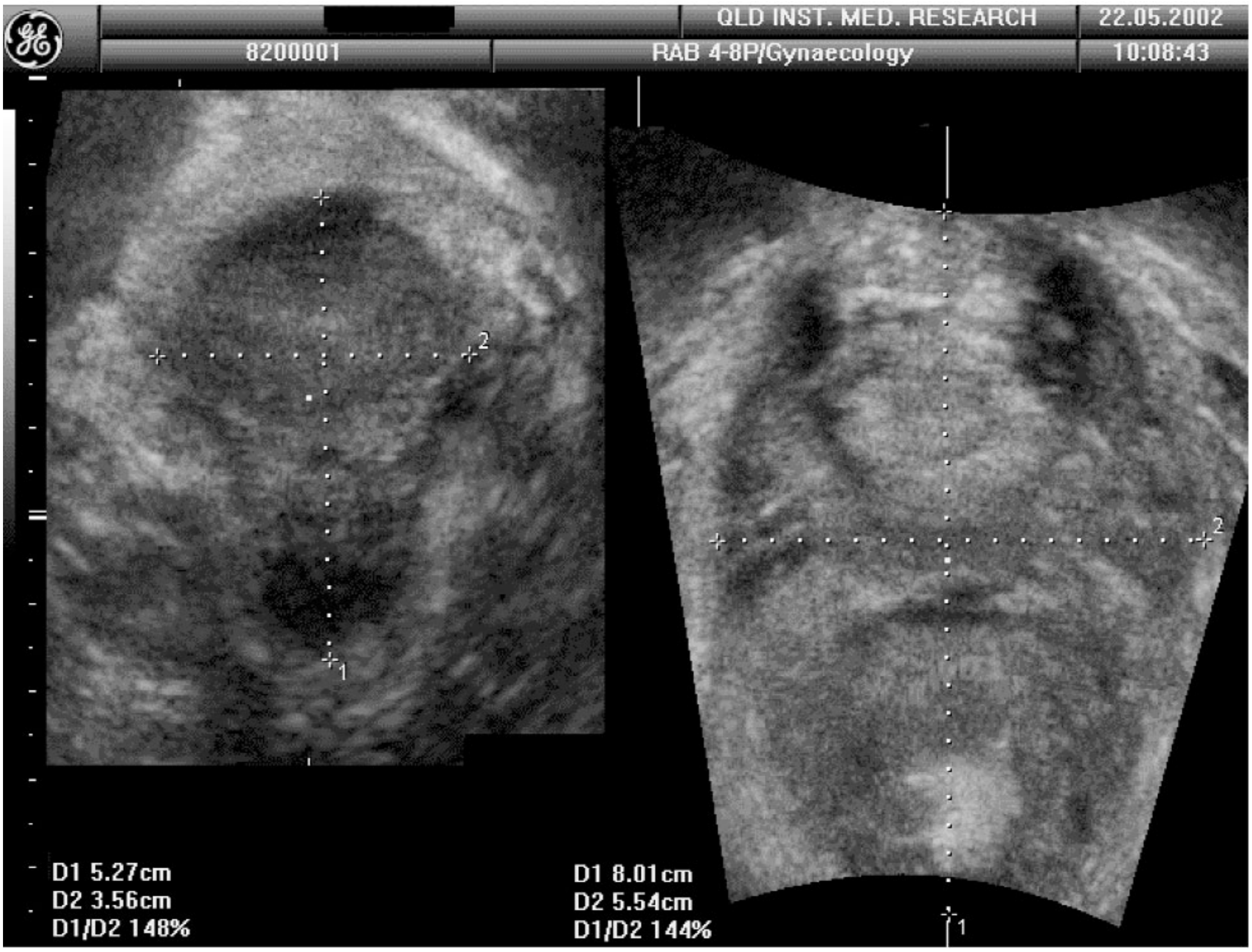


Figure 35. The levator hiatus at rest (left) and on Valsalva (right) in a young woman with significant pelvic organ descent. On Valsalva the levator is situated partly outside the acquisition volume.

asymmetry of the levator was observed, supporting the hypothesis that significant morphological abnormalities of the levator are likely to be evidence of delivery- related trauma [101]. Contrary to MRI data [100], there was no significant side difference, neither for thickness nor for area.

The above- quoted 3D ultrasound study defined a number of biometric parameters of the levator complex itself and of the levator hiatus [101]. Results agreed with MRI data obtained in small numbers of nulliparous women for the dimensions of the levator hiatus [100] and levator thickness [102]. In a test-retest series, it became evident that, with current methodology, diameter and area measurements of the pubococcygeus- puborectalis complex are less reproducible than measures of the levator hiatus. Possibly as a consequence, measures of muscle mass did not correlate with levator function as determined by displacement of the bladder neck on levator contraction, a finding that agrees with clinical impression: a bulky levator may not necessarily contract well.

Hiatal depth and area measurements (see Figures 34 and 35) however were highly reproducible (Intraclass correlation coefficients of 0.70 - 0.82) and correlated strongly with pelvic organ descent, both at rest and on Valsalva. While this is not surprising for the correlation between hiatal area on Valsalva and descent as downwards displacement of organs may push the levator laterally, it is much more interesting that hiatal area at rest is associated with pelvic organ descent on Valsalva. This data constitutes the first hard evidence for the hypothesis that the state of the levator ani is important for pelvic organ support [103], even in the absence of levator trauma. As regards morphological abnormalities of the levator muscle, it is evident that major levator trauma, i.e., avulsion of the puborectalis/ pubococcygeus from the pelvic sidewall, is not that uncommon and seems to be associated with early presentation and recurrent prolapse after surgical repair (see **Figure 36**). Clearly, this is a very interesting area for future research.

e) 3D Imaging of 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 [104]. However, proof has been lacking to date. In a pilot study in a group of women before and after their first delivery, the author attempted to define the integrity of paravaginal supports ('tenting', see **Figure 37**), using a Toshiba PowerVision 8000 system (Toshiba Medical Systems, North Ryde NSW 2113, Australia) with freehand acquisition technique [99]. While this technique is already obsolete, alterations in paravaginal supports were observed in 5 out of 21 women seen both ante- and postpartum, and the interobserver variability of the qualitative assessment of paravaginal supports was shown to be good. An incidental observation was that imaging quality was exceptional in late pregnancy, probably due to increased hydration of tissues.

Somewhat counterintuitively, there was no significant correlation between a loss of paravaginal support and increased bladder neck or urethral mobility on Valsalva in this study. The authors speculated that increased mobility might not necessarily mean disruption or avulsion of structures but rather stretching or distension, but it was pointed out that the method might not be powerful enough to detect changes due to the limitations of a freehand technique. Paravaginal tissues can also be assessed by transrectal or transvaginal 3D ultrasound using probes designed for pelvic or prostatic imaging [14], but this work does not seem to have progressed beyond the preliminary stage.

It remains to be shown whether loss of paravaginal tenting is in fact equivalent to what is clinically described as a 'paravaginal defect', a concept that is controversial in clinical Urogynaecology [88, 90] . In a recent study on 62 women presenting with pelvic floor disorders, only weak correlations were found between a blinded clinical assesssment 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 [105]. This may be due to inadequate clinical assessment technique or possibly an insufficiently sensitive imaging method. However, another explanation may be that true paravaginal defects are either not common or irrelevant for anterior vaginal wall support (or both). Until credible data is presented that demonstrates the reproducible detection of paravaginal defects preoperatively and validates this against the reproducible, blinded detection intraoperatively, the paravaginal defect as such has to be regarded as an unproven concept [105].

f) 3D Imaging of Prolapse

The downwards displacement of pelvic organs on Valsalva manœuvre in itself does not require 3D imaging technology, whether MRI- or ultrasound- based.

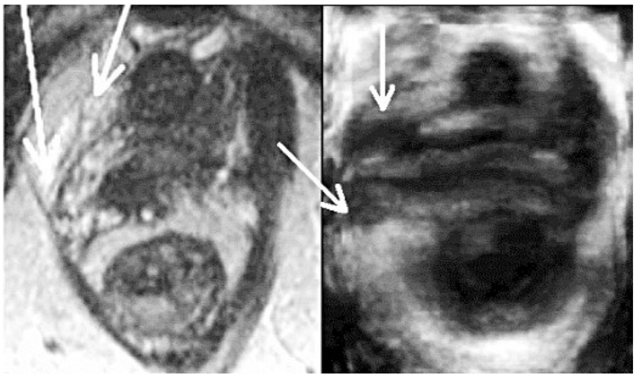


Figure 36. Levator avulsion (lower arrows) on MRI (left) and 3D ultrasound (right). While these images were obtained in different patients, the appearances are typical in that a levator avulsion (arrows) seems to most often occur on the patient's right (left side of the images). In both cases paravaginal tenting is also absent on the patient's right side (top arrows). MRI image courtesy of Dr. Ben Adekamni, Plymouth UK.

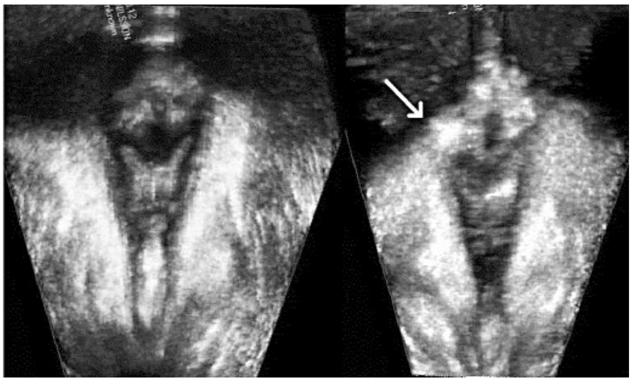


Figure 37. Loss of tenting postpartum (arrow) in a primipara after term normal vaginal delivery.

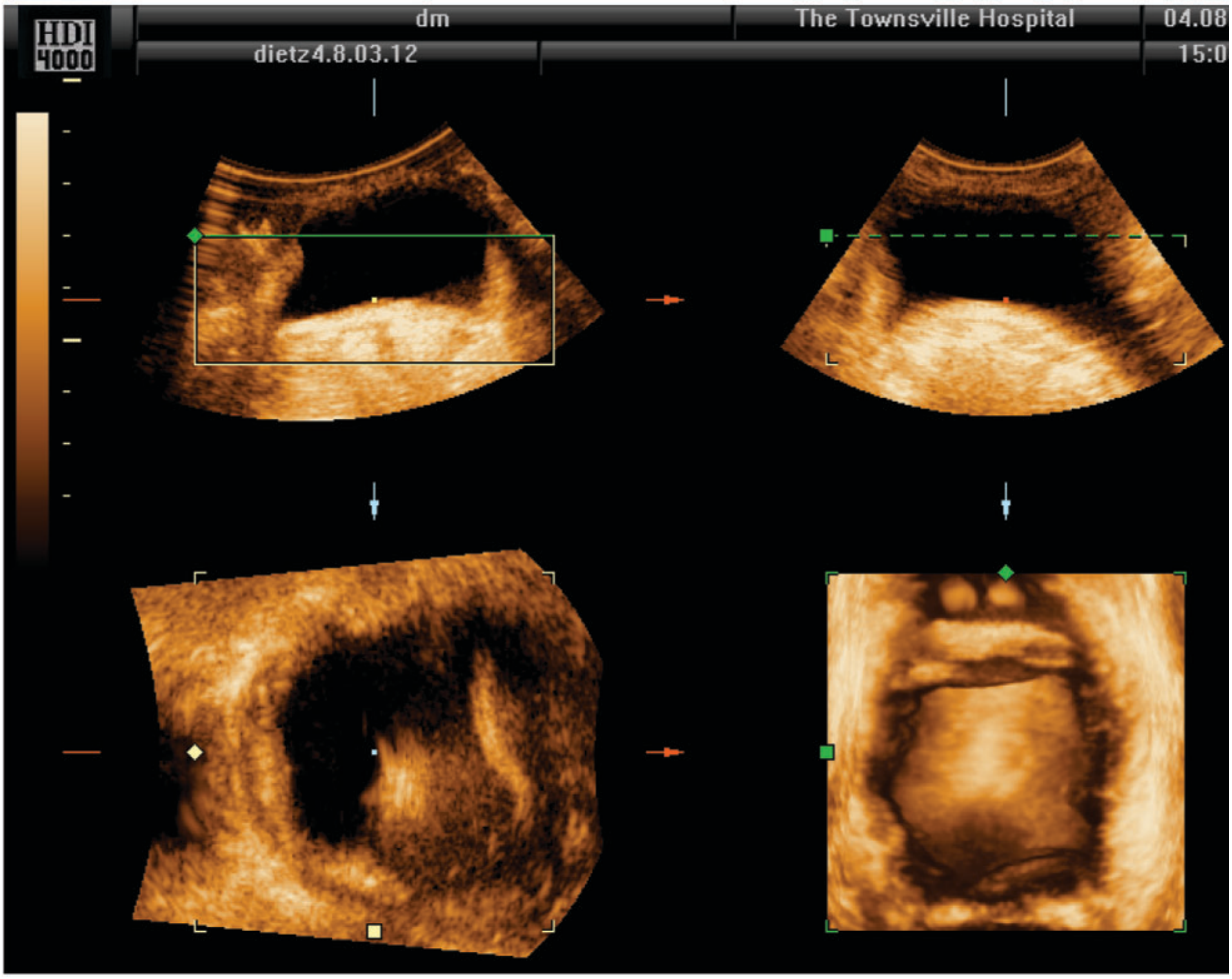


Figure 38. Large cystocele (arrow) in the three standard planes (sagittal top left, coronal top right, axial bottom left) and rendered image (axial, caudocranial rendering), showing a view through the cystocele onto the bladder roof.

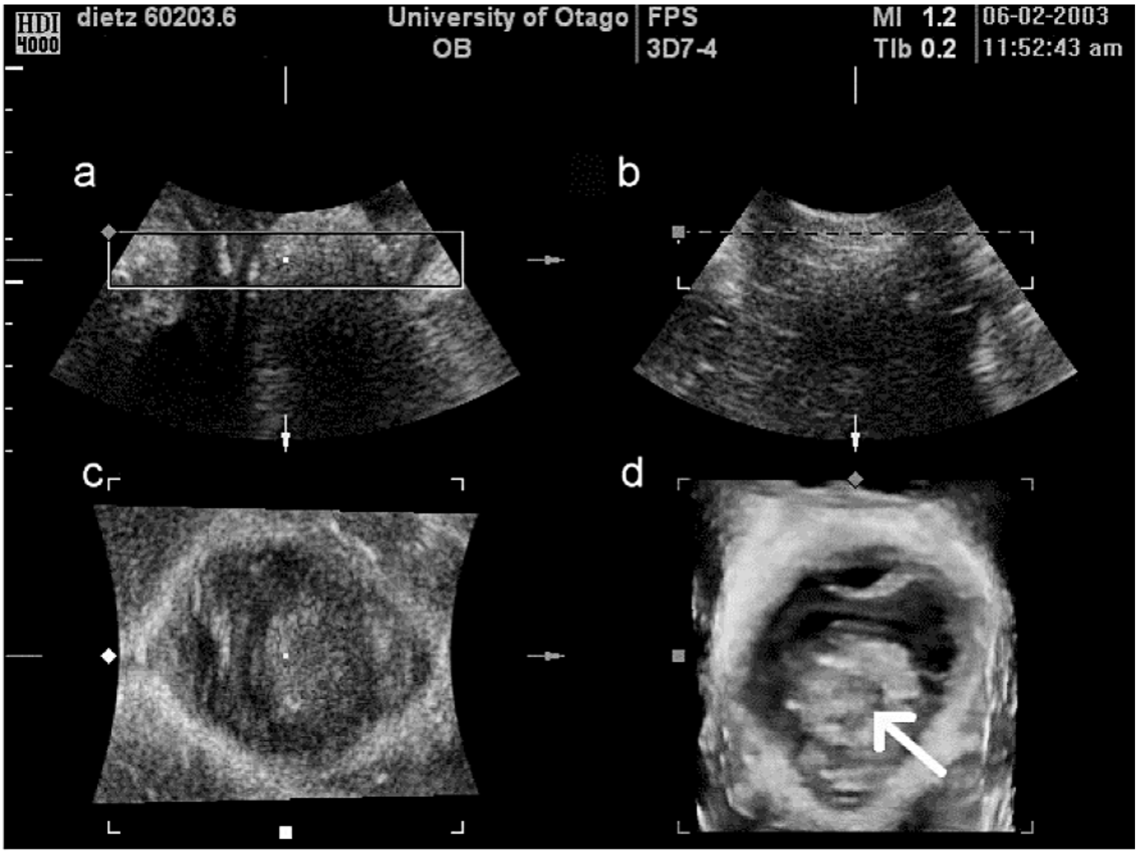


Figure 39. Large rectocele in the three standard planes plus rendered volume (bottom right), showing a large symmetrical rectocele filling most of the levator hiatus (large arrow). There also is a suburethral tape (small arrow)

Descent of the urethra, bladder, cervix, cul de sac and rectum is easily documented in the midsagittal plane [75]. However, 3D ultrasound is likely to become useful in the localization of fascial defects (e.g. transverse or lateral tears in the rectovaginal septum). Rendered volumes may allow a complete 3D visualization of a cystocele or rectocele (see **Figures 38 and 39**). When processed into rotational volumes, hyperechoic structures such as a rectocele become particularly evident. The ease with which pre- and postoperative data can be compared with the help of stored volume data will be especially useful in audit activities.

g) 3D Imaging of synthetic implant materials

Suburethral slings such as the TVT, SPARC or IVS have become very popular during the last 10 years [106-108] and are now the primary anti- incontinence procedure in many developed countries. These slings are not without their problems, even if biocompatibility is markedly better than for previously used synthetic slings. Imaging of such slings 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 sling failure, voiding dysfunction, erosion and symptoms of the irritable bladder may benefit from imaging assessment.

Fortunately, most of the modern synthetic implant materials are highly echogenic (see above), with TVT and Sparc usually being more visible than the IVS. 3D ultrasound has been used to locate the implant over its whole course [109], from above the pubis rami to behind the urethra, and back up on the contralateral side (see **Figure 40**) Variations in placement such as asymmetry, varying width, the effect of tape division and tape twisting can be visualized. The difference between transobturator tapes and the TVT- type implants, impossible to distinguish on 2D imaging, is readily apparent on rendered volumes (see **Figure 41**). It is quite likely therefore that 3D imaging will be helpful in the assessment of suburethral slings.

The same holds true for mesh implants used in prolapse surgery. There is a worldwide trend towards mesh implantation, especially for recurrent prolapse, and complications such as failure and mesh erosion

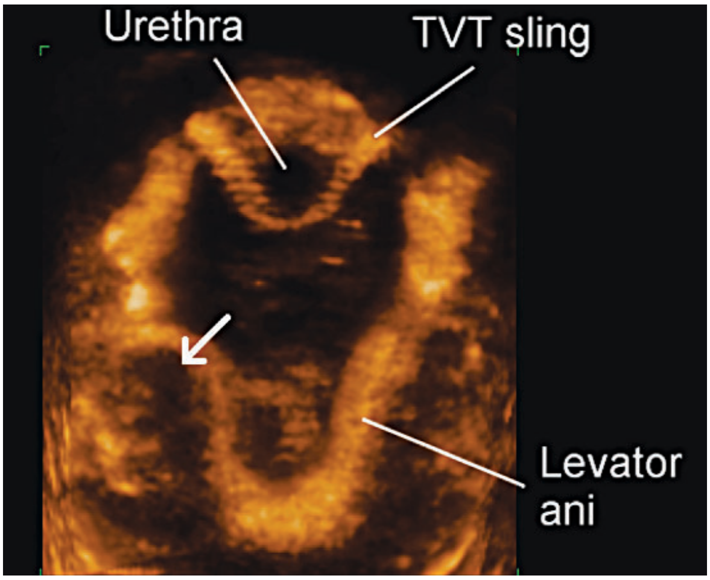


Figure 40. The TVT as imaged on an oblique rendered volume of the levator hiatus. The mesh structure of the tape is clearly visible. There is also a local abnormality of the levator on the patient's right (left side of the image, arrow).

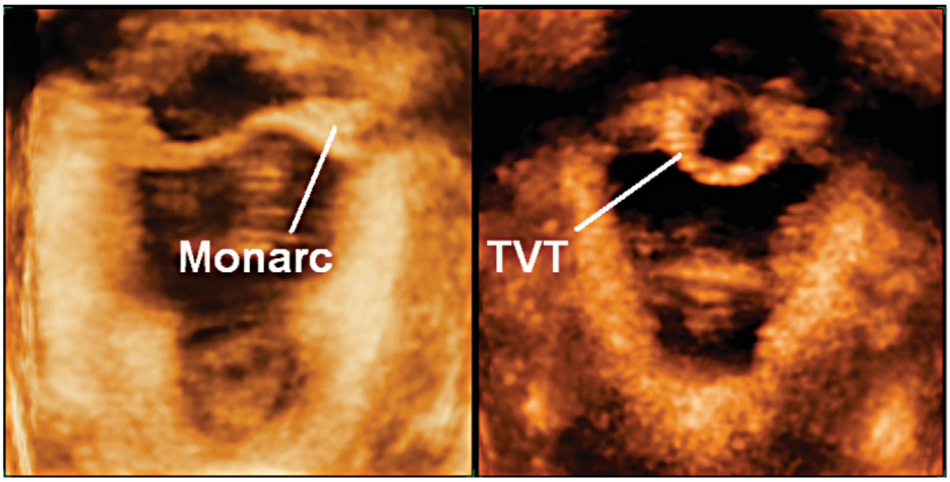


Figure 41. Monarc sling (left) vs. TVT sling in rendered volumes of the levator hiatus. The difference in placement is obvious: the Monarc sling is inserted through the obturator foramen, the TVT through the space of Retzius. As a result the latter is situated much more medially.

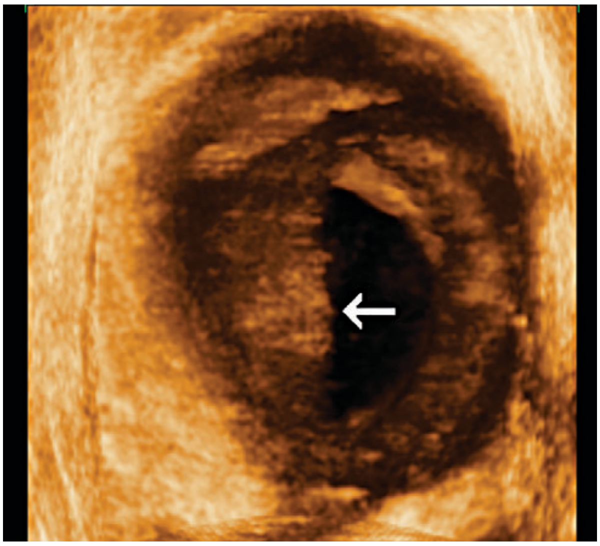


Figure 42. Recurrent cystocele after mesh detachment on the left. Rendered volume, seen from below (caudocranial rendering). The edge of the mesh is clearly apparent close to the midline (arrow).

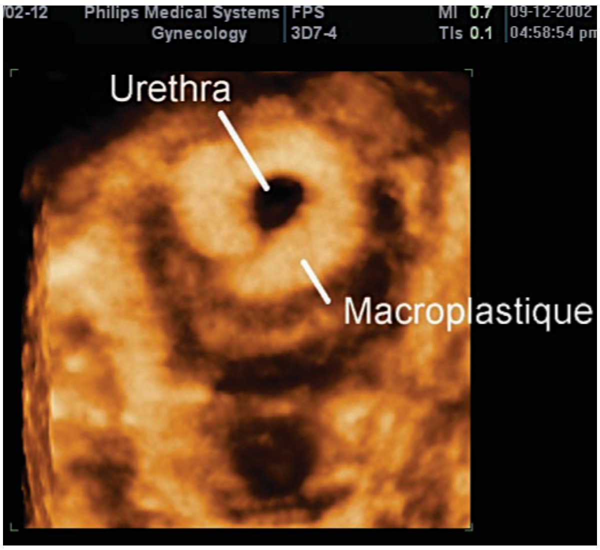


Figure 43. Macroplastique injectable in optimal position around the urethra as demonstrated in a rendered axial volume.

are not uncommon [110-111]. While there are no publications on the imaging of mesh by 3D ultrasound as yet, the new method will be useful in determining functional outcome and location of such implants (see **Figure 42**). Finally, most of the injectables used in anti- incontinence surgery are also highly echogenic and can be visualized surrounding the urethra (see **Figure 43**).

h) Conclusions

Ultrasound imaging, and in particular translabial or transperineal ultrasound, is in the process of becoming a standard diagnostic method in urogynaecology. 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 enhance our understanding of the different mechanisms by which conservative methods, colposuspension or urethropexy procedures, slings and (most recently) the suburethral tapes achieve -or fail to achieve- continence. It may even be possible to identify distinct fascial defects (such as defects of the rectovaginal septum in true rectoceles) which should enable new surgical approaches.

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 research on the aetiology of pelvic floor and bladder dysfunction.

On the other hand, there is no doubt that childbirth can cause significant alterations of pelvic organ support and levator function. It is also possible that pelvic floor ultrasound will help 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.

3D volume ultrasound opens up entirely new possibilities for observing functional anatomy and examining muscular and fascial structures of the pelvic floor. Data acquisition will be simplified and research capabilities enhanced, and surgical audit in this field is likely to undergo significant change.

There is currently no evidence to prove that the use of modern imaging techniques improves patient outcomes in pelvic floor medicine. However, this limitation is true for many diagnostic modalities in clinical medicine. Due to methodological problems, this situation is unlikely to improve soon. In the meantime, it has to be recognized that any diagnostic method is only as good as the operator using it, and diagnostic ultrasound is well known for its operator-dependent nature. Teaching is therefore of paramount importance to ensure that imaging techniques are used appropriately and effectively.

SUMMARY

- Ultrasound is widely used for diagnostic imaging in women with incontinence and prolapse as well as after reconstructive pelvic floor surgery.
- Due to ease of use, wide availability and absence of adverse effects, it is currently the most convenient imaging method available.
- Translabial, transvaginal and transrectal approaches have been used, with the former having found most widespread application due to its noninvasiveness and the relative absence of tissue distortion.
- The most commonly used transducer types are electronic curved array transducers of 3.5- 5 MHz frequency and a footprint of 4-8 cm. Higher footprints are preferable to allow simultaneous imaging of all three compartments. 3D transducers should provide acquisi-tion angles of 70 degrees or more to allow imaging of the full lateral extent of the levator hiatus.
- Imaging conditions (i.e., bladder filling, patient position) and equipment used (eg route and transducer type) should be specified when reporting examinations.
- For hygienic reasons, transducers should be covered with plastic wrapping or nonpowdered gloves and disinfected between uses.
- Pelvic floor imaging by ultrasound allows determination of position and mobility of pelvic organs on coughing/ Valsalva to assess urinary incontinence and prolapse. Quantification of descent can

be undertaken either as documenting the most distal position occupied by an organ on maximal Valsalva, or as documenting the difference between position at rest and the most distal position reached on Valsalva. Urethral rotation can be measured by comparing inclination angles at rest and on Valsalva. Retrovesical angles are obtained at rest and on Valsalva. Funnelling is diagnosed if opening of the proximal urethra is documented on Valsalva. Quantification of organ position or angles is undertaken in a coordinate system formed by either

- lines parallel and vertical to the transducer axis, intersecting in the inferoposterior margin of the symphysis pubis, or
- the central axis of the symphysis pubis and a line vertical to this axis.

• Ultrasound imaging for bladder neck descent, funneling and urine leakage correlates well with radiological findings on fluoroscopy and cysturethrography.

• Assessment of maximal pelvic organ descent by translabial ultrasound correlates well with ICS POP-Q assessment.

• Concomitant levator activation is a major confounder for quantification of descent, especially in nulliparous women, and should be avoided. It can be recognized either as a movement of the prepubic fat pad or as narrowing of the levator hiatus on attempted Valsalva.

• Pelvic floor ultrasound can be used to assess levator function and provide visual biofeedback for teaching. Ultrasound data on levator function correlates well with perineometry and digital assessment.

• Translabial Color Doppler can be employed to demonstrate stress urinary incontinence per urethram. Both CDV and CDE (Power Doppler) imaging are suitable. Settings should be adjusted to allow detection of venous flow and avoid flash artefact.

• Ultrasound is the imaging method of choice for the identification of suburethral slings and other echogenic implants.

3D Ultrasound now allows access to structures in the axial plane such as paraurethral/ paravaginal supports and the levator ani. Its use in women with incontinence and prolapse currently remains limited to research settings.

RECOMMANDATION

• Ultrasound is not recommended in the primary evaluation of patients with urinary incontinence and/or pelvic organ prolapse (rectal prolapse is dealt with in a different section). **[Level of evidence 3, Grade of recommendation C]**

• Ultasound is an optional test in the evaluation of patients with complex or recurrent urinary incontinence and/or pelvic organ prolapse. **[Level of evidence 3, Grade of recommendation C]**

SUGGESTED RESEARCH AREAS

• Role of pelvic floor imaging in the evaluation of female urinary incontinence

• Standardisation of US imaging in incontinence Relation of ultrasound imaging to bladder neck function

• Relation of ultrasound imaging to treatment outcome

• New technologic developments

• Need for proper training and full understanding of methodology

III. MRI OF PELVIC FLOOR

The rationale for the use of MR imaging in the evaluation of urinary incontinence and pelvic floor dysfunction derives from the observation that although patients might present with symptoms isolated to one of the pelvic compartments, they may have concomitant defects in other compartments [1]. Furthermore, surgical failures could result from lack of a thorough preoperative evaluation of the female pelvis and to inadequate diagnosis and staging of pelvic floor dysfunction [2], accurate diagnosis of the coexisting abnormalities is essential in planning reconstructive and anti-incontinence procedures. Although most diagnoses of pelvic floor prolapse are made on detailed physical exam, some studies have alluded to the poor sensitivity and specificity of the pelvic exam in diagnosing various forms of pelvic floor prolapse [3-5]. Ultrasound and fluoroscopy have been used to improve diagnosis of certain aspects of pelvic floor dysfunction [6,7] and the role of MRI in pelvic floor dysfunction is rapidly changing and new developments may become clinical mainstays if they can demonstrate improved outcome.

MRI provides anatomical detail to the pelvic floor including assessment of bladder neck and urethral mobility, rectocele, cystocele, enterocele and uterine prolapse, in a single non-invasive study that does not expose the patient to ionizing radiation [8-17]. MR imaging also provides a multiplanar thorough evaluation of the pelvic contents including the uterus, ovaries, ureters, kidneys, and levator muscles, as well as the urethra, that is unavailable by any other imaging modality [10,12-16,18,19]. MRI provides useful information regarding ureteral obstruction, hydronephrosis, and uterine and ovarian pathology, which is essential in the management of women with pelvic floor disorders. In addition, at this time, MRI is the study of choice for the evaluation of urethral diverticuli.

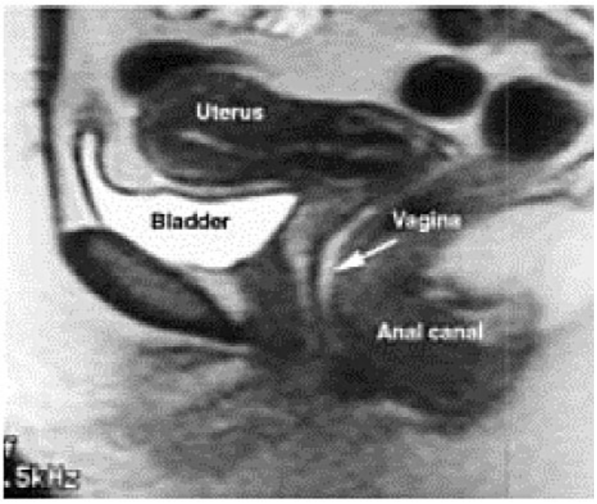


Figure 44. Female pelvic floor MRI: sagittal view

1. Methodology

a) Conventional MRI:

Standard MRI consists of two dimensional image acquisitions. Usually conventional T1 images and spin echo T2 weighted images are obtained. These static images provide good information on patient anatomy and pathological abnormalities but the long imaging time of conventional MRI hampers its ability to evaluate pelvic organ prolapse and pelvic relaxation. The muscular anatomy of the pelvic floor, as well as the anatomy of the pelvic organs can be visualized with the use of a body coil. The use of an endovaginal coil provides superior information regarding the zonal anatomy of the urethra but it can result in deformity of the normal anatomy [20-21].

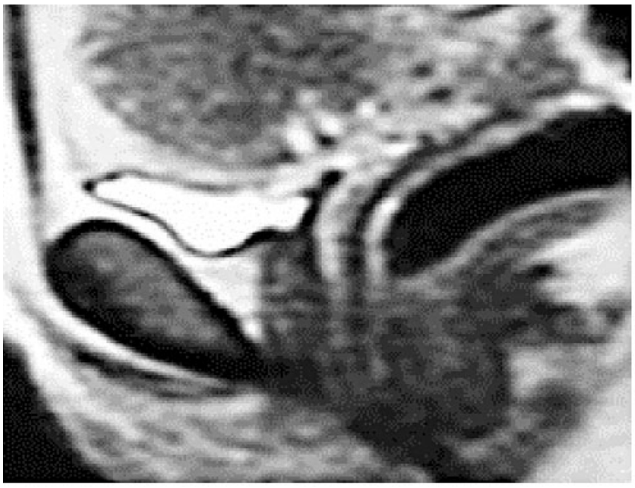
b) Ultra fast image acquisition and MR sequences

Very fast single-shot MR sequences have been developed for the evaluation of pelvic prolapse allowing excellent visualization of the pelvic floor in women [14,15,22-23]. These sequences allow a series of 1-second breath hold images to be obtained, either by obtaining a series of images covering the entire pelvis (static imaging) or repetitively in one plane while the patient is straining (dynamic imaging). The patients are placed in the supine position with legs slightly spread apart, and knees bent and supported by a pillow. There is no need for bowel preparation, premedication, instrumentation or contrast medium. The MRI torso coil is centered at the symphysis pubis. Images are acquired in the sagittal plane using single-shot fast spin echo (SSFSE) or half Fourier acquisition, single shot turbo spin echo (HASTE) sequences. Single, mid sagittal views are obtained during 3 seconds of apnoea with the patient relaxed and during various degrees of progressive abdominal straining. The total MR room time is approximately 10-15 minutes.

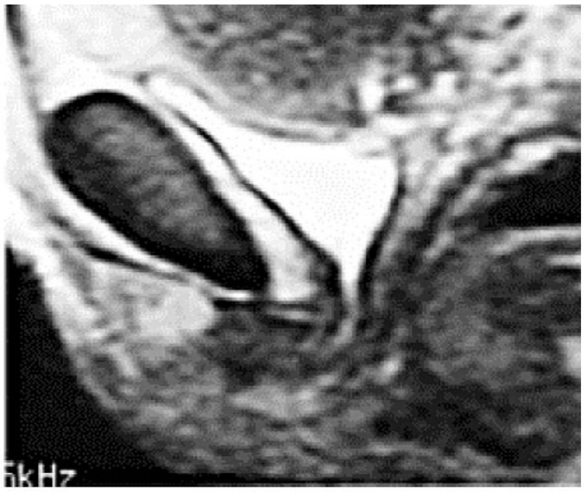
Two sets of images are obtained. The first set consists of static sagittal and para-sagittal images covering the pelvis from left to right sidewall. These images provide information on pelvic anatomy, pathological abnormalities, and are used to select the mid-sagittal plane for the dynamic second set of images. This static sequence also allows for anatomic delineation of the pelvic sidewalls and muscular and fascial components of the pelvic floor [14, 15, 22-23] (**Figure 44**). The urogenital diaphragm and the levator ani musculature, as well as the anal sphincter anatomy, are also clearly demonstrated (24-25).

The static set consists of 17-20 sequential images independently acquired in a total of about 18 seconds. Static images can be acquired with a SSFSE pulse sequence using 128 x 256 matrix with repetition time (TR) of 4000 ms, echo time (TE) of 22.5 ms, 5 mm slice thickness and field of view (FOV) of 28 cm [15]. Other similar sequences have been described.

The second set of images consists of relaxed and straining mid-sagittal images used to assess the degree of pelvic floor relaxation and organ prolapse (**Figure 45 a,b**). One series [15, 23] describes the SSFSE parameters as 128 x 256 matrix, TR=3000ms, TE=90ms, FOV=28cm and 5 mm slice thickness. Variations in these parameters have been described and thus the image acquisition sequences have are not standardized yet. Images can then be looped for viewing on a digital station as a cine stack.



a)



b)

Figure 45. a) Pelvic floor MRI: mid sagittal image: relaxed and b) pelvic floor MRI: mid sagittal view on straining

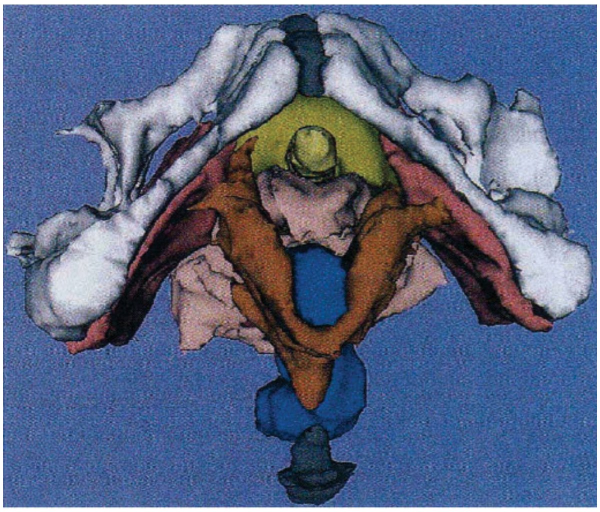


Figure 46. Pelvic organs as seen from caudal on a three-dimensional reconstruction from Magnetic resonance images. Copyright Mosby Inc.

c) Three dimensional MRI

Three dimensional (3-D) MRI provides great detail of the bony and muscular pelvic structures (**Figure 46**). In this technique, static or dynamic images are reconstructed using consecutive planes in the axial, sagittal and coronal dimensions. Anatomic variations of the insertion and path of the pubococcygeus and iliococcygeus muscles can be easily seen. Fielding et al. studied nulliparous continent female volunteers and found that the muscle morphology, signal intensity and volume are relatively uniform [28]. They described an average volume of the levator ani of 46.6 cc, width of the levator hiatus of 41.7 mm and an average posterior urethrovesical angle of 143.5°.

A large range of motion of the pelvic floor is seen in younger women as compared to older women. In multiparous and older women the width of the levator hiatus is enlarged. This is due to the central separation of the levator musculature allowing decensus of the pelvic floor and the pelvic organs. These structures play a role on urethral support, hopefully understanding the normal anatomy as well as changes seen on the levators and pelvic floor musculature will shed light on the etiology and possible treatment of urinary incontinence. A possible disadvantage of 3-D MRI its the relatively long time needed to obtain the three dimensional reconstructions. A further discussion of 3-D MRI reconstructions is provided below under the evaluation of pelvic organ prolapse.

2. Normal pelvic floor support [Levator Ani Muscle] support

Static, dynamic and three-dimensional MRI studies of normal subjects have improved our understanding of normal pelvic anatomy [28-30]. The use of MRI to image the pelvic floor musculature has also contributed greatly to our understanding of pelvic floor dysfunction [19, 21, 31]. MR imaging has been used to study the normal female pelvic anatomy, as well as the anatomy of the aging female and the symptomatic patient. It has been shown that in the supine position the female pelvic floor is dome shaped at rest [31-32]. During voluntary pelvic floor contractions the levator musculature straightens and becomes more horizontal. With bearing down the muscle descends, the pelvic floor becomes basin-shaped, and the width of the genital hiatus widens. A limitation of

MRI in the evaluation of the female pelvis is that the studies are usually done with the patients supine. Upright dynamic MRI exists mostly as a research tool and is not widely available. Recently, Bø et al [33] evaluated the changes seen with pelvic floor contraction in continent and incontinent women using MRI in an upright sitting position. Although there was no statistical difference between the two groups, the authors demonstrated an inward movement with pelvic floor contraction (average 10.8 mm) and an outward movement with straining (average 19.1 mm). This was also reflected in the bladder neck. Interestingly, the coccyx appeared to move in the cranial direction with contraction and caudally with straining. Further consideration of this issue specifically related to pelvic organ prolapse below

3. MRI AND THE STRESS CONTINENCE MECHANISM

a) Evaluation of SUI etiology

MRI has proven useful in demonstrating the soft tissues of the urethra, levator ani, and fascial tissues involved in urinary continence mechanism. As far as issues of urethral support are concerned, sagittal images obtained with the patient at rest usually show the urethra to be vertical in orientation. In patients with urethral hypermobility, with increased abdominal pressure, the proximal urethra moves inferiorly and the axis of the urethra becomes horizontal (**Figure 47**) [34]. In normal patients the urethral angle is usually greater than 30° and the urethrovesical angle greater than 115°. Tunn et al. [24] evaluated women with stress incontinence and compared them to

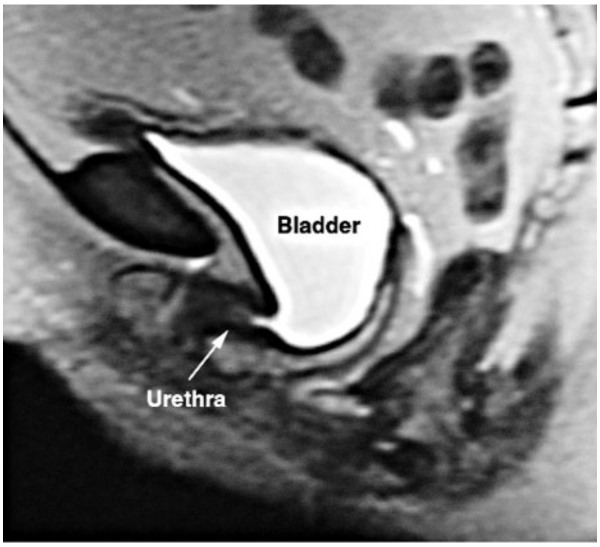


Figure 47. Ultrafast MRI of pelvic floor during Valsalva

controls. They found higher intensity of the levator musculature and loss of the hammock-like configuration of the anterior vaginal wall in patients with incontinence. A possible source of bias is that MRI is performed with the patient supine and that the lack of gravitational force might affect the observed anatomy. This appears to be only a theoretical problem when evaluating patient with urethral hypermobility since both the descent of the bladder neck and the posterior urethrovesical angle do not seem to be affected by the MRI being performed in the sitting versus supine position [35].

More recent studies have shown how specific populations can be studied and the results quantified. Beyersdorff [56] studied ten healthy control subjects and 38 patients with Stage II urinary incontinence. They found that 22 of the 38 incontinent women had morphologic abnormalities seen on MR images. These included 14 individuals with lateral defects where the musculo-fascial connection between the levator and the lateral wall were found to be damaged; 16 individuals in whom the urethra appeared abnormal. Eight cases showed levator ani muscle defect. Unterweger [58] studied ten women with stress incontinence and compared them with equal numbers of nulliparous, primiparous, and women with cesarean section delivery using Ultrafast T2-weighted-shot fast spin echo sequences. They quantified the anatomy of the bladder and vesical neck. The mean distance between the bladder base and pubococcygeal muscle line did not differ at rest but on straining, bladder descent was greater in the stress incontinent group (3.2 ± 1.0 cm) when compared with any of the other groups (nulliparous 1.1 ± 0.9, cesarean section only 1.0 ± 1.1, 1.9 ± 0.9 in the parous continent individuals) $p = 0.002$. deSouza [50] used high resolution magnetic resonance images to compare 11 continent women with ten stress incontinent women using an endovaginal coil. They looked at the "paravaginal fascial volume" as well as the retropubic length of the urethra. The Authors found that the urethral paravaginal fascial volume was smaller in urodynamic stress incontinent women (3.5 cm q ± 2.0) compared with continent ones (5.3 cm q ± 0.6) ($p = 0.02$).

The retropubic urethral length was also shorter in these individuals. In a larger and more recent study, Stocker [48] evaluated 20 women with stress incontinence and compared them with 20 age-matched healthy volunteers. Endovaginal coils were also used in this study. They found that lesions of the urethral support system and levator were significantly more prevalent in cases that controls ($p \leq 0.01$). In particular, medial levator ani thickness in patients was 2.5 mm compared with 3.9 mm in control women. Kim [49] who carried out an evaluation of several different elements of the continence mechanism in 63 stress incontinent women comparing them with 16 continent women found that the striated muscle layer of the urethra was thinner in stress incontinent women than normal controls (1.9 ± 0.5 mm vs. 2.6 ± 0.4 mm, $p \leq 0.001$). Asymmetry in the pubovisceral part of the levator ani muscle was more common in stress incontinent women (29%) compared with the continent controls (0%). There was also felt to be subjective distortion of the periurethral ligaments in 56% stress incontinent women compared with 13 of the normal continent women.

The possibility of increased or decreased risk of stress incontinence in different ethnic groups has been investigated. Howard [59] studied 18 nulliparous black women compared them with 17 nulliparous white women. This showed a 21% larger urethral volume in African American than in Caucasian women that also correlated with a 29% higher average urethral closure pressure among African American women.

b) Zonal anatomy of the urethra

MRI has been successfully used to show the zonal anatomy of the urethra as well as the components of the intrinsic sphincter unit. **Figure 48** shows a coronal view of the urethra on a static MRI obtained with a vaginal coil. The anatomy of the urethra is clearly demonstrated. The lumen, spongy tissue and fibromuscular envelope are easily seen and correspond to the structures seen in urethral histology studies [64]. A sagittal view of the urethral wall is seen in **Figure 49**. Future potential for detailed analysis of specific regions in the urethra was recently demonstrated by Umek [65] who showed the possibility of identifying location of different bladder neck structures in a group of 78 asymptomatic healthy nulliparous women. They found that the locations of different urethral structures could be adequately documented in preparation for future research in comparing continent groups (**Figure 50**).

c) MRI Evaluation of Stress Incontinence Treatment

Bombieri [52] developed a technique whereby MRI was used to look at elevation of the vesical neck and correlated with measurements made in the operating room with a ruler. These two techniques were found to be reliable. These techniques were then used to evaluate voiding dysfunction that patients may develop after colposuspension. Delayed day of first voiding after catheter removal in this study was found to be related to changes in preoperative flow rate and straining during voiding as well as increasing age. The elevation that occurred during the operation and approximation between the urethra and pubic bone also were correlated with delayed voiding. These factors were associated with detrusor overactivity found at three months. In a subsequent study, the same group evaluated MRI in intraoperative measurements and their ability to predict successive stress incontinence surgery. However, there were no associations found between continence outcome and postoperative bladder neck position and elevation in the 73 patients studied. In another study of stress incontinence [51], vesical neck was seen to be elevated by a mean of 9.4 mm by the operation when postoperative and preoperative evaluation were compared and the posterior urethral vesical angle was increased by an average of 127.8 degrees.

These studies repeat the type of information obtained with cystourethrogram and will be expanded to include analysis of the actual structures themselves (vesical neck, levator ani muscles, sphincters) in the future and their ability to predict operative outcome and treatment complications.

4. Pelvic Organ Proplase

a) MRI of the pelvic floor relative to prolapse

The pathophysiological issues of stress urinary incontinence and pelvic organ prolapse are inextricably linked. Pelvic organ prolapse is a problem that arises from damage to connective tissue, muscles, and nerves that are invisible on standard radiography, and it is only with the advent of ultrasound and especially MRI, that the actual structures involved in the cause of prolapse can be seen and examined. This is possible not only in static scans that reveal morphological details of the pelvic structure, but also in dynamic scans where the movements of the various organs can be studied.

b) MRI definition of the pelvic floor

MRI in pelvic organ prolapse requires that the specific structure involved are identified and their normal variations described. Tan [66] demonstrated that the anatomy of the female pelvic floor with endovaginal magnetic resonance (MR) imaging. Ten healthy nulliparous volunteers (age, 22-26 years) underwent MR imaging with an endovaginal coil. Pelvic floor structures such as the pelvic diaphragm and the uro-

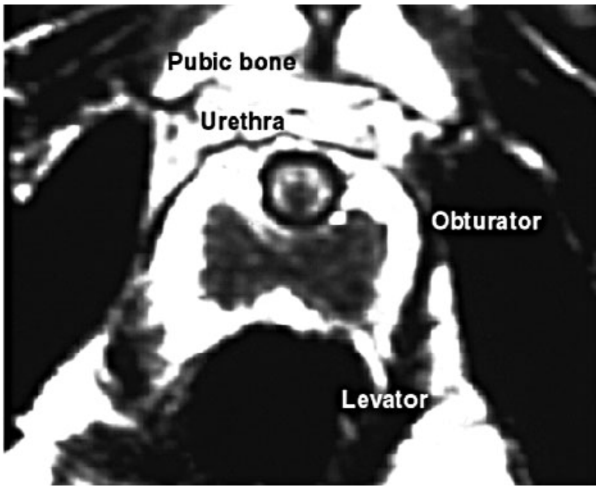


Figure 48. MRI by vaginal coil . Zonal anatomy of the urethra

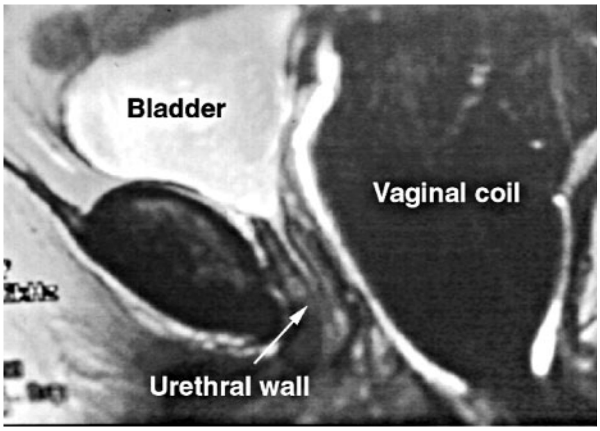


Figure 49. MRI by vaginal coil . Sagittal view

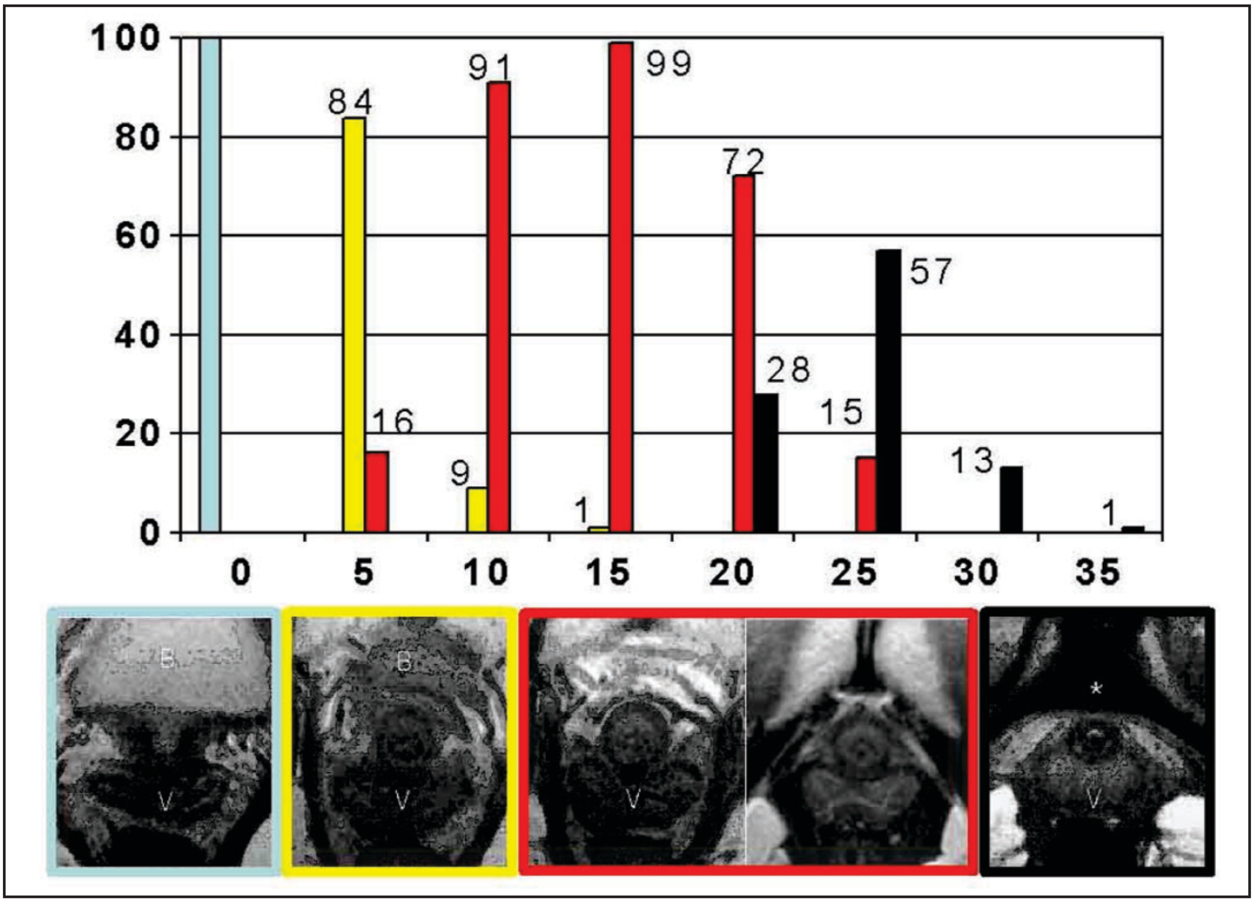


Figure 50. Typical appearances of urethral morphology from bladder base (left) to distal urethra (right) and their percent distribution. X-axis indicates distance from bladder base in millimeters, Y-axis represents percent of total with a given morphologic appearance. Copyright DeLancey.

genital diaphragm were well depicted as were urethral supporting structures—the periurethral and paraurethral ligaments—were visualized. The zonal anatomy of the urethra was clearly visible. The endovaginal MR imaging findings in the volunteers correlated with the endovaginal MR findings and gross anatomy in the cadavers. Chou [67] developed a systematic method for analyzing the normal magnetic resonance imaging location and appearance of structural features involved in urethral support. Multiplanar proton density magnetic resonance images of 50 nulliparous women were made at 0.5-cm intervals. This allowed the presence or absence of urethral support structures in each scan level relative to the arcuate pubic ligament to be evaluated and recorded as the percent likelihood that the structure is seen at that level. Support structures examined included the arcus tendineus fasciae pelvis, the perineal membrane, the pubococcygeal levator ani muscle and its vaginal and bony attachments, and the pubovesical muscle. This systematic magnetic resonance evaluation allows quantification of the normal anatomic location of urethral support structures.

Hoyte [57] studied two- and 3-dimensional MRI comparison of levator ani structure, volume, and integrity in women with stress incontinence and prolapse to identify imaging markers for urodynamic stress incontinence and pelvic organ prolapse by using MRI and reconstructed 3-dimensional models. Thirty women were examined; 10 with prolapse, 10 with urodynamic stress incontinence, and 10 asymptomatic volunteers. Manual segmentation and surface modelling was applied to build 3-dimensional models of the organs. Mean 3-dimensional parameters in the 3 groups showed levator volumes of 32.2, 23.3, and 18.4 cm ($P < 0.005$); hiatus widths of 25.7, 34.7, and 40.3 mm ($P < 0.005$); left levator sling muscle gaps of 15.6, 20.3, and 23.8 mm ($P = 0.03$), right levator sling muscle gaps of 15.6, 22.5, and 30.8 mm, ($P = .003$), and levator shape (90%, 40%, and 20% dome shaped; $P < 0.005$). This studies show that MRI can be used to demonstrate both 2-dimensional magnetic resonance images and 3-dimensional models yield findings that differ among asymptomatic subjects compared with those with urodynamic stress incontinence and prolapse.

Tunn [68] addressed the topic of anatomical variation in the normal pelvic floor. They developed a system to quantify inter-individual variation in the appearance of continence system structures in 20 healthy continent nulliparous women (mean age, 30.1 +/- 5.1 years) with normal pelvic organ support

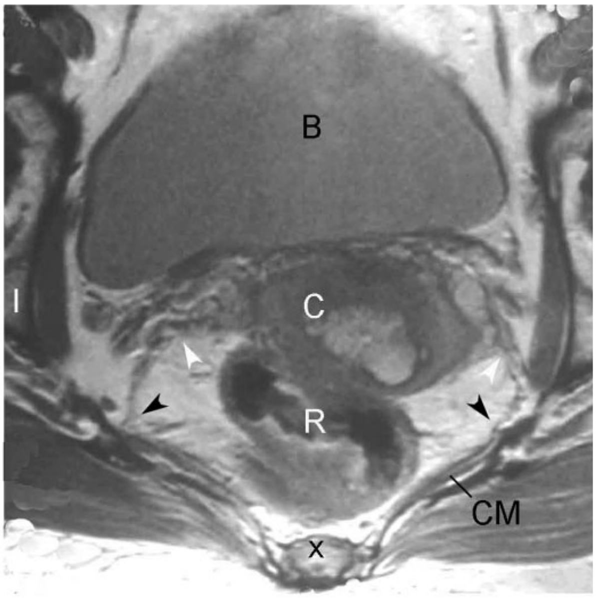


Figure 51: Uterosacral ligaments on MRI; points of origin from the genital tract (white arrowheads) and insertions to the pelvic sidewall (black arrowheads), bladder (B), cervix (C), rectum (R), coccyx (X), ischial spine (I), and coccygeus muscle (CM) are shown. Copyright DeLancey.

and urodynamics. The ratio of the maximum-to-minimum measured values shows that 2- to 3-fold differences occur in distance, area, or volume measures of continence system morphologic features that are detailed in the paper. Umek [76] found that in 80 healthy women, the uterosacral ligaments exhibited greater anatomic variation than their name would imply (**Figure 51**).

MRI has also been used to compare the pelvic size in individuals with and without pelvic organ prolapse [71]. Fifty-nine women with pelvic floor disorders were compared with 39 women without pelvic floor disorders. After controlling statistically for age, race, and parity, a wider transverse diameter (odds ratio 3.4) than a shorter obstetrical conjugate (odds ratio 0.2) were found to be associated with pelvic floor dysfunction.

c) MRI of pelvic floor after vaginal delivery

Vaginal birth increases the likelihood that a woman will develop pelvic organ prolapse by 8 fold after 2 deliveries and 12 fold after 4 [72]. There are modifications observed in the levator ani and pelvic floor musculature immediately after delivery which appear to change over time. Tunn evaluated patients on postpartum day 1 and compared the MRI images to those obtained at 1, 2, and 6 weeks and 6 months after delivery [25]. The authors evaluated levator muscle signal intensity, muscle topography, muscle thickness and pelvic floor descent. There was increased muscle signal intensity on T2 weighted images at 1 day postpartum but the signal intensity approached normal by 6 months. The area of the urogenital and levator hiatus decreased significantly by 2 weeks postpartum. There was no statistically significant difference seen in muscle thickness over time.

More recent studies have added further information to these investigations. Lienemann [60] studied 26 primiparous women after vaginal delivery and had a control group of 41 healthy asymptomatic nulliparous volunteers. They found thinning of the puborectal muscle in the study group (0.6 cm vs. 0.8 cm) and increased descent of the bladder, vaginal fornix, and anorectal junction in the study group during straining. In a study that evaluated changes in the levator ani group among primiparous women, DeLancey [73] studied 80 nulliparous asymptomatic women, 160 vaginally primiparous women half of whom had new stress incontinence after their first birth. A visible defects in the levator ani muscle was identified in 32 primiparous.

Twenty-nine of these 32 defects were in the pubovisceral portion of the levator and three were in the iliococcygeal portion. Both unilateral and bilateral defects were found. None of the nulliparous women showed these abnormalities. If we consider the possible link between pelvic organ prolapse and birth injury to the levator ani muscles, then obstetrical factors that are associated with pelvic organ prolapse can be investigated soon enough after birth that good records are available concerning birth parameters. Reduction of vaginal birth injury by 50% would save 60,000 women a year from developing this condition as approximately 85% of women have this risk factor.

d) MRI for identifying Types of Prolapse

• Enterocele

Enterocele can be seen during MRI [70]. In the past they were usually only appreciated on radiographic examination after repeated straining after evacuation and usually required opacification of the vagina in order to demonstrate the insinuation of small bowel loops between the rectum and vagina [39]. MRI has proven to be a much simpler and less invasive technique for the evaluation of enteroceles. Gousse et al. compared physical examination, intraoperative findings and MR images in women with and without prolapse [15].

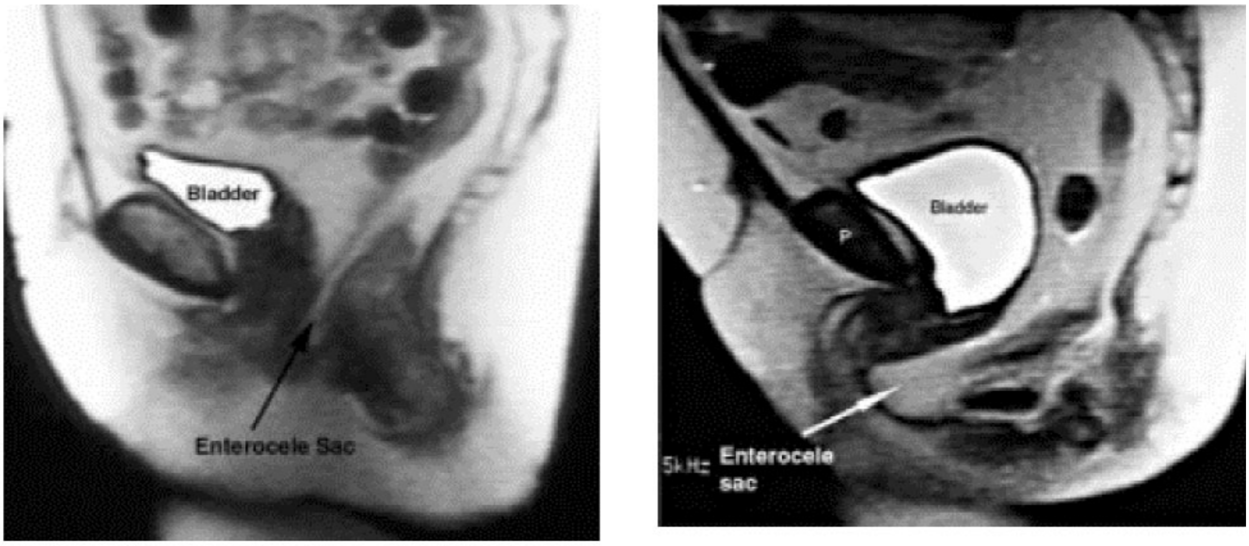
The investigators found that when compared to intraoperative findings, MRI had a sensitivity of 87%, specificity of 80%, and positive predictive value of 91%. MRI was significantly superior in detecting enterocele when compared to physical examinations. The images are obtained with the patient supine in the relaxed and straining state (**Figure 52 a. b**). Neither instrumentation nor invasive procedures are required. Similarly, Lienemann et al., using MRI with opacification of organs, showed that MRI had a much higher sensitivity for detection of enteroceles when compared to physical exam and dynamic cystoproctography [40]. Whether or not this technique alters clinical outcome remains to be seen.

e) Cystocele

High-grade cystoceles, as other forms of prolapse, usually do not occur in isolation and represent a spectrum of pelvic floor dysfunction [1, 3, 14]. When a large vaginal mass is present differentiating between a high-grade cystocele, an enterocele, vaginal vault prolapse or high rectocele by physical examination alone can be challenging for those inexperienced with physical examination of prolapse [3-5]. Gousse et al found that, repair of only the cystocele without attention to the rest of the pelvic floor predisposes patients not only to increased incidence of urinary incontinence, but also to an increased incidence of enterocele, rectocele, and/or uterine prolapse postoperatively [15]. In the same study, MRI had a sensitivity of 100%, specificity of 83%, and positive predictive value of 97% when evaluating for cystocele compared to intraoperative findings. In addition, urethral hypermobility and post-void urine residual can be documented, as well as evaluation of ureteral obstruction and other pelvic abnormalities. Gousse et al. also found that MRI was able to diagnose other type of pelvic pathology besides prolapse in 55 of 100 patients studied, including 3 with bilateral hydroureteronephrosis. **Figures 53** a, b show an MRI of two patients with grade 2 and 3 cystocele, respectively.

• Rectocele

Rectoceles have been considered to exist in up to 80% of asymptomatic patients with pelvic floor dysfunction [13]. The diagnosis is usually made by physical exam, the reported sensitivity of pelvic examination for diagnosis of rectocele ranges from 31% to 80% [3-4, 6, 41-42]. This is usually secondary to organ competition for space in the vagina when accompanied by other significant prolapse [7]. In addition, it is often difficult to reliably distinguish an



a) b)

Figure 52. Pelvic floor MRI: enterocele at rest a) and during Valsalva b)

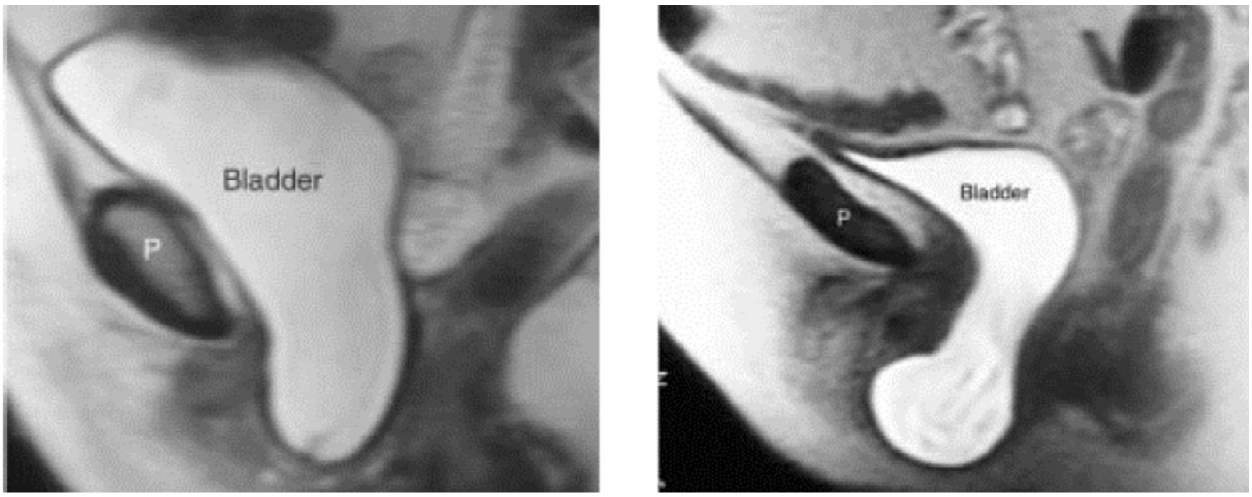


Figure 53. Pelvic floor MRI: grade 2 (a) and grade 3 (b) cystocele

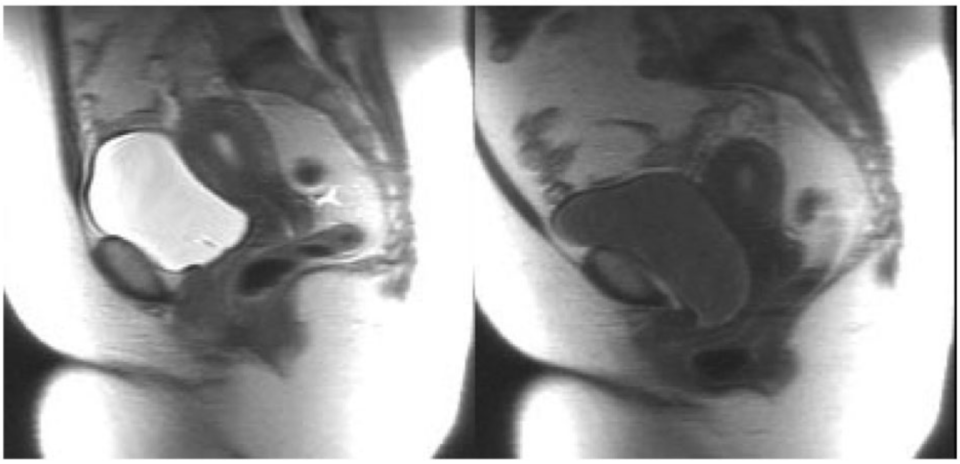


Figure 54: Resting (a) and straining (b) midline sagittal section section showing a rectocele that traps intestinal contents.

enterocele from a high rectocele. **Figure 54** shows a rectocele diagnosed by dynamic MRI. A rectocele is easily seen when filled with gas, fluid, or gel. Although highly specific, when no rectal or vaginal opacification is used, MRI can miss up to 24% or rectoceles [15]. When rectal opacification is used during MRI, a correct diagnosis of rectocele can made in 100% of patients studied when compared to intraoperative findings [18]. It therefore appears that in order to increase MRI's ability to diagnose rectocele, rectal opacification is necessary. This is usually accomplished by introducing sonographic transmission gel or gadolinium into the rectum prior to MRI scanning. What remains unclear is the relationship between anatomical findings and functional problems. The diagnosis of an anatomical abnormality does not mandate surgery. Simply identifying a woman has having a rectocele on an imaging study based on the location of the intestinal lumen to a reference line does not mean that correction of the rectocele will cure defecation problems. Rectocle surgery is not without complications and the risk of dyspareunia after posterior colporrhaphy is real. Attention should be paid to make sure that symptoms are truly depending on stool trapping and the condition must be shown on imaging.

f) Uterine Prolapse

MRI is an excellent modality to demonstrate uterine prolapse (**Figure 55**). In addition to depicting the position of the uterus and adjacent organs, it has the ancillary benefits that evaluates not only uterine size, position, orientation (retroversion) and pathology (fibroids, tumors, Nabothian cysts. etc.), but also ovarian pathology (cyst or mass) which is essential information in determining if a vaginal of abdominal hysterectomy is indicated. In addition, MRI provides

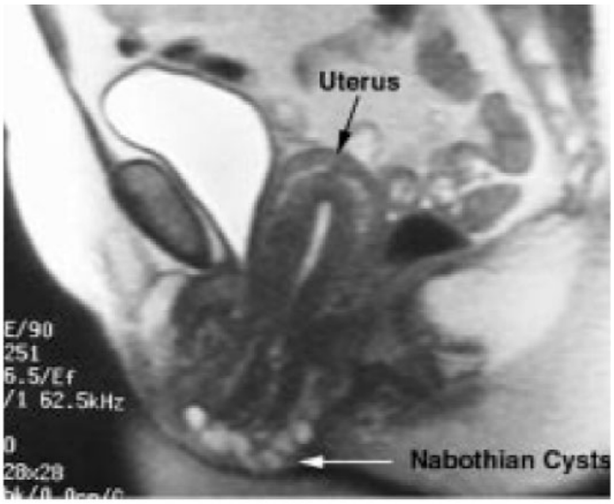


Figure 55. Pelvic floor MRI: hysterocele

information on the presence or absence of cystocele, rectocele, urethral hypermobility and urethral diverticula, and evaluates for ureteral obstruction [9-10, 13-15, 38]. Gousse et al. report a sensitivity of 83%, a specificity of 100% and a positive predictive value of 100% when comparing dynamic MR imaging to intraoperative findings. These numbers were similar when compared to physical examination alone [15]. More importantly, MRI was able to clearly define the other compartments of the pelvic floor and diagnose uterine and/or ovarian disorders in 30 of 100 patients evaluated [15].

g) Grading of pelvic floor relaxation

A number of studies have described reference values for grading of organ prolapse [14-15, 17]. In order to evaluate pelvic organ descent, certain anatomic landmarks are used. The pubococcygeal line (PCL) marks the distance from the pubis to the coccyx and serves as a fixed anatomical reference. In the nomenclature used by Comiter et al. [14], Gousse et al. [15], and Barbaric [23], the width of the levator hiatus is measured as the distance from the pubis to the pubococcygeus muscle (H-line). The hiatus is formed by the puborectalis muscle and encompasses urethra, vagina, and rectum. The M-line depicts the relaxation of the muscular pelvic floor by measuring the descent of the levator plate from the pubococcygeal line. Using these three simple measurements, an MRI classification for degree of organ has been described [14, 23]. In the normal population, during straining, the hiatus (H-line) is less than 6 cm long and does not descend (M-line) more than 2 cm below the PCL line. The upper urethra, urethrovesical junction, bladder, upper vagina, uterus, small bowel, sigmoid colon, mesenteric fat and rectum are all above the H-line. A combination of hiatal enlargement and pelvic floor descent constitutes relaxation. As the pelvic floor descends so do the organs above it. The grading system for prolapse of any pelvic organ is based on 2 cm increments below the H-line. By determining the degree of visceral prolapse beyond the H-line, the degree of rectocele, enterocele, cystocele, and uterine descent can be graded in a 0 to 3 scale as follows: 0=none, 1=minimal, 2=moderate, and 3=severe (**Table 2**). Other similar systems have been described [17] and therefore there is a need for standardization of nomenclature and grading of organ prolapse using MRI.

Singh [69] more recently assessed a new technique of grading pelvic organ prolapse by using dynamic magnetic resonance imaging with the clinical staging proposed by the POP-Q system [74]. In a cross-sec-

Table 2. Grading of hiatal enlargement, pelvic organ prolaspe and pelvic floor dscent using MRI

Grade	Hiatal enlargement	Pelvic Organ Prolapse	Pelvic floor descent
0	Less than 6 cm	Organ above H line	0-2 cm
1	6-8 cm	0-2 cm below H line	2-4 cm
2	8-10 cm	2-4 cm below H line	4-6 cm
3	10 cm or more	4 cm or more below H line 6	cm or more

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tional study, 20 patients with pelvic organ prolapse underwent dynamic magnetic resonance imaging and clinical staging along with 10 women with normal support. A new reference line, the mid-pubic line, was drawn on the magnetic resonance image to correspond to the hymenal ring marker used in the clinical staging. The proposed staging by magnetic resonance imaging showed good correlation with the clinical staging (kappa = 0.61). As this more closely approximates the location of the clinically used hymenal ring, the mid-pubic line was a useful reference line for grading prolapse on magnetic resonance imaging. Torricelli [70] also used magnetic resonance imaging to evaluate functional disorders of female pelvic floor. Healthy volunteers and 30 patients with clinically suspected pelvic floor deficiency, with or without pelvic organ prolapse, were evaluated both at rest and during Valsalva's manoeuvre. In the group of symptomatic women MRI diagnosed. MRI confirmed the pelvic examination findings in all cases; In 7 cases MRI detected additional alterations (4 cases of uterine prolapse and 3 of enterocele) that had been missed at clinical evaluation. Whether or not these would have been noted at the time of surgical repair or not remains to be determined. Deval [61] compared dynamic MR imaging with physical examination as an alternative to dynamic cystoproctography for the evaluation of pelvic floor prolapse. Pubococcygeal line and puborectalis muscle were the references points. The grading system is based on degree of organ prolapse through the hiatus and the degree of pubo-rectalis descent and hiatal enlargement. They also used, the mid pubic line, was drawn on the magnetic resonance image to correspond to the hymeneal ring marker used in clinical staging. Intra-operative findings were considered the gold standard against which physical examination, dynamic colpocystodefecography and MRI were compared. Using these criteria the sensitivity, specificity and positive predictive value of MRI were 70%, 100%, 100% for cystocele; 42%, 81%, 60% for vaginal vault or uterine prolapse; 100%, 83%, 75% for enterocele; 87%, 72% and 66% for rectocele.

h) Comparison with other examinations

In the evaluation of incontinence and simple low-grade cystoceles, the studies of choice are the voiding cystourethrogram (VCUG) and urodynamics. VCUG is useful in determining the severity of cystocele, evaluating for urethral hypermobility and stress urinary incontinence, and documenting post void residual [6]. In addition to the above information, the evaluation of high-grade cystoceles should provide information on concomitant pelvic floor prolapse and presence or absence of urinary retention and ureteral obstruction [9-10, 13-15, 38]. Gufler et al. compared chain cystourethrography with dynamic MRI [38]. The authors found that with pelvic straining the measurements of bladder neck descent, angle of the urethra and the posterior urethrovesical angle, were not significantly different. This was not the case with perineal contraction, where the difference between the measurements was more marked. In the diagnosis of cystocele, MRI had a high degree of correlation to lateral cystourethrography with a Spearman correlation coefficient of 0.95 [38].

Until recently, dynamic contrast roentography and multiphasic fluoroscopic cystocolpoproctography were considered the best radiological studies for detecting organ prolapse. These studies rely on the opacification with contrast material of the bladder, vagina, small bowel, and rectum with all organs opacified together or in phases with each organ opacified individually prior to each straining phase [4, 41. 43-44]. These studies fail to detect up to 20 percent of all enteroceles [38. 44-46]. Therefore, MRI has proven to be a much simpler and less invasive technique for the evaluation of enteroceles. In addition, MRI is able to differentiate the enteroceles according to their contents (small bowel, large bowel, rectosigmoidocele or mesenteric fat). MRI is also an excellent study to differentiate high rectoceles form enteroceles, thus allowing adequate surgical planning and safer planes of dissection [14, 15, 18, 40]. Although a recent study found that multiphasic MRI with opacification of organs and multiphasic fluoroscopic cystocolpoproctography had similar detection rates for enterocele [44], excellent images can be obtained from dynamic MRI without giving the patient oral contrast for opacification of the small bowel or giving rectal contrast. Thus the minimal added information obtained by contrast administration does not seem to warrant the invasiveness of organ opacification at this time [15, 39, 45].

In the evaluation of rectoceles, evacuation proctography has been used to diagnose enterocele, rectoceles, perineal descent and rectal intussusception. Dynamic contrast roentography or fluoroscopic cystocolpoproctography have also been used [4. 41-42, 43-44] to diagnosed rectoceles. The disadvantages of these techniques are the inability to visualize the soft tissue planes comprising the pelvic floor, their invasiveness, and their use of significant levels of ionizing radiation. Without the use of rectal opacification, MRI appears to be a poor choice for the evaluation of rectoceles missing up to 25% of such defects. When rectal opacification is used during MRI, Tunn et al. showed that a correct diagnosis of rectocele can made in 100% of patients studied when compared to intraoperative findings [181]. Other investigators have also shown that triphasic dynamic MRI and triphasic fluoroscopic cystocolpoproctography have similar detection rates for rectocele [44]. Recently, upright dynamic MR defecating proctography has been reported [47]. Although these studies might prove to be more sensitive in detecting anorectal anomalies, their utility seems to be more pronounced in patients with disorders of defecation including anismus, intussusception, and others, and may be too invasive to justify their routine use in the evaluation of rectocele.

In the past pelvic ultrasound has been used for the evaluation of the pelvic organs specially prior to hysterectomy for uterine prolapse. MRI provides excellent information on uterine masses such as fibroids or carcinoma, as well as ovarian cystic (simple or complex) and solid masses. Hydrosalpynx and other abnormalities of the fallopian tubes as well as Nabothian cysts of the cervix and Bartholin's gland cysts are also easily seen. MRI can also be used in the evaluation of endometriosis since size and extent of edometriomas as well as pelvic organ involvement can be easily evaluated.

Recently, Kaufman [62] evaluated dynamic pelvic magnetic resonance imaging and dynamic cystocolpoproctography in the surgical management of females with complex pelvic floor disorders. Twenty-two patients were identified from a Pelvic Floor Disorders Centre database who had symptoms of complex pelvic organ prolapse and underwent dynamic magnetic resonance, dynamic cystocolpoproctography, and subsequent multidisciplinary review and operative repair. Physical examination, dynamic magnetic resonance imaging, and dynamic cystocolpoproctography were concordant for rectocele, enterocele, cystocele, and perineal descent in only 41 percent of patients. Dynamic imaging lead to changes in the initial operative plan in 41 percent of patients. Dynamic magnetic resonance was the only modality that identified levator ani hernias. Dynamic cystocolpoproctography identified sigmoidoceles and internal rectal prolapse more often than physical examination or dynamic magnetic resonance. Whether this type of imaging creates measurably better outcomes remains to be seen.

i) Assessment of treatment for pelvic organ prolapse

Various studies have looked at the anatomic changes seen after surgical procedures in order to better understand how surgical therapies affect pelvic support and structures. Lineman et al. [36] evaluated women after abdominal sacrocolpopexy. The authors found that functional cine MRI identified the exact sacral fixation points after the procedure and easily identified the axis of the vagina and the exact position of the synthetic material used for the repairs. Goodrich et al used MRI to provide a dynamic analysis and evaluation of patients before and after surgical repair to evaluate structures involved in pelvic support [37]. Similar studies will be needed in order to better evaluate the structures important for pelvic support, continence as well as the effects of surgical interventions. These comparisons were further studied by Gufler [75] who studied 15 patients with uterovaginal prolapse and 15 asymptomatic female volunteers comparing preoperative evaluations with those determined two to four months after surgery. Of the seven patients who had symptoms postoperatively, only two had abnormal findings on physical examination but MRI showed pathologic findings in five of the seven patients. Sze [55] used MRI to study vaginal configuration on MR after abdominal sacrocolpopexy and sacrospinous ligament suspension. This study was able to demonstrate the differences in the geometry of these two operations and should prove helpful in establishing outcome variables for different surgical procedures.

j) MR results compared with other forms of evaluation

The relationship between MRI and other investigative techniques has been the subject of investigative efforts of several groups. Twenty-two patients with pelvic floor disorders who underwent MR imaging were compared with dynamic cystocolpoproctography and physical examination. Three studies were concordant in 41% of the patients. Dynamic imaging lead to changes in the initial operative plan in 41% of patients. Magnetic resonance imaging had the unique ability to identify levator ani hernias and the radiographic studies identified sigmoidoceles and internal rectal prolapse. The complimentary nature of these examinations was discussed. MRI examinations have been compared with physical examination, [63]. There was reasonably good correlation between clinical staging and MRI staging (Kappa = 0.61) with the mid pubic line being used as a surrogate for the hymenal ring. In addition, specific features such as the levator-vaginal angle and the area of the genital hiatus could be assessed quantitatively on magnetic resonance images.

Torricelli [70] studied ten healthy volunteers and 30 patients with suspected pelvic floor deficiency with and without pelvic organ prolapse. They compared MR findings with findings on pelvic examination. They found good concordance between physical examination and magnetic resonance imaging with four cases of uterine prolapse and three cases of enterocele seen on MRI that had not been suspected on pelvic examination. Whether these would have been detected at the time of surgery was not discussed. In a study looking at the diagnostic characteristics of pelvic floor imaging, Deval [61] compared intraoperative findings as a gold standard for MRI based diagnosis. Using these criteria, they found that the sensitivity, specificity, and positive predictive value of MRI were 7%, 100%, 100% for cystoceles; 42%, 81%, 60% for vaginal vault or uterine prolapse; 100%, 83%, 75% for enteroceles; 87%, 72%, 66% for rectocele. Although all of these measurements are somewhat subjective, these figures show that it is possible to quantify the individual elements of pelvic floor dysfunction in reasonable parameters.

RECOMMENDATIONS

1. MRI is not [yet] indicated in the evaluation of patients with [uncomplicated primary] urinary incontinence or pelvic organ prolapse**. [Level of evidence 3, Grade of Recommendation C]**

2. MRI should be considered an investigational imaging technique in the evaluation of female urinary incontinence and pelvic floor dysfunction [but information is rapidly growing that may change this before the next international conference]. **[Level of evidence 3, Grade of Recommendation C]**

SUGGESTED RESEARCH AREAS

1. Additional studies comparing MRI of healthy volunteers and patients with urinary incontinence and prolapse are needed to better evaluated the anatomic changes involved in urinary incontinence and pelvic floor prolapse.

2. Serial MRI's of healthy volunteers are needed to better understand the effects of aging in the support structures of the pelvis and the association of these changes to the development of urinary incontinence and/or pelvic organ prolapse.

3. Additional studies evaluating patients before and after surgical correction and comparing anatomic changes of surgery to clinical outcomes are needed to better understand the effects of surgical intervention in the management of women with incontinence and/or pelvic organ prolapse.

4. Serial MRI in pre and postmenopausal women can help evaluate the influence of hormones in the pelvic support structures and the intrinsic structure of the urethra.

5. Studies of MRI with endoluminal coils might help understand the structural relationship between the spongy tissue and the fibromuscular envelope of the female urethra and evaluate their role in the intrinsic function of the urethra.

IV. LOWER URINARY TRACT IMAGING IN POST-PROSTATECTOMY INCONTINENCE

Video-urodynamics is at present the gold standard for evaluating post-prostatectomy urinary incontinence [1-4]. The retrograde urethrogram and cystourethrography (as well as endoscopy) can have a role in identifying the presence of anastomotic strictures and possibly in defining the pathophysiology of urinary incontinence [5]. Presti et al, comparing 24 incontinent patients to 13 continent patients after radical prostatectomy, showed that the appearance of the bladder outlet on voiding cystourethrography was correlated with urodynamic parameters and the presence or absence of incontinence [6]. Tubularisation above the level of the external sphincter was present in continent but absent in incontinent patients. The anatomical configuration of the reconstructed bladder outlet can influence, together with the integrity of the distal urethral sphincteric mechanism and the functional detrusor behaviour, the degree of urinary continence after radical prostatectomy.

Interestingly, the length of membranous urethral measured by MRI on coronal plane seems to be associated with the risk of post-prostatectomy incontinence. A longer membranous urethra appears to be related with a more rapid return to continence. Eighty-nine per cent of patients with a membranous urethral of 12 mm or longer were completely continent 1 year after surgery compared to 77% of those with a lower urethral length. The difference between the two groups was statistically significant (p=0.02 on multivariate analysis) after correction for age and surgical technique. In case these data were confirmed from other groups MR imaging might provided a useful prognostic factor for one of the most scaring complications of radical prostate surgery [7].

RECOMMENDATIONS

- Radiologic evaluation of the lower urinary tract by means of the retrograde urethrogram and voiding cystourethrography (or preferably video-urodynamics) is recommended in cases of persistent postprostatectomy urinary incontinence. (**Level of Evidence 3 – Grade of recommendation C**)

SUGGESTED RESEARCH AREAS

- Correlation between the morphologic appearance of the bladder outlet, functional parameters and clinical status (incontinence or continence) post-prostatectomy.

V. LOWER URINARY TRACT IMAGING IN NEUROGENIC INCONTINENCE

Ultrasound and cystourethrography are important tests of the lower urinary tract in patients with neurogenic dysfunction and urinary incontinence. They can provide information regarding the anatomy of the bladder and urethra, reflux in the upper urinary tract, presence of diverticula, bladder wall thickness, presence of stones, and a reasonable assessment of residual urine. LUT imaging by ultrasound or cystourethrography can be performed as a separate test, but it is better performed at the time of urodynamic study (video-urodynamics) [1]. A recent paper by Sakikabara and co-workers suggest that the combination of post-voiding residual urine >100 ml, detrusor sphincter dyssinergia, open bladder neck at rest, and neurogenic sphincter motor unit potentials are highly suggestive of Muliple System Atrophy and support the use of videourodynamics whenever such a diagnosis is suspected [2]. The use of ice-cooled contrast medium (iced cystourethrography) [3] can be useful in some suprasacral neurogenic patients in order to elicitate detrusor reflex and voiding. Severe bladder trabeculation with diverticula and pseudodiverticula, reflux, wide bladder neck and proximal urethra, and narrowing at the level of the membranous urethra can suggest, mainly in children, the presence of neurogenic dysfunction of the lower urinary tract (occult spinal dysraphism, non-neurogenic neurogenic bladder) even in the absence of neurogenic symptoms and signs [4,5]. In these cases imaging abnormalities indicate the need for urodynamic evaluation, electrophysiological tests and central nervous system imaging.

RECOMMENDATIONS

1. Imaging of the lower urinary tract (preferably by cystourethrography) is recommended in the evaluation of evident or suspect neurogenic urinary incontinence. **(Level of evidence 3, Grade of Recommendation C)**

2. Imaging would be preferably performed simultaneously with urodynamic evaluation (videourodynamics). However, when videourodynamics can not be performed, cystourethrography should be performed as a separate test **(Level of evidence 3, Grade of Recommendation C)**.

SUGGESTED RESEARCH AREAS

- Evaluate the clinical benefit on videourodynamics versus urodynamics and cystourethrograms performed separately in different neurological voiding dysfunction

- Investigate the correlation among LUT, morphology and functional parameters in neurogenic patients.

B3. SPECIAL ISSUES

I. RESIDUAL URINE EVALUATION

Residual urine is defined as “the volume of urine left in the bladder at the end of micturition (ICS definition) [1].

The measurement of postvoid residual urine (PVR) can be performed by invasive and noninvasive means. Invasive means are: in-and-out catheterisation and endoscopy. Noninvasive means are transabdominal ultrasonography and radioisotope studies.

In-and-out catheterization is indicated as the gold standard for the measurement of PVR. Nevertheless the method is subject to inaccuracies, if the person performing the catheterization is not fully instructed as to the procedures and techniques to assure complete emptying (moving the catheter in and out slowly, twisting it, suctioning with syringe, suprapubic pressure), especially in cases of bladder diverticula and vesicoureteric reflux [2]. Stoller and Millard [3] showed inaccuracies in 30% of 515 male patients evaluated by full-time urological nurses with a mean difference between the initial and the actual residual volume of 76 ml in 30 % of inaccurate assessments. After further education of the nurses, inaccurate assessments were reduced to 14% with a mean difference of 85 ml. PVR can be measured at the time of endoscopy, provided there is a blinded insertion of the instrument to avoid irrigation fluid inflow. Both invasive means require local anaesthesia and carry the risk of urethral damage and urinary infection.

Before the era of ultrasonography, PVR was measured non-invasively by the phenolsulfonphthaleine excretion test [4] or with isotopes [5]. Ultrasound is the least invasive method of determining the PVR. There are several methods for its estimation

based on transverse and longitudinal ultrasound bladder imaging. Using either three diameters (length, height, width) or the surface area in the transverse image and the length obtained in the longitudinal image, various volume formulae for a spherical or a ellipsoid body are utilised to estimate the bladder volume (**Table 3**). All five formulae are equally good in assessing residual urine (93.6% concordance). Currently, no single formula can be indicated as the one best volume calculation formula. Several studies report a sufficient accuracy in the ultrasound estimation of PVR [6-12]. False negative results are rare with PVR less than 20 ml [13]. Recently portable scanners were introduced, with automatic measurement of bladdder volume. In a prospective comparison [14] of one hundred measurements of PVR by portable ultrasound with measurements by catheterisation, the mean absolute error of the scanner was 52 ml. For volumes below 200 ml and 100 ml, the error was 36 ml and 24 ml respectively. Residual urine is usually referred as an absolute value, but it can be measured also as a percentage of bladder capacity.

The intra-individual variability of PVR is high from day to day and even within a 24 hour period. This was reported in men with BPH by Birch et al [15] and by Bruskevitz et al [16]. Griffiths et al [17] examined the variability of PVR among 14 geriatric patients (mean age 77 years), measured by ultrasound at three different times of day on each of two visits separated by 2-4 weeks. Within-patient variability was large (SD 128 ml) because of a large systematic variation with time of day, with greatest volumes in early morning. The inherent random variability of the measurement was much smaller (SD 44 ml). Several factors can influence PVR variability: voiding in unfamiliar surroundings, voiding

Table 3. Comparison of different formulae to assess PVR by transabdominal ultrasound in 30 men with BPH scanned three times [15].

Author/reference	Method	Standard error (%)	95% Confidence limits
Hakenberg et al	625 x H x W x (D1+D2)/2	17.5	34.3
Poston et al	7 x H x W x D1	20.0	39.2
Hartnell et al	625 x H x W x D1	17.0	33.3
Rageth and Langer	Nomogram based on areas	15.0	29.4
Orgaz et al	12.56 x H x r	12.9	25.5

Reproduced from the Proceedings of the 4th International Consultation on Benign Prostatic Hyperplasia on command with a partially filled or overfilled bladder, the interval between voiding and the estimation of residual (it should be as short as possible), the presence of vesicoureteric reflux or bladder diverticula. Several studies [18-23] reported the questionable value of PVR as an important outcome prognosticator in male patients with benign prostatic enlargement and benign prostatic obstruction. The cause of PVR is probably mutifactorial, and no consensus exists on the relation of PVR, bladder outlet obstruction and detrusor contractility.

Analysis of elderly patients with urinary incontinence failed to identify any significant association between PVR and any other clinical or urodynamic parameter [24]. Little information is available as to the risk factors of PVR in female patients. A retrospective analysis from Fitzgerald and co-workers suggest a higher incidence of elevated PVR in patients with wet OAB than in those with urgency and frequency without incontinence (10 vs 5%). In patients with urge incontinence, the presence of pelvic organ prolapse ≥stage 2, symptoms of voiding difficulty and absence of stress incontinence symptoms predicited 82% of patients with elevated PVR [25]. A recent paper by Sanders and co-workers addressed the issue of the real need for measuring flow rates and post-void residual urine in women with urinary incontinence. Analysis of 408 women suggest a 4% incidence of PVR of 200 ml or greater and a 6% rate of PVR of 149 ml or greater. The authors calculated that only 1.5% of patients (6 of 408) had their management modified because of the results of free uroflowmetry and PVR measurement. In their opinion, these data do not justify the inclusion of these tests in the "minimal care" programme for assessing primary, uncomplicated, urinary incontinence in female patients [26]

Conclusion

The knowledge as to the pathophysiology of PVR in male and female patients with urinary incontinence is uncomplete, particularly as regards its value as a safety parameter and particularly its relation with upper tract dilation and with bacteriuria and urinary infection. The intra-individual variability of PVR has been investigated mainly in male patients with bladder outlet obstruction but little information is available as to its variability in patients with urinary incontinence.

Ultrasound is the least invasive method and is sufficiently accurate for clinical purposes, yet is the most expensive. In-and-out catheterization is invasive and can be inaccurate even if carefully performed.

The general opinion is that PVR measurement forms an integral part of the study of urinary incontinence, as a safety parameter to exclude a voiding dysfunction associated with incontinence.

Recommendations

1. Residual urine measurement is recommended in the initial assessment of urinary incontinence as a safety parameter and in the evaluation of treatment outcome (**Level of evidence 3- Grade of recommendation C**)
2. The determination should be performed utilising realtime sonography or portable scanner or inand-out catheterisation (**Level of evidence 3- Grade of recommendation C**).
3. Due to intra-individual variability, in cases where significant PVR is detected by the first measurement, several measurements should be performed (**Level of evidence 3- Grade of recommendation C**)
4. The modality of measurement should be indicated

Suggested research areas

1 Presence and prevalence of residual urine in various incontinent populations.

2 Aetiology of PVR in male and female patients with urinary incontinence.

3 Physiological variability and diurnal variation of residual urine

4 Validation of the role of PVR measurement in the assessment of urinary incontinence

5 Determination of the cut-off value of significant residual urine

6 Residual urine as a prognostic indicator of outcome after treatment of incontinence

II. OPEN BLADDER NECK AND PROXIMAL URETHRA AT REST

In patients with stress incontinence, but also in asymptomatic women [1], funneling of the internal urethral meatus may be observed on Valsalva (Fig. 15) 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 can not be used to prove USI. Marked funneling has been shown to be associated with poor urethral closure pressures [2,3].

Reports in the peer reviewed literature suggest that the open bladder neck and proximal urethra at rest, during the storage phase, can be observed during cystography, videourodynamics or bladder ultrasound, both in patients with and without neurologic disease and is interpreted as a sign of internal sphincter denervation as occurs in 53% of patients with Multiple System Atrophy [4]. Distal spinal cord injury have been associated with an open smooth sphincter area, but whether this is due to sympathetic or parasympathetic decentralization or defunctionalization has never been settled [5]. Relative incompetence of the smooth sphincter area may also result from interruption of the peripheral reflex arc very similar to the dysfunction observed in the distal spinal cord injury. Twenty-one out of 54 patients with spinal stenosis were found to have an open bladder neck at rest [6]. In a review on 550 patients [7], 29 out of 33 patients with an open bladder neck had neurologic disease. Although the association was more commonly seen in patients with thoracic, lumbar and sacral lesions, the difference when compared to cervical and supraspinal lesions was not significant. Damage of sympathetic innervation to the bladder was also frequently observed in patients undergoing major pelvic surgery, such as, abdominal perineal resection of the rectum. Patients with myelodysplasia had an inordinately high incidence of open bladder neck (10 out of 18 patients. versus 19 out of 290 having different neurological disorders). Patients with sacral agenesis are included in the larger category of myelodysplastic patients and suffer from an open bladder neck with an areflexic bladder. Shy-Drager syndrome is a Parkinson-like status with peripheral autonomic dysfunction. Detrusor hyperreflexia is usually found in association with an open bladder neck at rest and a denervated external sphincter [8]. Peripheral sympathetic injury results in an open bladder neck and proximal urethra from a compromised alpha-adrenergic innervation to the smooth muscle fibres of the bladder neck and proximal urethra [9]. Although it can occur as an isolated injury it is usually associated with partial detrusor denervation and preservation of sphincter EMG activity. The loss of bladder neck closure suggests an autonomic neural deficit. The site and nature of the requisite deficit is unclear. Most of the authors agree on the importance of the sympathetic system in maintaining the integrity of the bladder neck [10-13] although the possible role of parasympathetic innervation has been proposed by others [14-15].

An open bladder neck at rest in children or in women without neurologic disease can represent a different disorder, either related to a congenital anomaly or secondary to an anatomical pelvic floor defect. Stanton and Williams [16] described an abnormality in girls with both diurnal incontinence and bed-wetting, based primarily on micturating cystourethrography, in which the bladder neck was wide open at rest. Murray et al [17] reported the “wide bladder neck anomaly” in 24.5% of the girls (35) and 9.3% of the boys (10) out of 251 children (143 girls and 108 boys) undergoing videourodynamics for the assessment of non-neuropathic bladder dysfunction (mainly diurnal incontinence). The authors considered the anomaly congenital and made the hypothesis that wide bladder neck anomaly in girls may provide a basis for the development of urodynamic stress incontinence in later life. Chapple [18] reported that 21% per cent of 25 totally asymptomatic women he investigated by transvaginal ultrasound had an open bladder neck at rest. Versi [19] found a 21% prevalence of open bladder neck at rest in 147 women presenting to a urodynamic clinic and suggested that the finding is of little consequence.

Open bladder neck is a key point in defining type III stress incontinence according to the classificaton of Blaivas and Olsson [20]. This classification is based on history, imaging, and urodynamics, and distinguishes five diagnostic categories of stress incontinence. Incontinence type III is diagnosed by the presence of an open bladder neck and proximal urethra at rest in the absence of any detrusor contraction suggesting an intrinsic sphincter deficiency. The proximal urethra no longer functions as a sphincter. There is obvious urinary leakage which may be gravitational in nature or associated with minimal increase in intravesical pressure. In pelvic fracture with membranous urethral distraction defects, when cystography (and/or cystoscopy) reveals an open bladder neck before urethroplasty, the probability of postoperative urinary incontinence may be significant, although the necessity of a simultaneous (or sequential) bladder neck reconstruction is controversial [21-23].

Recommendations

- When observing an open bladder neck and proximal urethra at rest, during the storage phase, whatever imaging technique is used, it may be worthwhile to evaluate the possibility of an underlying autonomic neural deficit. **(Level of Evidence 3, Grade of Recommendation C)**

Suggested research areas

1. The relation of open bladder neck and proximal urethra at rest to the different neurogenic disorder
2. Longitudinal study of wide bladder neck and proximal urethra at rest in asymptomatic women
3. Evaluate the prognostic value of the open bladder neck and proximal urethra at rest

III. FEMALE URETHRAL DIVERTICULA

The first case of female urethral diverticulum was reported in 1805 [1]. Since the report from Davis and Cian in 1956 [2] using positive-pressure urethrography, the diagnosis has become much more common even though, despite increased clinical awareness, this pathology continues to be frequently overlooked. Urinary incontinence is frequently associated with a urethral diverticulum. Incontinence may be a sequel to urine loss from the diverticulum itself with stress manoeuvres, urodynamic stress incontinence or urge incontinence [3]. Aldrige et al [4] reported urethral diverticula in 1.4% of patients with stress urinary incontinence. The presenting symptoms of a urethral diverticulum have classically been described as the three Ds (Dysuria, postvoid Dribbling, and Dyspareunia). Since most patients present with nonspecific lower urinary tract symptoms, and the pathognomonic presentation (postvoid dribbling, urethral pain, tender periurethral mass and expression of pus form the urethra) is very uncommon, these patients undergo extensive evaluation and treatment before a correct diagnosis is established [5,6]. The diagnosis of a urethral diverticulum may be achieved by physical examination, voiding cystourethrography, positive-pressure (double-balloon) urethrography, urethroscopy, endocavitary (transurethral or transvaginal) or transperineal ultrasound sonography, urethral pressure profile or MRI. Positive pressure urethrography is usually accomplished using a double balloon catheter according to the method described by Davis and Cian [7]. Two different models exists: the Davis-TeLinde and the Tratner catheter. Positive-pressure urethrography (and voiding urethrography) may result in a false negative study when the inflammation of the diverticulum neck prevents contrast medium to flow into the diverticulum cavity.

Comparison of voiding cystourethrogram (VCUG) versus double-balloon urethrography (DBU) showed a 66.7 and 100% sensibility, respectively for the diagnosis of urethral diverticula. In some patients, VCUG only delineated the lower part of the diverticulum [8]. Ultrasound sonography and MRI should be theoretically free of such false negative imaging. Chancellor et al [9] described the use of intraoperative intraluminal echographic evaluation which may be of help in dissecting the diverticulum and achieving complete excision without damaging the bladder neck and urethra. A number of studies have shown that MRI is a superior image modality to both voiding cystourethrography and positive-pressure urethrography and can be considered, if available, the imaging of choice when the diagnosis of urethral diverticulum is suspected [10-15] (**Figure 56 a, b**). MRI proved to be superior to X-ray studies because diverticula can go undiagnosed on voiding cystourethrogram, furthermore size and complexity of the diverticulum is better defined on MRI [13]. Endoluminal MRI is considered to be of particular importance in the diagnosis of circumferential urethral diverticulum, a condition which is relatively rare but the prevalence of which may increase with the increased use of eMRI. Proper evaluation of diverticulm anatomy is essential in planning reconstructive surgery [16]. MRI also proved to be useful in diagnosing inflammation and tumour of the diverticulum [17,18]. Endoluminal MRI with either a vaginal or rectal coil, may provide even better image quality than simple MRI [14].

A comparison of MRI versus urethrography and urethroscopy, in a group of 20 women with urethral diverticulum, reported a 69 and 77 per cent accuracy of the two latter imaging studies versus MRI [10].

When surgical findings were compared to MRI, urethrography and urethroscopy, the diagnostic ability of the three methods was 70, 55 and 55 per cent, respectively. Diverticular ostia could not be identified by MRI study notwithstanding the use of contrast material. Neitlich et al [11] reported in a series of 19 patients that MRI (using a fast spin echo T2-weighted pulse sequence and a dedicated pelvic multicoil) had a higher sensitivity for detecting urethral diverticula and a higher negative predictive rate in comparison with double balloon urethrography. Blander et

Figure 56 . (a) MRI: urethral diverticulum (coronal view) b : MRI: urethral diverticulum (sagittal view)

al [13], comparing MRI and VGUG in 27 patients with urethral diverticula, found that endoluminal (endorectal or endovaginal) MRI was extremely accurate in determining the size and extent of urethral diverticula compared to VCUG; the related information can be critical when planning surgical approach, dissection and reconstruction.

In conclusion, review of the peer reviewed literature suggests that positive pressure urethrography is still a valuable tool to diagnose female urethra diverticula notwithstanding both ultrasound sonography and particularly MRI can represent valuable alternatives with a significantly higher diagnostic accuracy.

In males, both VCUG and ultrasonography can be successfully used to diagnose syringocele (cystic dilatation of the Cowper's gland), congenital and acquired diverticula [19].

RECOMMENDATIONS

- In cases of female urinary incontinence if a urethral diverticulum is suspected, appropriate imaging (positive pressure urethrography, voiding cystourethrography, urethroscopy, ultrasound, MRI) is recommended. (The choice of the type of imaging depends on their availability. Data show a higher accuracy of MRI.) (**Level of Evidence 3 – Grade of Recommendation C**)

AREAS FOR RESEARCH

- Properly conducted prospective studies are needed to compare the accuracy of ultrasonography and MRI in the diagnosis and staging of female and male diverticula

IV. IMAGING OF THE NERVOUS SYSTEM (NEURO-IMAGING) IN URINARY INCONTINENCE

1. LUMBOSACRAL SPINE X-RAYS

Lower urinary tract dysfunction with urinary incontinence in children can be the expression of an underlying spinal dysraphism. In the majority of cases, abnormalities of the gluteo-sacral region and/or legs and foot are visible, but there can be cases where the abnormalities are minimal or absent. A careful evaluation of the anteroposterior and lateral film of the lumbosacral spine can identify vertebral anomalies commonly associated with nervous system anomalies. Sacral agenesis involves the congenital absence of part or all of two or more sacral vertebrae. In the absence of two or more sacral vertebrae a neurogenic bladder is the rule.

Spina bifida occulta has a variable significance. Simple failure to fuse the laminae of the fourth and fifth lumbar vertebrae is unlikely to be important, but if the spinal canal is noticeably widened, there may be cord involvement (diastematomyelia, tethered cord syndrome).

RECOMMENDATIONS

- In patients with suspected congenital neurogenic incontinence, with or without abnormalities of neurourologic physical examination, lumbosacral spine anteroposterior and lateral radiological evaluation (or MRI) is indicated. (**Level Evidence 3, Grade of Recommendation C**)

2. CT, MRI, SPECT AND PET (CNS)

The peer reviewed literature concerning the role of imaging of the central nervous system in patients with urinary incontinence can be divided into three major parts. Numerous papers refer to rare neurological conditions presenting with different symptoms including urinary incontinence in which CT scan, MRI, SPECT, and PET imaging were carried out identifying the underlying CNS disease. These references have little impact on the daily practise although can be helpful in occasional difficult cases. A second set of references deal with the management of patient cohorts and are mostly retrospective, they certainly represent the highest quality of evidence in this field although the score low in the Oxford scale. Analysis of these paper can be of help in defining diagnostic and managing strategies for patients suffering lower urinary tract symptoms and dysfunction of neurogenic origin. A third group of papers refer the use of CNS imaging in clinical research of voiding dysfunction physiology and pathophysiology, although these references have no immediate and direct effect on our daily practise they are of importance to improve our knowledge of the neural control of the micturition cycle.

An Interesting paper from Breysem and co-workers suggest the use fetal MRI as an adjunct to ultrasound in prenatal diagnosis. In a series of 40 non-consecutive fetuses, ultrasound posed a suspicion of myelomeningocele, MR imaging provided additional information, such as the demonstration of a spinal communication (required for the diagnosis), in 2 of 3 fetuses. The diagnosis of myelomeningocele was confirmed after delivery in all 3 newborns [1]. MRI is also recommended in children with anorectal anormalities as abnormalities of the spine and of the spinal cord are diagnosed in 42 to 46% of cases and in about 50% of cases the spinal cord is involved. Although spinal cord defects are common in patients with anorectal abnormalities and lower urinary tract dysfunction, there is no specific pattern of spinal cord malformation that is associated with any particular LUT dysfunction [2]. A recent paper from Wraige and Borzyskowski clarified the indications for MRI of the spine in children with voiding dysfunction. In the Authors' opinion, spinal cord imaging should be considered in children in whom daytime wetting is associated with impaired bladder sensation or poor bladder emptying even in the absence of clinical or radiological suspicion of lumbosacral spine abnormalities. Four out of 10 children with these symptoms had a spinal cord defect diagnosed on MRI [3]. According to Sakakibara and co-workers, careful neurourological assessment and spinal MRI are of importance for diagnosing spina bifida occulta in young adult patients which may present with LUTS in the absence of any obvious neurological disorder [4]

After a cerebrovascular accident, the urodynamic behaviour of the lower urinary tract has been correlated to CT pictures of the brain [5,6]. The presence of significant cerebral lesions has been clearly demonstrated by CT, MRI or SPECT in the absence of clinical neurologic symptoms and signs in patients complaining of urge incontinence [7]. This can be particularly significant in elderly patients. Griffiths et al [8], studying 48 patients with a median age of 80 years, reported that the presence of urge incontinence was strongly associated (P= 0.009) with depressed perfusion of the cerebral cortex and midbrain as determined from the SPECT scan. Kitaba et al [9] using MRI reported subclinical lesions in the brain in 40 out of 43 men more than 60 years old who complained of urinary storage symptoms; of these 40 patients, 23 (57.5%) had detrusor hyperreflexia.

MRI imaging of the lumbar spine is now the gold standard for evaluating children with spina bifida and adults in which an occult form of spina bifida is suspected.

Positron emission tomography (PET) studies provided information on specific brain structures involved in micturition in humans. In men and women who were able to micturate during scanning, an increase in regional blood flow was shown in the dorsomedial part of the pons close to the fourth ventricle, the pontine micturition center (PMC). PET studies showed also the activation during micturition in men and women of the mesencephalic periacqueductal grey (PAG) area. This area is known from cat experiments to project specifically to PMC and its stimulation elicits complete micturition; experimental interruption of fibers from the PAG to the PMC results in a low capacity bladder. PET studies during micturition in humans showed also an increased regional blood flow in the hypothalamus included the preoptical area which in cats can elicit bladder contractions [10,11]. These functional CNS imaging studies have a great potential to improve our knowledge on nervous functional anatomy related to vesicourethral function and dysfunction.

CNS imaging is rarely indicated in urinary incontinence. Spinal and spinal cord imaging is recommended in case of children with anorectal malformation and whenever spina bifida occulta is suspected. In the case of clinical neurological signs and/or symptoms suggestive of central nervous lesions, imaging may be indicated along with more specific neurophysiological tests (e.g. signal latency testing, evoked potential etc.). A better knowledge of the correlation between morphologic and functional evaluation of the CNS is foreseeable using present CNS functional imaging technology.

RECOMMENDATIONS

- Neuro-imaging should be considered when a nervous system disorder is suspected on the basis of clinical and/or neurophysiological test findings. (**Level of Evidence 3 – Grade of Recommendation C)**

SUGGESTED RESEARCH AREAS

- Correlation of CNS functional morphology to pathophysiology of urinary incontinence.

V. ENDOSCOPY OF THE LOWER URINARY TRACT

Since the introduction of the cystoscope in the early nineteenth century, endoscopy has played a growing and critical role in the evaluation of lower urinary tract disorders and dysfunctions. Many investigators have proposed the routine use of urethrocystoscopy in the evaluation of urinary incontinence. These recommendations have been rarely based on evidence. There are five specific areas pertaining to urinary incontinence in which cystourethroscopy has been advocated:

1) Observation of the female urethral sphincteric unit to assess its ability to close and coapt. Urethrocystoscopy has been advocated in the static state to assess for intrinsic sphincter deficiency (ISD) as well as in the dynamic state, when the patient is straining, to evaluate hypermobility and urethral closure while the patient is straining. It has been reported that sluggish closure of the bladder neck during periods of a rise in intra-abdominal pressure is associated with anatomical stress urinary incontinence. Intrinsic sphincter deficiency has classically been described as a fibrotic or pipe-stem urethra. It has been suggested that endoscopy can even help to differentiate between the hypermobile urethra and the intrinsically damaged urethra.
2) Assessment of the bladder, to rule out concomitant bladder conditions which may cause of detrusor overactivity and urinary incontinence or may simply require contestual treatment.
3) Search of extraurethral causes of urinary incontinence, such as vesico-vaginal fistula and ectopic ureter.
4) Intraoperative cystourethroscopy during correction of urodynamic stress incontinence to assess for bladder damage and ureteral patency.
5) Evaluation of the membranous and prostatic urethra in male patients with post-prostatectomy stress incontinence to evaluate possible iatrogenic damage of the external sphincter region.
6) Assessment of bladder outlet in males with urge incontinence considered to be secondary to bladder outlet obstruction to appraise prostate morphology.

1. EVALUATION OF THE FEMALE BLADDER OUTLET

Robertson described the procedure of dynamic urethroscopy to evaluate the bladder neck [1]. In this procedure a gas urethroscope is used to observe the urethra, bladder neck, and portions of the bladder. During visualisation manometric recording can be performed. Robertson described the appearance of true stress incontinence as a sluggish closure of the bladder neck and the appearance of the overactivity bladder as a bladder neck that closes and then opens like the shutter of a camera. This procedure was reported to be extremely useful in patients with urinary incontinence as the bladder neck can then be observed at rest, with straining, and Valsalva manoeuvres. Unfortunately, in Robertson's original description of this procedure, it was never compared to other standard methods of measuring outlet resistance. Others who advocate the technique of Robertson reported that only 43% of patients with stress incontinence actually had loss of bladder neck support on urethroscopy [2]. Scotti, et al performed a retrospective review of 204 patients who underwent dynamic urethroscopy for the evaluation of urodynamic stress urinary incontinence [3]. Of the 204 patients, 99 had urodynamic stress urinary incontinence confirmed by urodynamic testing. Urethroscopy was found to be an imprecise predictor of urodynamic stress urinary incontinence with a 62% sensitivity, a 74.6% positive predictive value and a specificity of 79.1%. Moreover, there were many equivocal studies. The authors concluded that urodynamic evaluation rather than urethroscopy was a more accurate predictor of urodynamic stress incontinence. Sand, and associates compared supine urethroscopic cystometry (dynamic urethroscopy) to the gold standard of multichannel urethrocystometry [4]. They found a sensitivity of only 24.6% and a positive predictive value of only 65.2% in predicting detrusor overactivity.

Horbach and Ostergard tried to predict urethral sphincter insufficiency in women with stress urinary incontinence using urethroscopy [5]. They retrospectively reviewed the records of 263 women who had a diagnosis of urodynamic stress urinary incontinence. They defined ISD as a maximal urethra closure pressure of 20 cm H_2O or less with the patient upright with a symptomatically full bladder. They then divided patients into two groups, those with ISD and those with maximal urethral closure pressures of more than 20 cm H_2O. Based on this classification, 132 women, or 50.2%, had evidence of ISD. However, when urethral function was assessed by endoscopy, only six of 132 patients with ISD were found to have an open or partially open proximal urethra and urethrovesical junction at rest during urethrocystoscopy. Clinically, these patients had very low urethral pressures and reported difficulty with continuous leakage of urine. Endoscopy appeared to have little predictive value for ISD as defined by urethral pressure profilometry. Govier et al compared cystoscopic appearance of the female urethral sphincteric mechanism to the videourodynamic studies in 100 consecutive women with complex types of urinary incontinence [6]. Sphincteric dysfunction was classified as minimal, moderate, and severe based on the radiographic appearance of the bladder neck with straining. Urethrocystoscopy underestimated the degree of sphincter deficiency 74% of the time in patients with moderate sphincteric dysfunction and 44% of the time in patients with severe sphincteric dysfunction. The authors conclude that cystoscopy is inadequate to judge the functional integrity of the bladder outlet. Furthermore, cystoscopy alone will underestimate intrinsic sphincter deficiency in a large number of patients.

2. Evaluation of the bladder

Is cystoscopy necessary to rule out concomitant bladder pathology in patients with urinary incontinence? Langmade and Oliver reported on 253 patients who were operated on for stress urinary incontinence [7]. They used a simple evaluation that consisted of history, stress tests, and urinalysis alone. They did, however, recommend cystoscopic evaluation if the patient also complained of symptoms of urgency. Although this dogmatic approach was recommended, it was never clearly stated if it made a difference in the treatment or outcome in these patients. Fischer-Rasmussen, et al performed extensive evaluation of women with urinary incontinence [8]. This included cystoscopy in 190 patients. They found cystoscopy to be abnormal in only 12 patients, 8 who had stress incontinence and 4 who had other types of incontinence. Abnormal findings were trabeculated bladder mucosa in five patients, benign bladder papillomas in four, and metaplasia of the trigonal mucosa in two. None of these was considered to be a significant finding. The authors concluded that cystoscopic examination did not contribute to the classification of incontinence in any case. Cardozo and Stanton evaluated 200 patients with stress incontinence and detrusor overactivity [9]. Cystoscopy revealed no abnormalities amongst the 100 patients with urodynamic stress urinary incontinence. Fourteen of the 100 patients with detrusor overactivity had cystoscopic abnormalities, eg trabeculation (11), injected mucosa (1), sacculation (1), a bladder capacity of less than 100 cc (1). However, in none of these patients was the treatment affected by the results of cystoscopy. In support of these findings, Mundy has stated that there is no direct diagnostic value of endoscopy in a patient with an overactivity bladder. It may sometimes be helpful to look for and exclude a cause of hypersensitivity when this is in the differential diagnosis [10]. Duldulao and colleagues found this necessary only in patients with hematuria [11]. They performed urinalysis, urine cytology, and cystoscopy on 128 women who presented with urge incontinence and/or irritative voiding symptoms. Of these, 68 patients had urge incontinence, 35 of whom also had microscopic haematuria. One patient with urge incontinence and haematuria was found to have a transitional cell carcinoma of the bladder. None of the patients with urge incontinence (or irritative symptoms only) and no haematuria was found to have significant cystoscopic findings. This would support the routine use of cystoscopy for patients with urge incontinence only if haematuria is present.

3. Extra-urethral urinary incontinence

Endoscopy can be an invaluable tool in the diagnosis and treatment of extraurethral incontinence due to vesico-vaginal fistula and ectopic ureter. With respect to vesico-vaginal fistula, cystoscopy can precisely localize the fistula site in the bladder and help plan surgical correction. Occasionally, a small fistula that is not seen on physical examination or by radiographic studies, can only be diagnosed by cystoscopy. Incontinence due to ectopic ureter in the female is usually diagnosed by radiographic studies. However, the exact location of the ureteral orifice in the urethra or vagina can be identified by cystourethroscopy and/or vaginoscopy. This can be extremely helpful in the planning of corrective surgery.

4. Intraoperative lower urinary tract evaluation

Several authors have studied the value of routine cystoscopy during operative procedures for incontinence and prolapse. The approach may be transurethral [12] or transvesical [13]. The American College of OB/GYN has published a Bulletin on Operative Lower Urinary Tract Injuries [14] in which is stated "at the conclusion of the procedure, when hemostasis has been ensured, both ureters and the bladder should be inspected to confirm their integrity." Harris and co-workers [12] reported 9 unsuspected ureteral or bladder injuries during urogynecological surgery, which included 6 ureteral ligations, with four of these occurring after Burch cystourethropexy. Burch sutures were also found in the bladder as well as fascial lata from a sling procedure.

5. Evaluation of the male bladder outlet

Urge incontinence is one of the lower urinary tract symptoms associated with benign prostatic hyperplasia, bladder outlet obstruction, and aging in the male population. Based on the available evidence and world literature, The World Health Organization Fourth International Consultation on BPH made the following recommendation: "Diagnostic endoscopy of the lower urinary tract is an optional test in the standard patient with LUTS (lower urinary tract symptoms) because: 1) the outcomes of intervention are unknown, 2) the benefits do not outweigh the harms of the invasive study, 3) the patients' preferences are expected to be divided However, endoscopy is recommended as a guideline at the time of surgical treatment to rule out other pathology and to assess the shape and size of the prostate, which may have an impact on the treatment modality chosen" [15]. Several contemporary series have described the value of urodynamics in the diagnosis of post-prostatectomy urinary incontinence [16-20]. However, only one describes the routine use of urethrocystoscopy. In that series 67% of patents had urethral fibrosis confirmed by endoscopy [17]. However, how this finding effected treatment was not discussed. In the study by Leach and Yun treatment of incontinence was based solely on urodynamic findings and was successful in 87% of patients [21]. Anastomotic strictures may be suspected based on uroflow and urodynamic (pressureflow) studies and can be confirmed by voiding cystourethrogram or videourodynamics as well as by endoscopy. However, if intervention for the stricture is deemed necessary, endoscopy would be a more critical part of the evaluation. Furthermore if surgical treatment of incontinence, such as, an artificial urinary sphincter, is planned it would seem to make good clinical sense to evaluate the urethro-vesical anastomosis with endoscopy prior to surgery.

Recommendations

- Routine urethro-cystoscopy is NOT indicated in primary female urinary incontinence, when other pathologies are not suspected **(Level of Evidence 3, Grade of Recommendation C)**
- Endoscopy can be considered **(Level of Evidence 3, Grade of Recommendation C)**:
  a) in urge incontinence to rule out other pathologies, especially in case of microscopic haematuria (e.g., bladder tumor, interstitial cystitis, etc)
  b) in the evaluation of recurrent or iatrogenic cases when surgery is indicated and planned
- Endoscopy is indicated in the evaluation of vesico vaginal fistula and extra-urethral urinary incontinence **(Level of Evidence 3, Grade of Recommendation C)**.
- Endoscopy is indicated intraoperatively in incontinence surgery to evaluate for ureteral or vesical injury **(Level of Evidence 3, Grade of Recommendation C)**.

Suggested research areas

- To relate endoscopic features to diagnosis and outcome of urinary incontinence (mainly urge incontinence)

C. IMAGING IN FAECAL INCONTINENCE

Faecal incontinence occurs when the sphincter fails to counteract any rise of intra-rectal pressure. A good estimate of external sphincter function is given by digital examination of the anal canal while the patient "squeezes" but clinical examination of the perineum [1] does not exclude sphincter damage. Digital examination is considered to be much less accurate than imaging [2]. Endosonography has revealed a relatively high incidence of occult sphincter damage following vaginal delivery [3] that may result in overt faecal incontinence at menopause. External sphincter atrophy can be observed on highly detailed images of the striated sphincter as obtained by magnetic resonance imaging (MRI) with endocoil [4,5]. Studies of rectal evacuation, which are performed mainly with fluoroscopy, give only a rough indication of faecal incontinence and are used mainly to investigate difficult defaecation and rectal prolapse.

I. INDICATIONS

The role of imaging is largely to place patients into defined management groups, so the emphasis may change as new treatments for faecal incontinence evolve. Endosonography took over from EMG studies as the gold standard to select patients with sphincter disruption for surgical repair, and this remains the main indication for imaging. A more complex question is when to investigate for external sphincter atrophy. Endocoil MRI may be indicated prior to sphincter repair if there is any doubt as to the quality of the external sphincter. Dynamic studies of rectal evacuation are indicated if incontinence is complicated by rectal prolapse.

II. IMAGING MODALITIES

Radiological evaluation of patients with faecal incontinence includes morphological evaluation of the anal canal with either ultrasonography or MRI and dynamic assessment of the anal canal with fluoroscopy and standard X-ray imaging

1. Endoanal ultrasound (EAUS)

Several systems are available, but the most commonly used is manufactured by B&K Medical (Sandoften 9, 2820 Gentofte, Denmark), who have recently developed an integrated 3D system. US probes designed for transvaginal examination with endfire linear arrays may be used in women to image the sphincters from the perineum [6]. Women should be examined prone with an endoanal system to minimise anatomical distortion [7].

Standard axial imaging of the anal canal is performed using a 10MHz mechanical rotating crystal that gives a 360˚ image of the typical 4 layer pattern of the sphincters (**Figure 57**).

The subepithelial layer is moderately reflective.

The internal sphincter is the most obvious landmark and is a well defined low reflective ring. The internal

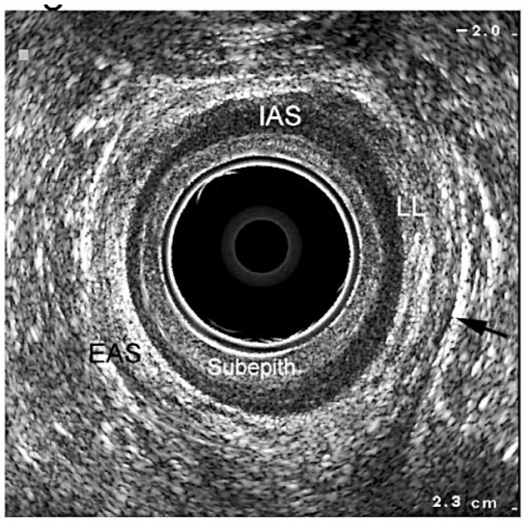

Figure 57 . Axial endosonography in the mid canal in a normal 38yr old female. Subepith = subepithial layer; IAS= internal anal sphincter; LL = longitudinal layer; EAS = external anal sphincter. The outer border of the external sphincter is defined by an interface reflection at the fat/muscle boundary (arrow).

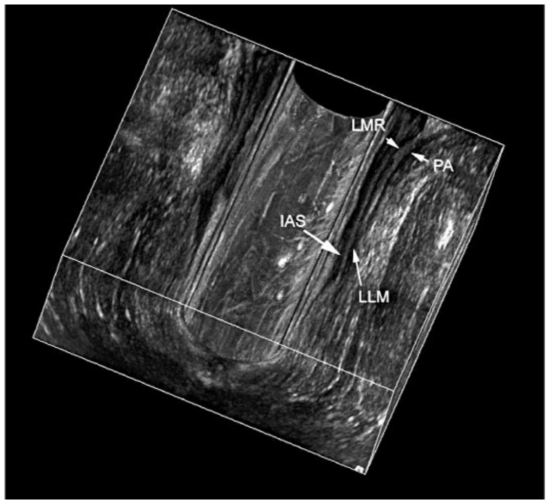

Figure 58. 3D view of the anal canal in the mid coronal plane with some image manipulation to highlight the internal sphincter (IAS) and the longitudinal muscle of the rectum (LMR) joining the puboanalis (PA) to form the combined longitudinal layer muscle (LLM).

sphincter varies in thickness with age, being <1mm in neonate, 1-2mm in young adults, 2-3 in middle age and >3mm in the elderly [8].

The longitudinal layer is a complex structure with a large fibroelastic [9] and muscle component, the latter is formed from the puboanalis as well as the longitudinal muscle of the rectum (**Figure 58**).

The external sphincter is better defined in men than women, where it tends to be similar in reflectivity to

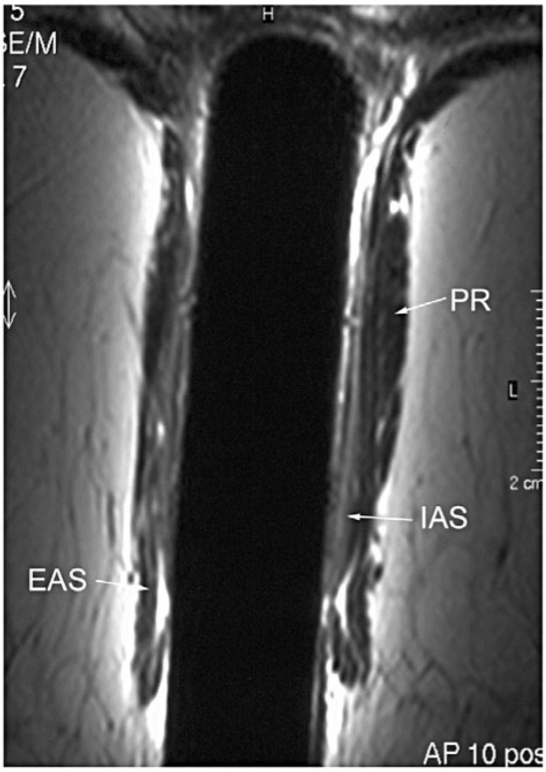

Figure 59. Mid coronal MR image with an endocoil. The endocoil causes the central black void from absent signal. The smooth muscle of the internal sphincter (IAS) is of moderate signal intensity, and higher than the striated muscle of the puborectalis (PR) and external sphincter (EAS). Note how well the striated muscle is demarcated by the high signal from the fat in the ischioanal fossae.

the longitudinal layer; it is then distinguished only by interface reflections between muscle/fat planes on either sides (**Figure 59**). In women the external sphincter is shorter anteriorly than posteriorly, this should not be misinterpreted as a tear.

The transverse perineii muscles fuse anterior with the sphincter in women, whereas in men they remain separate [10].

With experience the US imaging can be performed in about 5 minutes and provides an ideal method for a rapid assessment of sphincter integrity and thickness.

2. Endocoil MRI

Dedicated endoanal coils are not widely available, but could be used with any magnet. The coil is inserted with the patient in the left lateral decubitus, after the patient is turned supine the coil is maintained in position with sandbags. The total examination time is about 20 minutes. A sequence takes up to 5 minutes and the patient must remain still as any movement degrades the image quality.

The study is performed acquiring T2 weighted sequences in axial, coronal and sagittal planes. The smooth muscle of the internal sphincter is higher in intensity than the striated muscle of the external sphincter. Fat is much brighter than any muscle pattern, and this is the key to the outstanding advantage of the MRI. The clarity with which the quality of the external sphincter can be assessed (Figure 53) is of value in determining surgical outcome of sphincter repair [11].

3. Evacuation proctography

The rectum is opacified with 120 mls of a barium paste and the small bowel with a dilute barium suspension given orally about 30 minutes before. The patient is seated sideways within the fluoroscopic unit on a commode containing an equivalent of 4mm of copper to prevent screen flare out. Evacuation of the barium paste is recorded either on video or on cut film at 1 frame/sec using a low dose protocol [12]. At rest the anorectal junction projects at the level of the ischial tuberosities and the anal canal is closed. In normal subjects, evacuation is rapid (<30sec) and the rectum below the main fold should be emptied completely. During evacuation the anorectal angle widens as the anorectal junction descends and the anal canal opens. At the end of evacuation, pelvic floor tone returns and the puborectalis pulls the anorectal junction upwards and forwards back to the resting position. Slow evacuation (less than 66% evacuated in 30 seconds) with poor opening of the anal canal is typical of anismus [13] (**Figure 60**). Rectocoeles are measured from the anterior margin of the anal canal to the anterior aspect of the rectocoele (**Figure 61a**), they are common and usually asymptomatic. Failure to empty the rectocoele at the end of evacuation (**Figure 61b**) may be associated with a feeling of incomplete evacuation and the need to press on the posterior vaginal wall to achieve complete evacuation [14]. Intra-anal intussusception creates a thick double fold of rectum, which impacts into the anal canal on straining at the end of rectal evacuation (**Figure 62**). Rectal prolapse represents an extension of this process, with passage of the intussusception through the anal canal and inversion of the rectum depending on its redundancy (**Figure 63a-c**).

Dynamic examinations of rectal emptying may also be performed with MRI [15-17], the examination is usually more difficult from a technical standpoint and it is not worthwhile unless a global view of pelvic floor prolapse is required. A more simple procedure involves only views during rest and stress, and is useful to show bladder and uterovaginal prolapse as well as pelvic floor descent [18-20] (**Figure 64a,b**).

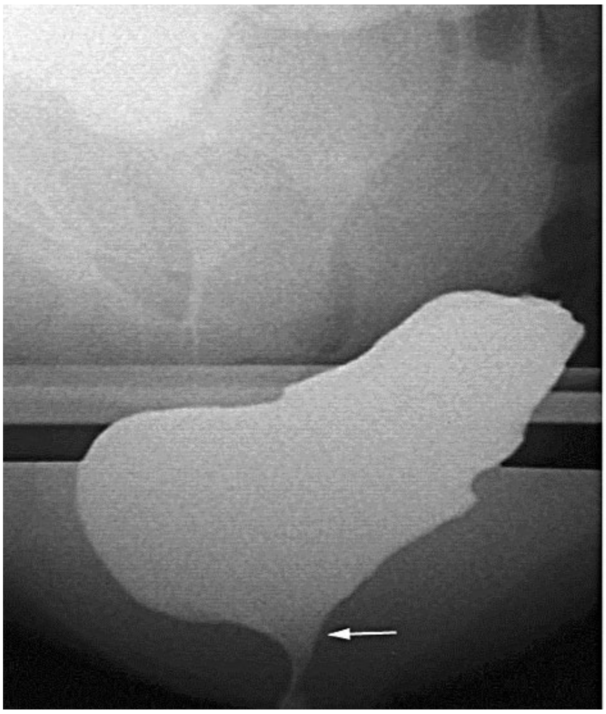

Figure 60. Evacuation proctography in a young woman with anismus. There is poor opening of the anal canal and very little of the contrast has been evacuated from the rectum after 30secs

Figure 62. Evacuation proctogram at the end of rectal emptying where there has been inversion of the distal rectal wall into the anal canal. The intussusception creates a thick layer being a double layer of wall (arrows).

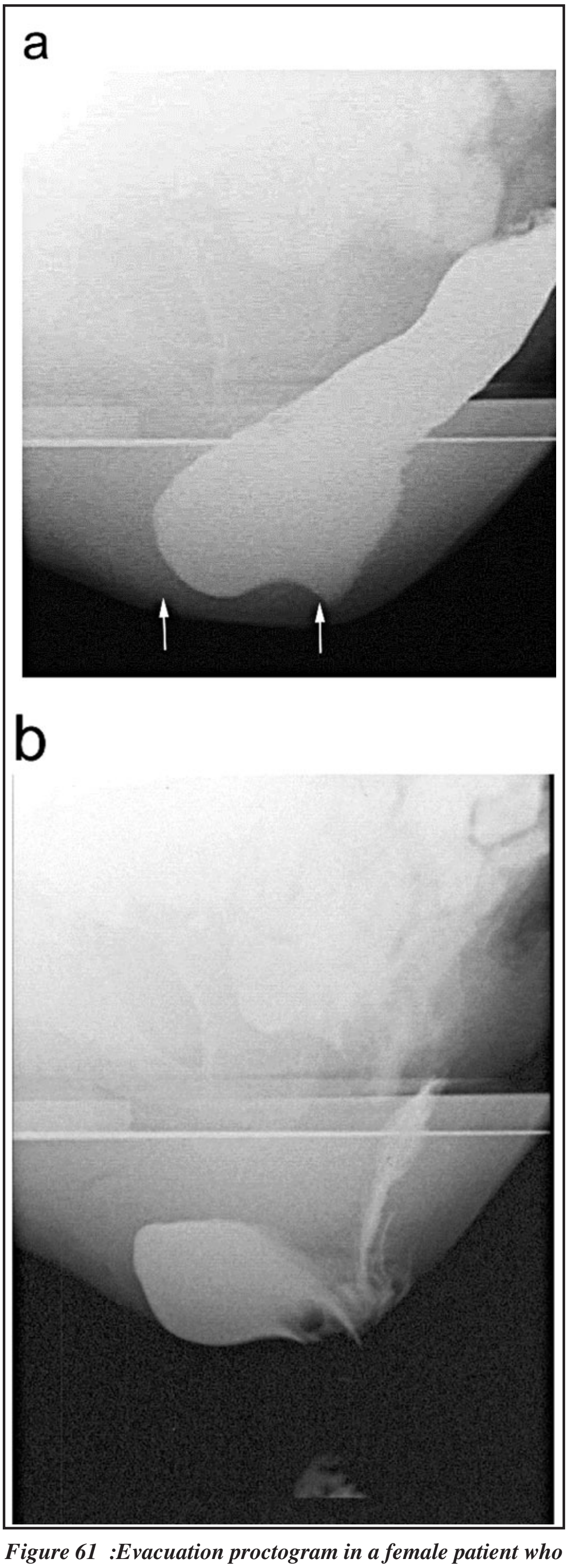

Figure 61 :Evacuation proctogram in a female patient who had to press digital on the perineum to achieve complete evacuation. (a) just at the start of evacuation there is a large anterior rectocoele. The depth of the rectocoele is measured between the two arrows. (b) The distal rectum has emptied, but in spite of repeated straining the rectocoele would only empty after digital manipulation. These features are consistent with significant barium trapping in the rectocoele.

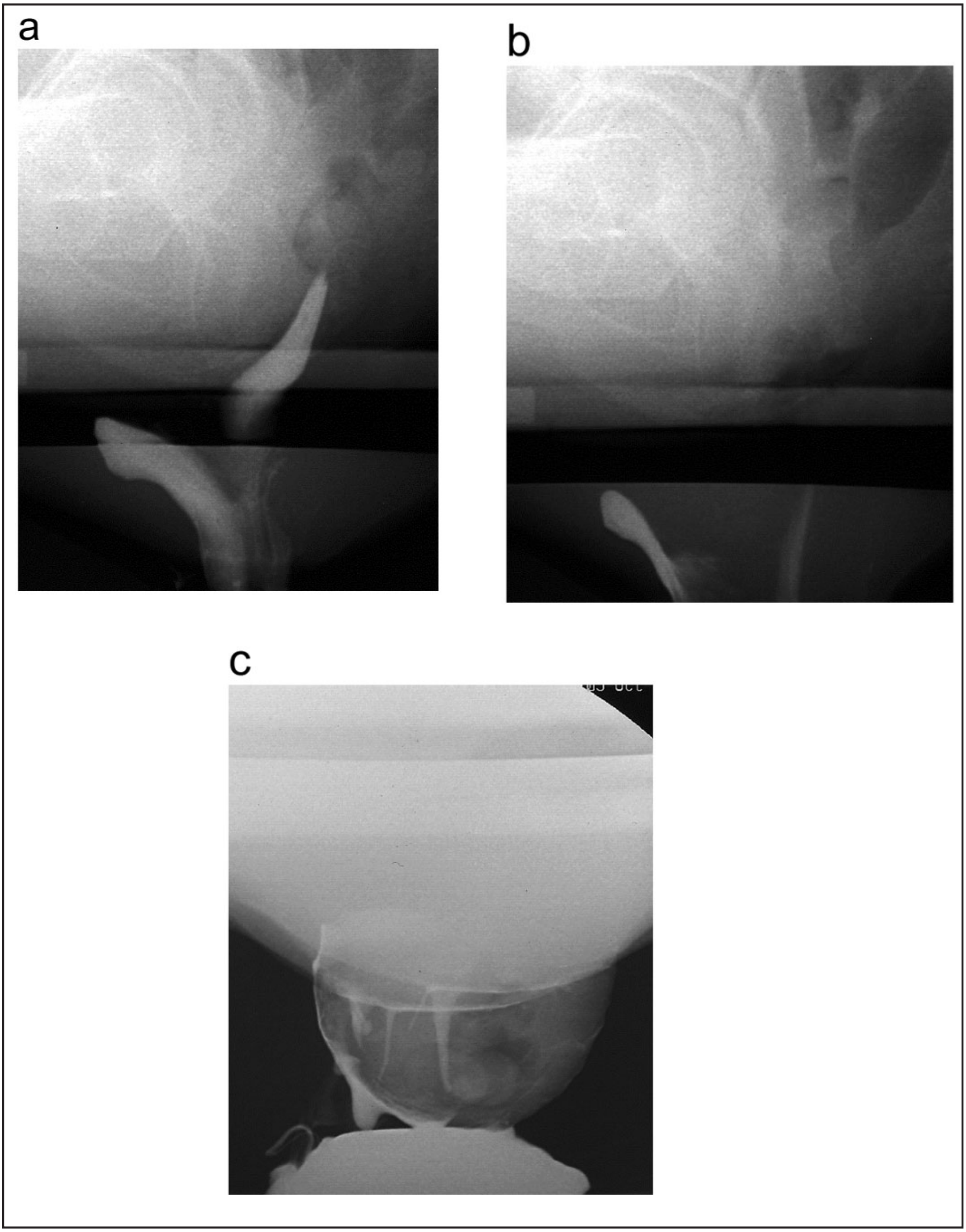

Figure 63. Evacuation proctogram showing the development of rectal prolapse. Intussusception starts at the end of rectal emptying (a) and rapidly passes through the anal canal (b) to form the external prolapse (c).

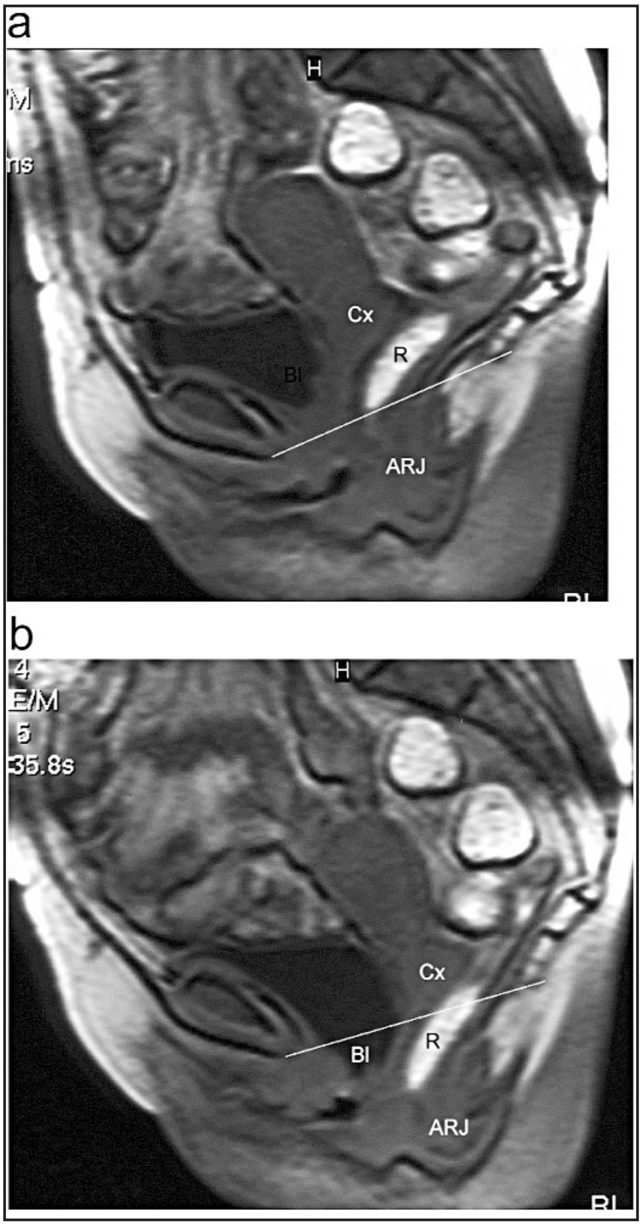

Figure 64. (a) Sagittal views from a dynamic MRI examination. The dotted line indicates the position of the pubococcygeal line. At rest (a) there is some descent as the anorectal junction (ARJ) is more than 1 cm below this. During pelvic stress (b) there is marked pelvic floor descent, with descent of the cervix (Cx) and bladder base (Bl).

III. SPHINCTER DISORDERS

The internal sphincter may show thickness abnormalities relative to aging. A sphincter less than 2mm thick in a patient more than 50 years of age is indicative of internal sphincter degeneration [21] (**Figure 65**) and it is associated with passive faecal incontinence. The sphincter should be intact but may show some variation in thickness. Measurements are taken in the mid canal, where the external sphincter forms an intact ring, at either 3 or 9 o'clock.

The termination of the internal sphincter may be ragged over the distal 2-3mm, but any disruption cranially is considered abnormal. Obstetric trauma to the internal sphincter usually parallels that of the external sphincter in extent, but should always be in the anterior half, any defect between 3 and 9 is considered due to some other cause. Sphincterotomy may be more extensive than realised, particularly in women [22], and 3D studies are especially helpful to assess the longitudinal extent of the defect. Dilatation procedures are hazardous and may fragment (**Figure 66**) the internal sphincter completely [23].

Striated muscle ruptures when stretched beyond the limits of its elasticity, and this results in a haematoma healing with granulation tissue and eventual fibrosis. Most tears are seen only in the chronic state with scar formation and present as a uniform area of low reflectivity distorting and obliterating the normal anatomy (**Figure 67**). A lack of symmetry and the anterior part of the external sphincter not joining together at 12 o'clock as the probe is moved slowly down the canal are key factors to the diagnosis [24]. Other perineal structures, such as the puboanalis and transverse perineii muscles are frequently torn, distinguishing tears of these muscles from external sphincter trauma requires experience, and 3D multiplanar imaging can be helpful. The distinction is important as tears of the puboanalis or transverse perineii muscles are not associated with a significant fall in squeeze pressure. Only traumatic damage to the external sphincter results in a significant change in sphincter function. Although the external sphincter is easier to see on MRI, granulation tissue and fibrosis are not markedly different in signal from normal muscle, so that the severity of tears may not be evaluated as good as with endosonography unless there is complete muscle separation with fat replacement (**Figure 68**).

Pelvic floor descent at rest is a good indicator of generalised pelvic floor weakness, an anal canal open at rest (**Figure 69**) suggests sphincter weakness [12]. Rectal prolapse may be associated with faecal incontinence as the continued prolapse damages the internal sphincter, which may appear fragmented on endonosonography. Rectocoele does not affect rectal emptying [14], though trapping of contrast in a rectocoele may be associated with a feeling of incomplete evacuation and the need to digitate to empty the rectocoele.

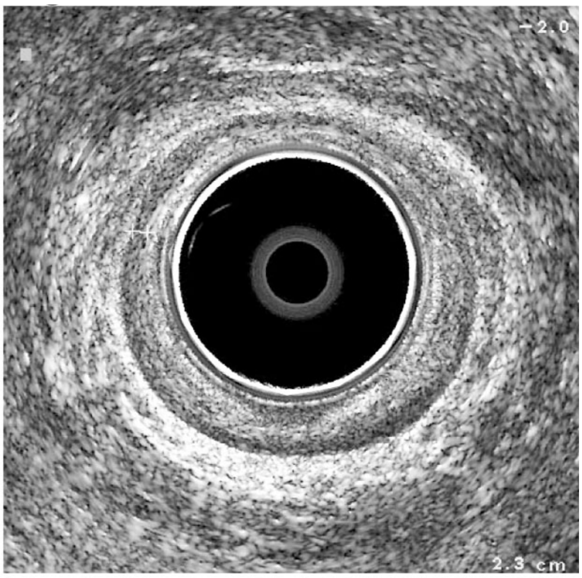

Figure 65. Endosonography with an axial image in the mid canal of an elderly patient, aged 73yrs with passive faecal incontinence. The internal sphincter measures only 1.1mm (markers) indicative of internal sphincter degeneration.

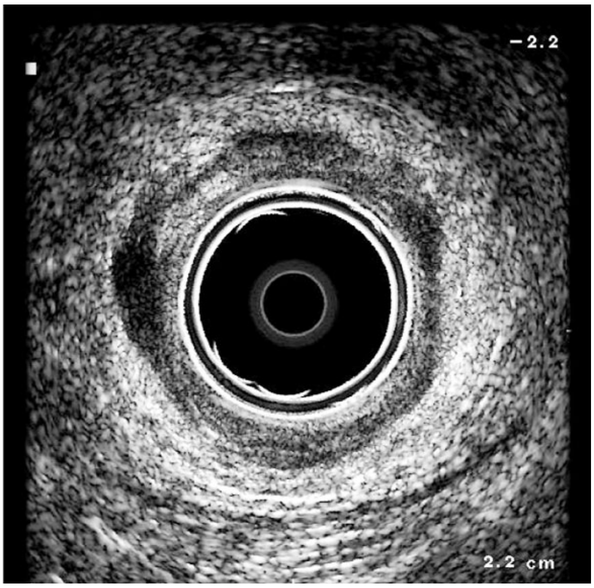

Figure 66. Endosonography in the mid canal showing gross internal sphincter irregularity, typical of the "fragmented" appearance from trauma after an anal stretch procedure

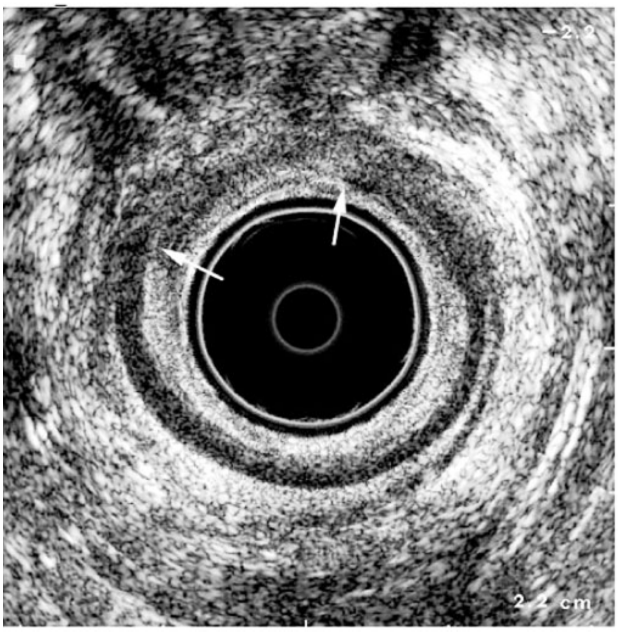

Figure 67. Tears of internal and external sphincters (arrows) between 10 and 1 o'clock following a traumatic vaginal delivery.

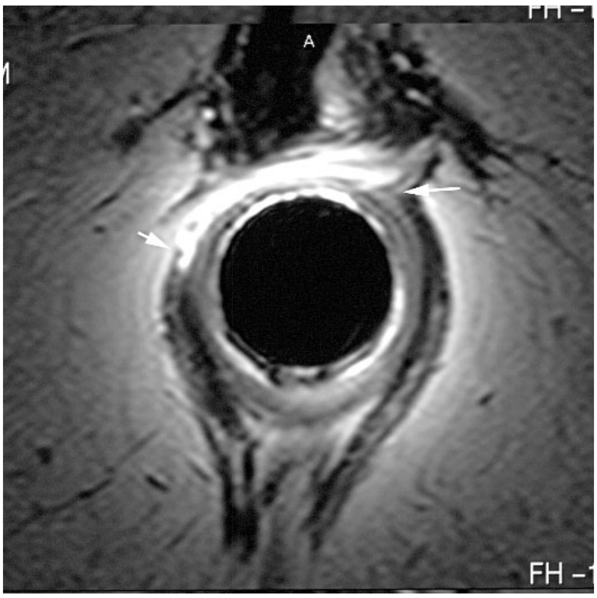

Figure 68. Axial MRI with endocoil image with tears of the external and internal sphincters between 9 and 1 o'clock following vaginal delivery.

Figure 69. Evacuation proctogram at rest with the anal canal open and spillage of contrast indicating gross sphincter weakness.

IV. CONCLUSIONS

A leading issue is the significance of occult sphincter tears (diagnosed on endosonography but not apparent clinically) following vaginal delivery. A meta-analysis of 717 vaginal deliveries [25] revealed a 26.9% incidence of anal sphincter tears in primiparous, with 8.5% new tears in multiparous women. Overall 29.7% of women with tears were symptomatic, compared to only 3.4% without tears. The probability of faecal incontinence due to a tear was 76.8-82.8%. As with all meta-analyses the quality of the data must be questioned and the problem here is that many tears of the puboanalis and transverse perineii are probably being classified as external sphincter tears. In one study, the overall incidence of tears may be 29%, the external sphincter was involved in only 11% (CI 4-24%) [24] and it is only recently that the anatomy of these structures has been defined. Questionnaires will reveal only about 60% of occult tears [26], so that endosonography with a clear understanding of the anatomy is essential to assess the true incidence of external sphincter disruption. Tears are more frequent after forceps compared to vacuum assisted deliveries [27,28]. An occult injury at the first delivery is associated with a higher risk of incontinence after the 2^{nd} [29]. One study has suggested that the baby's head circumference is more frequently associated with faecal incontinence than an occult tear [30], and a narrow sub pubic arch angle has been found to be an independent factor [31]. There are many factors involved in rendering a patient incontinent. However, whilst it is true that not all occult sphincter tears result in incontinence, this is the single most important predictive factor.

In young adults good correlation has been found between measurements of layers thicknesses on endosonography and endocoil MRI with an Ri of 0.96 for the external sphincter [10]. Claims for superiority of one or other for the detection of sphincter tears [5,32] probably depend as much on individual experience with the modality although endonosography is considered the gold standard.

Atrophy is a more difficult problem. Loss of definition of the outer border of the external sphincter on endosonography has a positive predictive value of 71% [33], and thinning of the internal sphincter a ppv of 75%, compared to ppv of 89% for the visual assessment of external sphincter atrophy on endocoil MRI [34]. A visual scale for the MR assessment of atrophy, with either increased fat replacement in intermediate atrophy with loss of muscle of muscle bulk in advanced atrophy has been shown to correlate with mean fibre density [10]. Sex and age related changes have been investigated using MRI, and a maximum thickness of less than 2mm considered abnormal for the external sphincter [35].

V. RECOMMENDATIONS

- The cheapness and speed of investigation makes endosonography the ideal screening procedure to assess sphincter [**Level of Evidence 3, Grade of Recommendation C**].
- Loss of sphincter bulk predicts outcome after sphincter repair, and pre-operative assessment in patients with possible atrophy is the main indication for MRI [**Level of Evidence 3, Grade of Recommendation C**].
- Fluoroscopic studies have little role in faecal incontinence, unless there is an underlying rectal abnormality such as prolapse [**Level of Evidence 3, Grade of Recommendation C**]
- Dynamic MRI studies have the added value of demonstrating prolapse in the rest of the pelvis, but apart from the lack of ionising radiation, unless this is important there is no real advantage for studying rectal function [**Level of Evidence 3, Grade of Recommendation C**].

VI. SUGGESTED RESEARCH AREAS

Although perineal anatomy has been clarified, the diagnosis of minor external sphincter tears remains difficult and requires further clarification. This may effect the reported incidence of occult tears, and could lead to a change in how their significance is viewed.

For example it may be that many of the asymptomatic "occult tears" are really just tears of the puboanalis or transverse perineii and that a much higher proportion of the genuine sphincter tears are symptomatic.

Sphincter tears are repaired surgically, although initial benefits may not be maintained in the long term [36]. There remains controversy as to the optimum method of repair, with no difference between approximation or overlapping techniques reported [37].

Endosonography is useful to show just how effective the repair has been, and imaging should be helpful in resolving such issues.

The concentration on tears has to some extent overlooked the larger problem of external sphincter atrophy. Specialised MRI is required to investigate this, and should be an expanding field.

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D. PAD TESTING

The pad test is a diagnostic method to detect and quantify urine loss based on weight gain of absorbent pads during a test period under standardized conditions.

The use of a perineal electronic nappy using electrical conductivity to estimate the amount of urine leakage was first proposed by James et al. [1,2]. Accuracy of this technique was, however, questioned by others [3,4,5,6,7] and the technique was improved [8]. A more simple approach was introduced by Walsh & Mills [9] and Sutherst et al. [10] estimating leakage by perineal pads weight gain. These tests were not standardised until Bates et al. [11] described a "structured" one hour pad test which was endorsed by the International Continence Society in 1988 [12]. This test, however, was shown to have poor interdepartmental correlation [13] and to be highly dependent on bladder volume [14]. In an attempt to make pad tests more reliable 24 hour and 48 hour pad tests were developed. A more precise estimation of urine loss was shown, but they were more cumbersome. The Pyridium pad test was also proposed for diagnosing urinary incontinence [15]. Janez et al 1993 tried to compare distal urethral electric conductance (DUEC) with the pad test (not well defined) and found both tests equal [16].

A pad test allows the detection and quantitation of urine loss, but it is not diagnostic of the cause of the incontinence. Several different standards were developed. Tests can be divided in four groups according to the length of the test: <1h, 1h, 24h and 48 h. (**Table 4**)

I. OFFICE-BASED PAD TESTING

Pad tests up to 2 hours have been developed to be performed in outpatient clinics or hospital wards under supervised conditions. Bladder volume is predefine to reduce variability and a structured set of exercise is usually implemented to elicit the occurrence of urine loss.

1. SHORT PAD-TEST

a) Quantification:

These tests are based on a fixed bladder volume and a standard set of activities to facililate the occurrence of urine loss, if any, over a short period of time. Jakobsen et al. [19] found that the 40 minute test with a bladder volume of 75% maximum cystometric capacity and similar activities as a 1-hour ward test produced consistently larger amounts of urine loss than a standard 1-hour ward test. The difference was attributed to significantly larger bladder volumes during performance of physical activity in a 40 minute pad test.

Table 4. types of pad test

Author	Time	Bladder load	Exercise
Hahn & Fall [17]	20 min	50% of MCC*	stair climbing, 100 steps, coughing (10x), running (1 min), wash hands (1 min) jumping (1 min)
ICS	1h	Drink 500 ml (15 min) before test	walking & stair climbing (30 min), standing up 10x, coughing (10x), running (1 min), bending (5x), wash hands (1 min)
Jorgensen et al [18]	24h		Everyday activities
Jakobsen et al. [19]	48h	Everyday activities	

**Maximum Cystometric Capacity*

Kinn & Larsson [20] reported no correlation between a short 10 minute test with fixed bladder volume and the degree of incontinence as judged from the symptoms.

Hahn & Fall [17] in a 20 minute test with half cystometric capacity showed no false negative results in 50 women with stress urinary incontinence although there was a discrepancy in 12% of patients between the perception incontinence severity and pad test results.

These data suggest that short pad tests are more provocative than activities of daily living.

b) Reproducibility:

The correlation factor (Pitman's nonparametric permutation test) between two separate 20 minute tests was 0.94 ($p<0.001$) [17]. Kinn et al [21] and Kinn & Larsson [20] showed that the 10 minute test with a fixed pre-test bladder volume of 75% of maximal capacity was moderately reproducible ($r=0.74$). Using a 1 minute pad test, a standardised bladder volume of 300ml and standardised physical activity mean differences of leakage was 8.5 ml and coefficient of repeatability was 33.6 ml [22].

2. One-hour test

The use of a one-hour pad test has been investigated thoroughly for validity, reproducibility and sensitivity to change.

a) Quantification:

Jakobsen et al. [19] reported that a one hour test detected less leakage (3 g) compared to a 40 minute (7 g) and a 48 hour pad test (37 g). In the elderly a one-hour ward test did not demonstrate incontinence in 66% of those complaining of incontinence compared to 90% with a 24 hour home test [23]. A one hour pad test was found to reflect everyday incontinence in only 48% of the patients in comparison to 81% in a 48 hour test and 77% in a 40 minute test. Jorgensen et al. [18] noted that 90% completed the test and 69% had test results which correlated with daily leakage. Mayne & Hilton [8] carried out a 1-hour pad test (n=33 patients with SUI) at a specific bladder volume (250 ml). Low correlation was attributed to small bladder volume (102 ml) during the test. Lose et al. [24] found a poor to moderate correlation of the modified one-hour test (200-300 ml in the bladder) with a history of stress urinary incontinence (n=31). Mouritsen et al. [25] (n=50) showed that a 1-hour ward pad test did not detect grade I stress incontinence in 46%, grade II in 27% and grade III in 66%. Thind & Gerstenberg [26] compared a 1-hour ward pad test to a 24-hour home pad test and found that a 1-hour pad test had a 36% false-negative rate as compared to a 24-hour home pad test. Martan et al. [27] found in 85 patients with incontinence that a modified 1-hour test at 75% of bladder capacity was positive in 44%.

b) Reproducibility:

Klarskov & Hald [28] demonstrated in 3 consecutive 1-hour pad tests, a correlation coefficient of 0.75 and 0.97 depending on the activity regime. The test, however, was quite demanding and a lot of patients did not complete the full testing. Christensen et al. [13] compared a one-hour pad test in two different urological and one Obstetrics & Gynecological departments (20 women). The test results in two urological departments did not differ with an average pad gain of 24g and 21g ($p>0.1$). However, pad test results between the departments of urology and gynaecology differed significantly, with average pad weight gain 9g and 24g respectively ($p<0.05$).

Kralj [29] showed the repetitiveness of a standard one-hour test to be 79%. Repetitiveness of the 2/3 bladder volume test was 84.2% and the full bladder test was 89.4% (n=418)

Lose et al. [30] showed a significant variation between 1-hour ward test and retest in 18 patients (correlation coefficient 0.68). In 50% of patients the leakage volume was variable due to differing bladder volume. When the results of the 1-hour pad test were corrected for urine volume, the correlation coefficient value increased to 0.96. Simons et al [31] found the reproducibility of the standard 1 hour pad test to be poor.

• Validity

Walsh & Mills [9] in the elderly and Holm-Bentzen et al [32] in patients with an AMS artificial sphincter showed that the one hour pad test did not correlate with subjective patient satisfaction but this may due to other lower urinary tract symptoms.

c) Bladder volume

Jorgensen et al [33] showed test-retest correlation was improved when the bladder volume was taken into account and the correlation value (r) raised from 0.68 to 0.93. Fantl et al [34] using a one hour test with the bladder filled to capacity had a test-retest correlation of 0.97 which was improved if the fluid loss was expressed as a percentage of bladder volume. Kralj [29] showed that a one-hour test at 2/3 of a bladder capacity had a correlation value (r) of 0.73 to symptoms of stress urinary incontinence and of 0.63 to symptoms of urge incontinence. Using a one-hour test at full bladder capacity, correlation values (r) of 0.63 for stress incontinence and 0.73 for urge incontinence were obtained. Lose et al. [35] (1988) used a 1-hour pad test with standardised bladder volume of 50% of maximal cystometric capacity (MCC) showed in 25 women a test retest correlation of 0.97 but the intertest variation was up to 24g. Jakobsen et al. [36] compared a 1-hour pad test with a bladder filled to 50% and 75% of maximal cystometric capacity and found that the final bladder volume was equal in both groups showing the importance of diuresis even with equal starting bladder capacities. The amount of leakage in both groups was the same. Simons et al [31] found the volume in the bladder after a standard 1 hour pad test varies by –44 to +66g in a test-retest situation.

The fluid volume in the bladder appears to be critical in making the pad test reproducible and increasing the sensitivity of the test for detecting leakage.

Aslan et al [37] compared a 1 hour pad test loss with the symptom impact index (SII) and the symptom severity index (SSI). Only the SSI showed a relationship between the severity of the score and the pad test loss. The 1 hour pad test has also been used in assessing the validity of the Incontinence Impact Questionnaire and the Urogenital Distress Inventory unfortunately both had poor correlations with the pad test [38]. This is to be expected as the questionnaires assess other urinary symptoms than just leakage.

d) Diagnosis

Fluid loss was significantly greater in patients with detrusor overactivity in comparison to urodynamic stress incontinence [34,39]. The reverse finding was reported by Matharu et al [40]. There is high variability in patients with detrusor overactivity making the test impractical as a diagnostic tool.

e) Sensitivity to change

The 1 hour pad test has been shown to be useful in detecting significant improvements after pelvic floor exercises for men suffering urinary incontinence after radical prostatectomy [41]. Ward et al [42] found the standard 1 hour pad test to show significant reductions in loss after tension free vaginal tape procedures from 18g (IQR 6-37) and Burch colposuspension from 16g (IQR 6-38) both decreasing to 0g (IQR 0). The 1 hour pad test has also been tested for the reduction in loss after conservative and surgical therapy [43]. The changes were significant but there was moderate correlation ($r = 0.53$) with the changes in the St George Urinary Incontinence Score.

3. 2-HOUR PAD TEST

A test period of 60-120 minutes after a 1 litre fluid load was proposed as the optimal duration for the pad test because of a consistently high bladder volume [44]. Han et al [45] showed, however, that a 1-hour pad test is more practical. In children a 2-hour ward pad test yielded 70% positive results for incontinence [46]. Kralj [29] showed a 2-hour pad test repetitiveness of 64.2%. Richmond et al. [47] compared two exercise regimes with a 2-hour pad test and showed no significant differences in regard to which order the exercises were performed. Walters et al. [48] performed a 2-hour pad test with standard exercise in 40 women with SUI showing 78% positive tests (>1g pad gain) after 1 hour and 98% after the second hour. Overall, the two-hours pad test was found to be superior to the one-hour one. There was no correlation between pad test results and the severity of a symptoms score.

II. HOME BASED PAD TESTING

These tests were developed to diagnose and measure urine loss in a situation as close as possible to standard daily life of the patient. The longer observation period usually requires a less structured procedure.

1. 12-HOUR PAD TEST

a) Quantification:

Hellstrom et al. [46] demonstrated in 30 children with incontinence a positive 12-hour home pad test in 68%. When a standard fluid load (13 ml/kg) was instituted in 20 children, the frequency of the positive test increased to 80%.

2. 24-HOUR PAD TEST

a) Quantification:

Lose et al. [24] found a 90% correlation of a 24-hour pad test with history of stress incontinence in 31 women. This was better than the results of a 1-hour test. Thirteen of 31 patients were found to be continent after a 1-hour ward test in comparison to only 3 with a 24-hour home pad test. Mouritsen et al. [25] showed that the 24-h home test is well tolerated and is as good at detecting incontinence as a 48-h test. Griffiths et al. [23] found only a 10% false negative rate of a 24-hour pad test in an elderly population. Using non-parametric coefficient of correlation, they found a significant difference between the 1-hour test and the 24 hour test. Jorgensen et al. [47] found that a 24h home test performed during daily activities is more sensitive that a 1-hour ward test with standardised bladder volume of 200-300 ml. High fluid intake did not change the results of a 24-h home test, but a low fluid intake reduced a positive test by 56% [50]. Ryhammer et al. [51] showed that 24-h test is superior to subjective self-reported assessment of urinary incontinence. Klevmark et al. [52] used “combined test” of a 24h pad test and a frequency-volume chart and suggested several advantages of this combination: diuresis can be monitored and controlled better, and calculation of the percentage of urine loss with respect to a 24 hour diuresis and diagnosis of urge incontinence can be better defined.

b) Reproducibility:

Jorgensen et al. (1985) showed a significantly positive correlation (r=0.82), p<0.001) between the results of two 24-hour home tests. Lose et al [24] showed, however, poor correlation in a test-retest study with a variation of more than 100%. Groutz et al. [53] using Lin’s concordance correlation coefficient (CCC) found 24-h test very reliable instrument. Increasing test duration to 48 and 72 hours slightly improved reliability but decreased patient compliance.

The values for the pad test increase in asymptomatic men and women was reported by Karantanis et al [54] with the median value 0.3g (IQR 0.2 – 0.6; 95th centile 1.3g). It is surprising that the loss is so low and the same for men and women.

c) Diagnosis

Matharu et al [40] found women with urodynamic stress incontinence leaked more than women with detrusor overactivity but the amounts were not diagnostic for the individual abnormalities. Pad test loss is unaffected by the degree of hypermobility however there is an increased loss associated with urethral sphincter incompetence diagnosed by a vesical leak point pressure less than 60 cmH_2O [54].

d) Validity

Karantanis et al [56] found the 24-hour pad test was poorly correlated in women with urodynamic stress incontinence with incontinence episodes on a 3 day urinary diary (Kendall’s corr coeff b = 0.4) and the ICIQ-SF (r = 0.4). Singh et al [57] reported that fewer (52%) women after surgery were willing to complete a 24 hour pad test at follow up.

3. 48-HOUR PAD TEST

a) Quantification:

Jakobsen et al. 19] showed that 48-hour pad test reflects everyday incontinence in 81% of patients. Kralj [29] demonstrated 96% (0.92 specificity) agreement with history of incontinence but commented that it was done entirely by the patient without objective control. No statistical analysis data was given. Ekelund et al. [58] found patients own weighing correlate well to control weighing at the clinic in 48-h pad test (r=0.99) (**Tables 5-6**).

Nygaard and Zmolek [62] in 14 continent women showed a mean pad weight, attributed to sweat for all exercises sessions of 3.19 $\pm$ 3.16 g (the Kendall coefficient of concordance of the test-retest reliability

Table 5. Test-retest correlation

Author	Test	Correlation coefficient	Symptoms
Klarskov&Hald 1984 [28]	1-h	0.96	SUI&UUI
Mundt-Petterssen et al 1984 [57]	1-h	Fairly good	SUI,UUI & MIX
Jorgensen et al. 1985 [49]	1-h	0.27	SUI & MIX
Lose et al 1986 [30]	1-h	0.68	SUI & MIX
Fantl et al. 1987 [34]	1-h (vol)	0.97	SUI
Fantl et al. 1987 [34]	1-h (vol)	0.84	SUI & UUI
Kinn et al. 1985 [21]	10-m (vol)	0.74	SUI
Lose et al. 1988 [32]	45-m (vol)	0.97	SUI & MIX
Victor et al. 1987 [60]	24-h	0.66	SUI
Lose et al. 1989 [24]	24-h	0.82	LUTS
Mouritsen et al. 1989 [25]	24-h	0.87	MIX
Versi et al. (1996) [61]	24-h	0.9	LUTS
Groutz et al. (2000) [53]	24-h	0.89	LUTS
Victor et al. 1987 [60]	48-h	0.9	SUI
Versi et al. (1996) [61]	48-h	0.94	LUTS
Groutz et al. (2000) [53]	48-h	0.95	LUTS

Table 6. Pad-weight gain (g) in normal women

Author	Time	No	Mean (g)	Range (g)	SD	SEM	Note
Hahn & Fall 1991 [17]	20 min	10	0.0				
Nygaard&Zmolek, 1995 [62]	39.5 min	14	3.19	0.1-12.4	3.16		Exercise
Versi&Cardozo 1986 [63]	1h	90	0.39	0-1.15		0.04	
Sutherst et al. 1981 [10]	1h 50	0.26	0-2.1	0.36			
Walsh & Mills, 1981 [9]	2h	6	1.2	0.1-4.0	1.35		Daily activity
Lose et al. 1989 [20]	24h	46	4.0	0-10			
Jorgensen et al., 1987 [18]	24h	23	4.0	0-10			
Mouritsen et al 1989 [25]	24h	25	2.6	0-7			
Karantanis et al 2003 [38]	24h	120	0.3	0-1.3			
Versi et al 1996 [61]	48h	15	7.13	4.32			

was 0.96) but there was a lot of variation between patients. Pyridium staining was not helpful in increasing specificity. Similar results with Piridium was reported by Wall et al. [15] in a 1-hour ward test. In his study (n=18) the Pyridium test was 100% positive in patients with SUI but had false positive results in normal women (52%).

Mean pad weight loss due to evaporation or leakage [9] was calculated to be 1.003 g, and ranged from -6.5 to +3.85 g (SD 1.85 g). Lose et al. [24] showed no evidence of evaporation over 7 days if the pad was stored in a plastic bag. Versi et al. [61] showed pads wetted with saline showed no difference in weight after 1 week and less than 10% weight loss after 8 weeks. Twelve pads were weighed by the patient and a healthcare worker with a coefficient of variance =1.55% with a mean deviation of 49%.

III. COMMENTS

A couple of important methodological issues have been raised concerning the use of pad testing. Khan & Chien [64] eloquently pointed out that test-retest comparison should include methods of blinding and use of an appropriate index of degree of agreement which is the intra-class correlation coefficient. In most of the literature this was not implemented. Kromann-Andersen et al. [65] argued that with considerable inter- and intra-individual variation of urine loss, the correlation of test/retest results may be overestimated and suggested different trials for small, modest and large leakage in large numbers of the patient. This trial has not been carried out.

IV. ROLE OF THE INVESTIGATION

The test has been standardised by ICS [12] for quantification of urine loss and suggested uses for assessment and comparison of treatment results for different urinary incontinence types in different centres. Also, the AUA report on Surgical Management of Female Stress Urinary Incontinence includes a pad test (pretreatment evaluation) as a standard of efficiency for clinical trials [66]. The Urodynamic Society included a pad test in a Standards of Efficacy for Evaluation of Treatment Outcomes in Urinary Incontinence [67]. No suggestion was made in the last two reports of which test to use.

V. SUMMARY

- The 1-hour pad test is not very accurate unless a fixed bladder volume is applied
- Set exercises during the test improve test-retest reliability
- The sequence of exercises has little effect on test results
- A pad weight gain ≥1 g suggests a positive 1h test
- A 24 hour test correlates well with symptoms of incontinence
- A 24-hour test has good reproducibility but poorer compliance
- A pad weight gain ≥1.3g = positive 24 h test
- A test lasting longer than 24 h has little advantage
- A pad test cannot distinguish between urodynamic stress incontinence and detrusor overactivity

VI. RECOMMENDATIONS

- The pad test is an optional investigative tool in routine evaluation of urinary incontinence **(Level of Evidence 3, Grade of Recommendation C)**
- Pad test is a useful outcome measure in clinical trials and research studies. **(Level of Evidence 3, Grade of Recommendation C)**

The following standards are suggested:

- 20 min-1 h ward test with fixed bladder volume (pad weight gain >= 1g = positive test) **(Level of Evidence 3, Grade of Recommendation C)**
- 24 h home pad test during daily activity (pad weight gain >= 1.3g/24h = positive test) **(Level of Evidence 3, Grade of Recommendation C)**

VII. SUGGESTED RESEARCH AREAS

- Proper validation analysis using the coefficient of variability
- Evaluation of the ability to detect all the spectrum of urinary incontinence (from mild to severe)
- Sensitivity to change in time of incontinence status for 24 hour pad tests
- Validity of pad tests with other measures of incontinence such as urinary diaries and system questionnaires

E. OTHER INVESTIGATIONS

I. URINALYSIS IN THE EVALUATION OF THE INCONTINENT PATIENT

“Urinalysis is a fundamental test that should be performed in all urological patients”. Although in many instances a simple dipstick urinalysis provides the necessary information, a complete urinalysis including both chemical and microscopic analysis [1]. In patients with urinary incontinence, urinalysis is not a diagnostic test, but it is rather used to screen for haematuria, glucosuria, pyuria and bacteriuria. Even in the absence of controlled studies, there is general expert consensus that the benefits of urinalysis clearly outweigh the costs involved, although the use of urinalysis should always be associated with prognostic significance [2]. A positive urinalysis will prompt infection treatment and/or the use of additional tests such as endoscopy and urinary tract imaging. In the evaluation of urinary incontinence in the female, urinalysis is recommended since 60% of women with stable bladder will develop detrusor overactivity at the time of urinary tract infection (UTI). Pyuria was found to be common among incontinent but otherwise asymptomatic, female patients. Pyuria was not necessarily associated with UTI, the significance of sterile pyuria in the elderly population is still unclear [3]. A Norwegian survey of general practitioners' management of female urinary incontinence suggested that urinalysis is the most frequently performed test (73%) and is far more frequent than gynaecological examination (54%) [4]. Another survey suggested that urinalysis is one of the three-part assessment of UI together with patient history and physical examination [5]. The same apply, according to Stricker, for patient selection for collagen implant [6]. A minority of the reviewed papers suggested that urine culture should be carried out together with urinalysis [7, 8]. Urinalysis is also considered of importance in the evaluation of nursing home residents who are incontinent [9], in peri- and postmenopausal women [10], in older women reporting urinary incontinence [11]. Belmin J, et al, suggested than significant urine samples can even be obtained from disposable diapers in elderly incontinent women [12, 13]. It is recommended that geriatric incontinent patients undergo history, physical examination, tests of lower urinary tract function and urinalysis. The latter test is proposed to rule out the presence of UTI [14]. The clinical relevance of asymptomatic bacteriuria in the elderly is controversial. Although DuBeau and Resnick suggest the use of urinalysis in the diagnostic algorithm to identify asymptomatic bacteriuria in incontinent residents of nursing homes [15], others consider that the condition does not deserve any treatment [16].

1. Recommendation

- It is considered standard to perform a urinalysis either by using a dipstick test or examining the spun sediment. (**Level of Evidence 3, Grade of Recommendation C**)
- If a dipstick test is used, it is recommended chosing of a “multiproperty” strip that includes fields for haematuria, proteinuria, glucose and ketones, leukocytes esterase (indicating the presence of leukocytes in the urine) and nitrite tests (suggesting bacteriuria). (**Level of Evidence 3, Grade of Recommendation C**)

2. Suggested research areas

Determine the role of urinalysis as a screening test in various incontinent populations.

Determine the prognostic significance of urinalysis in urinary incontinence

II. BLOOD TESTS

The prevalence of renal damage or of biochemical abnormalities in the general population of patients with urinary incontinence is very low, but there are subgroups of patients where the prevalence can be higher (e.g., neurogenic incontinence, overflow incontinence). The routine use of a battery of common chemical and/or haematological tests in patients with urinary incontinence appears to be a prudent rule of good clinical practice in the following situations:

a) chronic retention with incontinence

b) neurogenic LUT dysfunction

c) when surgery is contemplated

d) when there is a clinical suspicion.

Special tests such as ADH and measurement of atrial natriuretic polypeptide have proven useful in research of enuresis in childhood and nocturia in the elderly [1,2]. Changes in the circadian rhythm of these, and probably also other hormones regulating the renal excretion of water, will in the future contribute to a better understanding of pathophysiology. Synthetic ADH analogues have already come into clinical use for the treatment of nocturnal enuresis. However, the clinical value of these specific tests remains to be established.

Sex hormones exert physiological effects on the female urinary tract, with estrogens having an additional influence on the structures of the pelvic floor [3]. High affinity estrogen receptors have been identified in the bladder, trigone, urethra and pubococcigeus muscle of women. Oestrogen pretreatment enhances the contractile response of animal detrusor muscle to alpha-adrenoceptor agonists, cholinomimetics and prostaglandins, as well as enhances the contractile response to alpha-agonists in the urethra. The dependence on oestrogens of the tissues of the lower urinary tract contributes to increased urinary problems in postmenopausal women. Usually oestrogen deficiency is clinically evaluated on the basis of the presence of atrophic urethritis and vaginitis. Estrogen status can be ascertained via plasma estradiol and estrone levels, as well as from parabasal and superficial cell counts from both the urethra and the vagina [4,5]. Recently, Ayshek et al developed a method of determining the ability of plasma to inhibit purified elastase activity and showed that the plasma from 30 women with stress urinary incontinence had a reduced capacity to inhibit the activity of purified elastase compared to 30 age-matched control women. The loss of inhibition of elastase activity might result in increased elastin degradation in connective tissues supporting the bladder and the urethra and contribute to the development of stress incontinence.

1. Recommendation

- Standard chemical tests for renal function are recommended in patients with urinary incontinence and a high probability of renal damage [**Level of Evidence 3, Grade of Recommendation C**]

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2. Suggested research areas

Search for plasma markers of defective pelvic floor connective tissue

III. TISSUE ANALYSIS

Microscopic, morphometric, histochemical and ultrastructural analysis of specimens from the lower urinary tract, pelvic organs and floor is an exciting research area which applied mainly in female urinary incontinence with or without genital prolapse. A defect in connective tissue has been considered to play a role in the pathophysiology of female stress urinary incontinence, possibly associated with defective support due to concomitant genital prolapse.

Brincat et al [1-3] intensively studied skin collagen in relation to menopause, concluding that skin collagen is influenced by sex hormones status and declines after menopause. Skin collagen content from skin biopsy specimens was found to be significantly greater (48%, $p<0.01$) in a group of postmenopausal women (29) treated with sex hormone implants, compared to an untreated group of women (26) who were matched for age. Versi et al [4] hypothesized skin collagen as a model of urethral collagen and concluded that collagen may be the pivot through which oestrogens have their beneficial effect on sphincteric function. The positive effect of oestradiol treatment on vaginal collagen metabolism was confirmed by Jackson et al. in 2002 [5]. Norton et al [6] showed that collagen synthesis is altered in recurrent inguinal haernia and in recurrent genital prolapse. They reported also that joint hypermobility, a clinical marker for abnormal collagen, was prevalent in women with genital prolapse but not in women with stress incontinence. They were not able to show differences in collagen synthesis in women with stress incontinence as later on reported by other authors [7]. Evaluation of collagen content in women with pelvic organ prolapse with or without urinary stress incontinence by Wong et al. revealed a significant reduction in total collagen content versus controls [8].

Different Authors investigated the quality of collagen in pelvic tissue in women with stress urinary incontinence and/or pelvic organ prolapse. Keane et al [9] compared the collagen content, the type I:III collagen ratio and the collagen cross-link content in specimens obtained from periurethral vaginal biopsies in 36 premenopausal nulliparous women with urodynamically proven genuine stress incontinence, with 25 continent controls. Similar results were published more recently by Geopel et al. [10]. Synthesis of collage III type was found to be reduced in the pubocervical fascia of patients with SUI [11] while reduced synthesis of collagen type VII in the arcus tendineous fascia pelvis was reported by Piotr and co-workers [12]. Decreases in the collagen content of cardinal ligaments was described in patients with uterine prolapse [13]. On the contrary, type I expression was found to be independent from the presence of pelvic prolapse or menopausal status [14]

Modification of collagen pattern was reported in patients with urinary stress incontinence by FitzGerald and co-workers [15]. The nulliparous women with genuine stress incontinence had significantly less collagen in their tissues (P <0.0001) compared with the continent controls. There was also a decreased ratio of type I to type III collagen (P= 0.0008) and a decrease of the collagen cross-link content. The concept at the basis of this research line is that there is an active and dynamic ongoing process of turnover and remodelling of the pelvic connective tissue which can explain acquired or congenital, general or sectorial disorders.

Quantitative mRNA expression of matrix metalloproteinases MMP-1, MMP-2, MMP-9 and their inhibitors were measured in vaginal wall tissues from 7 women with SUI/severe pelvic prolapse and compared with 15 continent controls. Increase in MMP-1 mRNA expression and decrease in the inhibitor TIMP-1 mRNA expression suggest an increased collagen breakdown as a pathologic aetiology of incontinence [16]. An higher collagenolytic activity, restricted to uncrosslinked collagen, as measured by urinary levels of helical peptide ?1 (I) 620-633, was found in women with SUI compared to controls [17]

The biomechanical properties of anterior vaginal wall tissue were studied in prolapsed specimens of 8 premenopausal and 10 postmenopausal women using a new method for testing visco-elastic properties of connective tissues. A slightly higher elastic modulus was noted in post-menopausal vaginal tissue, suggesting an age-related phenomenon [18]. Decreased innervation in female stress incontinence is another point of interest. Gilpin, Gosling et al [19] compared histological and histochemical analysis of biopsy samples of pubococcygeus muscle obtained from asymptomatic women and from women with stress urinary incontinence. In incontinent women there was a significant increase in the number of muscle fibres and changes in the diameter of type I (slow-twitch) and type II (fast twitch) fibres showing pathological damage, attributable to partial denervation of the pelvic floor. The presence of striated muscle tissue in biopsies from pubococcygeal muscle has been considered of prognostic importance for the outcome of patients with genuine stress incontinence undergoing anteroposterior vaginal repair. The absence of striated muscle tissue in 19 patients was associated with poor clinical and urodynamic outcome in comparison with 11 patients with the presence of striated muscle tissue in the specimen. Helt et al [20] found no evidence of denervation or reinnervation in levator ani muscle biopsies from incontinent and/or prolapse patients compared to asymptomatic women. Falconer et al [21] studied transvaginal biopsies near the external meatus from 11 stress incontinent women of fertile age and from 10 comparable controls, processed for indirect immunochemistry using protein b gene product 9.5 (PGP 9.5) as a general neuronal marker. Nerve fibre profiles/mm of projected epithelial area were significantly lower in the incontinent group, suggesting decreased innervation. Elbadawi et al [22] in an extensive study program showed distinctive ultrastructural features of muscles, nerves and interstitium of the detrusor in various urodynamic conditions (detrusor overactivity, impaired contractility, outflow obstruction, aging bladder). These findings need to be reproduced by different groups.

Analysis of the relation between collagen content in pubocervical fascia and outcome of incontinence surgery failed to show a significant relation after 5 years of follow-up [23].

In conclusion, tissue analysis in urinary incontinence is an interesting and promising research line. There is a need for further studies on pelvic floor components (connective and muscular tissue) and on detrusor.

1. Recommendation

Tissue analysis is not recommended in the management of urinary incontinence and its use is currently limited to research programmes. **(Level of evidence C, Grade of Recommendation C)**

2. Suggested research areas

- role of vaginal tissue biopsy in establishing the collagen status of connective tissue to guide delivery mode and type of surgical repair
- mechanism by which collagen metabolism is altered
- biomechanical properties of new allograft or syn-

thetic materials and of human vaginal wall

- assessment of in-,vivo properties of allograft and synthetic materials used for incontinence surgery using animal models

F. CONCLUSIONS

Imaging, as other diagnostic techniques suffers a number of limitations in clinical research because of the intrinsic difficulties of evaluating accuracy and validity of it. After sensitivity, specificity, positive and negative predictive values have been defined the clinical benefit of the test needs to be assessed (i.e.: the consequences of the obtained diagnosis on patient management and outcome). Furthermore, research in the field of imaging is mostly non-industry sponsored and this makes more complex to organise and fund properly conducted trials.

Having said this, we have to acknowledge that only a few of the imaging techniques and other investigations we considered have been properly evaluated in the literature with respect to reproducibility, specificity, sensitivity and predictive value in connection with the diagnosis and the management of urinary incontinence. Although it would be unfair to negate that progress has been made since the last consultation was held and a large number of good new papers were available as a knowledge base for this new chapter.

The use of imaging and other investigations, dealt with in this chapter, remains mostly based on expert opinion, common sense, availability and local expertise, rather than on evidence based clinical research. The diagnostic tests we considered can be subdivided into safety tests, tests with specific indications and investigational tests.

Safety tests. They are indicated in all patients complaining of urinary incontinence as they are intended to protect patients' health. They include urinalysis and measurement of post-voiding residual urine. While a consensus is easily achieved for urinalysis, the clinical benefit and cost-effectiveness role of PVR measurement in primary evaluation of urinary incontinence needs to be confirmed in prospective studies.

Tests with specific and selected indications. Upper urinary tract imaging (as well as renal function assessment) may be indicated in cases of neurogenic urinary incontinence with risk of renal damage, chronic retention with incontinence, incontinence associated with severe genitourinary prolapse and suspicion of extraurethral incontinence. No other imaging techniques is recommended in the primary evaluation of uncomplicated urinary incontinence and/or pelvic organ prolapse. Cystourethrography has been well studied in terms of intra- and inter-observer variability, it is not recommended for the diagnosis or classification of urinary incontinence while it is a reasonable option in the preoperative evaluation of complicated and/or recurrent cases. Video urodynamics, remain the gold standard in the evaluation of neurogenic and post-prostatectomy incontinence although the clinical benefit of it remains unclear. In female urinary incontinence videourodynamcis is not recommended. MRI remains the gold standard for the diagnosis of urethral diverticula and ultrasonography stands as a good alternative option. Lumbosacral spine X-rays have specific indications in children with suspect neurologic incontinence without gluteo-sacral stigmata. Imaging of the CNS should be considered when a neurologic disorder is suspected on the basis of clinical, imaging and neurophysiological findings. Urethrocystoscopy is indicated in cases of incontinence with microscopic haematuria, in the evaluation of recurrent or iatrogenic cases, in the evaluation of vesico-vaginal fistula and extra-urethral urinary incontinence.

Endoanal ultrasound and endocoil MRI are the gold standard for the evaluation of anal sphincter disorders, dynamic X-ray imaging remain the standard for evaluating rectal prolapse.

Investigational tests. Pelvic floor ultrasound is widely used as an adjunct to physical examination in patients with urinary incontinence and/or pelvic organ prolaspes. Although the technique is rapidly evolving and much progress has been made in clinical research in this field, ultrasonography remains optional as evidence of its clinical benefit is still weak.

MRI of the pelvic floor is rapidly gaining field in the evaluation of enteroceles and in the morphological analysis of pelvic floor muscles although the evidence of its clinical benefit is still unclear. Both ultrasonography and MRI are the most rapidly evolving techniques and hold promises for potential future clinical applications. Functional neuroimaging continues to provide new insight on functional anatomy of CNS related to vesicourethral function and dysfunction. Many of these tests promise improvements in our knowledge of pathophysiology of urinary incontinence and possibly better management.

The content of the draft inevitably reflects the composition of the Committee which is made of six clinicians and one radiologist with a particular interest in a specific area of imaging. The chapter certainly reveals the enthusiasm the authors poured in clinical research in this area but it is undoubtedly balanced by a collegial discussion of all recommendations and careful the analysis of the level of evidence according to the Oxford guidelines We believe this is the best possible guarantee of an independent and trustful opinion. We hope that this chapter will stimulate clinical research in this field and will inspire those involved in the management of urinary or faecal incontinence and pelvic organ prolapse.

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B. IMAGING IN URINARY INCONTINENCE AND PELVIC FLOOR DYSFUNCTION

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B2-III. MRI IMAGING OF PELVIC FLOOR

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