Committee 7 B

Imaging and Other Investigations

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ABBREVIATIONS

3D	three dimensional
ACC	anterior cyngulate cortex
ACG	anterior cyngulate gyrus
ADH	anti diuretic hormone
ARJ	anorectal junction
ATT	alpha-1 antitrypsin
BBI	bladder base insufficiency
BCR	bulbocavernosus reflex
BMI	body mass index
BOO	bladder outlet obstruction
BWT	bladder wall thickness
CCC	concordance correlation coefficient
CMAP	compound muscle action potential
CMCT	central motor conduction time
CNEMG	concentric needle electromyography
CT	computerised tomography
DO	detrusor overcativity
EAS	external anal sphincter
EAUS	endoanal ultrasound ultrasound sonography
ED	erectile dysfunction
EMG	electromyography
FOV	field of view
HASTE	single-shot turbo spin echo
HOXA	Homebox A
IAS	internal anal sphincter
ICTP	carboxy-terminal telopeptide of type I collagen
IIQ-7	incontinence impact questionnaire
IP	interference pattern
ISD	intrinsic sphincter deficiency
IVU	intra venous urography
LLM	longitudinal layer muscle
LMR	longitudinal muscle of the rectum
LUT	lower urinary tract
LUTD	lower urinary tract dysfunction
LUTS	lower urinary tract symptoms
MCC	maximum cystometric capacity
MEP	motor evoked potential
MMPS	matrix metalloproteinases
MRI	magnetic resonance imaging
MSA	multiple system atrophy
MU	motor unit
MUP	motor unit potential
PA	puboanalis
PAG	periacqueductal grey
PCL	pubococcygeal line
PD	Parkinson's disease
PET	positron emission tomography
PFMT	pelvic floor muscle training
PGPI	patient global perception of improvement
PICP	propeptide of type I procollagen
PIIINP	amino-terminal propeptide of procollagen III
PIVS	posterior intravaginal singplasty
PMC	pontine micturition centre
POP-Q	pelvic organ prolapse quantification
PNTML	pudendal nerve terminal motor latency
PUV	posterior urethrovesical (angle)
PVR	post-void residual
QST	quantitative sensory testing
SCP	sacrocolpopexy
SEP	somatosensory evoked potential
SERMS	selective estrogen-receptor modulators
SFEMG	single fibre electromyography
SII	symptom impact index
SMA	supplementary motor area
SO	symphysis orifice (distance)
SSF	sacrospinous fixation
SSFSE	single-shot fast spin echo
SSI	symptom severity index
SSR	sympathetic skin responses
STARD	Standards for Reporting of Diagnostic Accuracy
SUI	stress urinary incontinence
T/A	turns/amplitude
TE	echo time
TGF-ß	transforming growth factor-ß
TIMP	tissue inhibitor of metalloproteinases
TR	repetition time
UAR	urethral axis at rest
UAS	urethral axis suring straining
UEBW	ultrasound estimated bladder weight
UP	urethropelvic (angle)
UPP	urethral pressure profile
USI	urodynamic stress incontinence
USS	ultrasonography
UTI	urinary tract infection
VCCU	voiding colpo cystourethrography
VUCG	voiding urethrocystogram
WA	white American

CONTENTS

Imaging and Other Investigations

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A. INTRODUCTION

The Committee reviewed the evidence provided in the 2005 edition and updated the chapter with data from the peer-review literature published in the last 4 years. The chapter covers different issues including: imaging, neurophysiological testing, and other investigations (laboratory tests, tissue analysis and Pad test) with reference to paediatric and adult population, male and female subjects, neurogenic and non-neurogenic patients.

Imaging: the Medline database was searched using the following keywords: imaging, urinary incontinence, continence, anal incontinence and faecal incontinence; the search has been limited to period from 2004 to 2008. Neurophysiology: clinical neurophysiology, conventional urodynamics, neurourology, urinary dysfunction. Other investigations: keywords including urinary incontinence, continence, pad test, urinalysis, urine culture, tissue analysis were used. Members of the committee were allocated the different topics of the chapter based on their specific expertise in the field. All committee members reviewed the chapter draft, recommendations were collegially discussed on at the occasion of the ICI meeting in Paris (July 2008), the final draft was then edited first by the Committee Chair and then by the book Editors. As far as imaging is concerned, the chapter is structure based on anatomical issues: upper, lower urinary tract, bowel, central nervous system, and imaging technique: X-rays, ultrasonography, Magnetic Resonance Imaging. Imaging techniques were analysed taking into considerations the technique and its standardisation, intraobserver and interobserver variability, diagnostic accuracy, cost/benefit ratio and clinical benefit.

Levels of evidence and grades of recommendations were provided according to the guidelines of the ICUD summarised elsewhere in this book. Areas of future research were identified. The application of the ICUD guidelines to diagnostic issues such as those dealt with in this chapter is not without problems as they were developed for the evaluation of formal clinical trials. Proper design, implementation and reporting of studies on diagnostic accuracy are essential to improve their quality and make evaluation of research easier. Most of the issues discussed in the present chapter fall within the remits of diagnostic tests and the evaluation of diagnostic accuracy as regulated by the Standards for Reporting of Diagnostic Accuracy (STARD) initiative provides a checklist and flow diagram that are essential to achieve transparent reporting [1]. The highly dynamic world of diagnostic tests requires a rigorous evaluation process to prevent premature dissemination of tests of unproven clinical value. Studies in this particular area provide additional information on patient health status that are important for managing the underlying condition or disorder such as pelvic organ prolapse, urinary or faecal incontinence. Evaluation of diagnostic accuracy can not be separated from analysis of the clinical benefit, in the absence of which diagnostic tests (laboratory and imaging tests, history, physical examination or pathology) can not be recommended.

Imaging studies should follow the suggestions of the STARD initiative and they differ substantially from clinical trials. The aim of clinical studies of diagnostic tests should in fact aim to provide information regarding the diagnostic accuracy of the proposed test. Imaging studies represent per se a unique category because of the known issues involving interrater variability in the interpretation of radiological pictures and the variability in imaging techniques (although this mainly applies to ultrasonography and endoscopy only). Consequently, the criteria proposed by the Agency for Health Care Policy and Research endorsed by the Oxford Centre for Evidence Based Medicine for evaluating levels of evidence and for deriving grades of recommendation do not apply as, for example, randomization is not a issue and consequently, levels of evidence 1 and 2 can not be found in the peer-review literature and grades of recommendation A and B rarely occur. Furthermore recommendation for imaging studies is not just related to the quality of the published manuscripts but on the presence or absence of clinical benefit for the patient category of interest.

Imaging is currently used in the field of urinary and anal incontinence or pelvic organ prolapse to evaluate parameters with proven positive or negative predictive value for patient management or to investigate the prognostic value of novel parameters. Imaging can be used to reduce the diagnostic burden providing information on parameters with known safety or prognostic value (eg: ultrasound imaging of post void residual) or to investigate new parameters that can not be investigated in any other way (eg: bladder wall thickness).

A few considerations on the levels of evidence in imaging studies may be instrumental in reading this chapter and are summarizsed herewith.

Imaging of parameters with known prognostic value (e.g. PVR)

- The first issue is to prove that imaging studies image what they are supposed to image. Although the issue may be trivial in case of PVR imaging or anal sphincter imaging, the issue is relevant in other areas (eg: enterocele imaging) and should be solved using imaging in cadavers or other approaches such as intraoperative confirmation of the observed condition.
- When the imaging is quantitative, accuracy versus the gold standard technique should be provided. When the imaging is qualitative (e.g. presence or absence of vaginal vault prolapse) the diagnostic value should be provided (sensibility sensitivity, specificity, positive and negative predictive value, accuracy, iterrrater and intrarater variablity).
- Once validity has been proven, one can assume that the predictive value of the imaging study is equal to that observed for the parameter measured with the gold standard. The same applies to its value for patient management.

Imaging of parameters with unknown prognostic value (e.g. MRI of the pelvic floor)

- When the imaging in qualitative (eg: intact versus damaged levator ani), once validity is proven, the diagnostic value should be investigated providing sensitivity, specificity, positive and negative predictive value, accuracy, interrater and intrarater variability in cadavers or patients undergoing surgery.
- Once validity is proved, the prognostic value for patient management should be investigated.
- Extramural confirmation of the proposed imaging study is required ideally for both validity and prognostic value or at least for the latter parameter (we can assume that confirmation of the prognostic value is obtained, validity of the imaging technique can be inferred).

A proposal for new levels of evidence and grades of recommendations for imaging studies is provided elsewhere in this book.

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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 was first identified in myelodysplatic children and then considered to apply in all neurogenic 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 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.

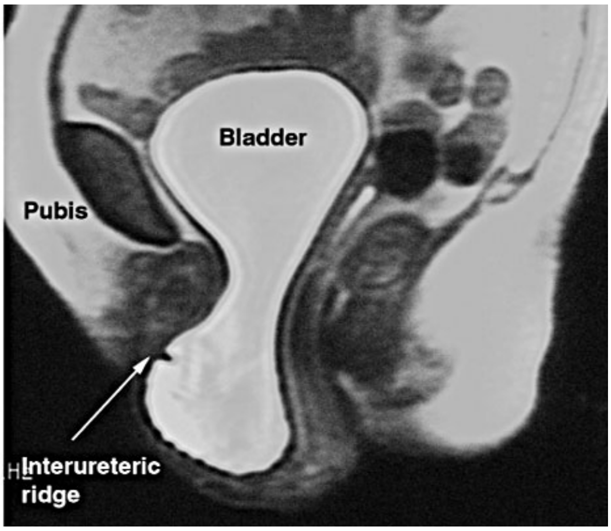

Figure 2 a. MRI: complete urogenital prolapse

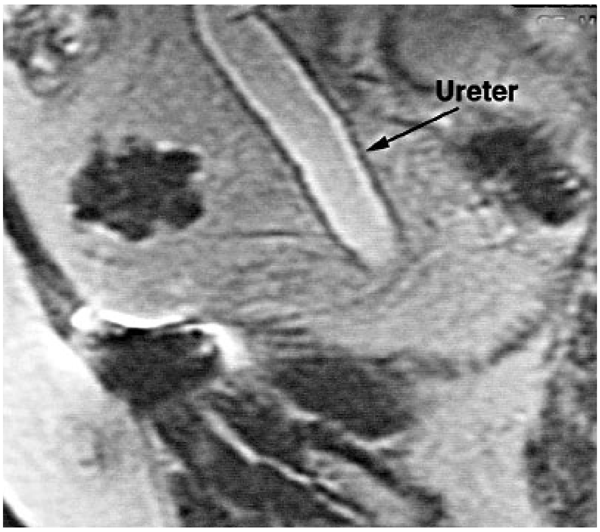

Figure 2-b. MRI: ureteral dilation

Figure 2-c. MRI: ureteral dilation

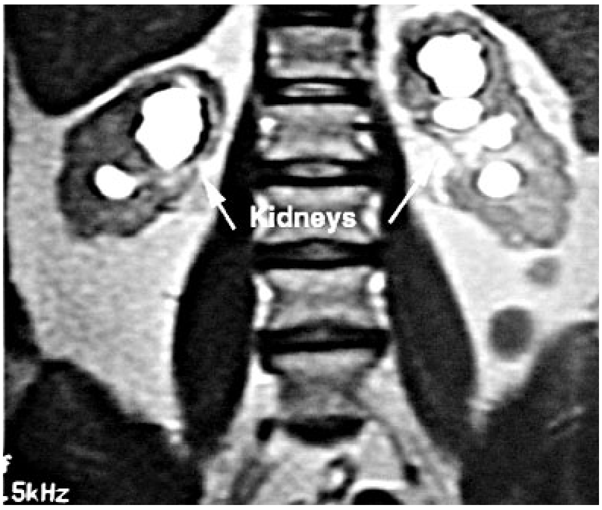

Figure 2-d. MRI bilateral hydronephrosis

II. TECHNIQUES

Upper tract imaging modalities include intravenous ultrasonography (USS), intra-venous urography (IVU), compu-terized tomography (CT scan), 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 wide 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. Although, no correlation exists between the degree of dilatation and the severity of obstruction, the grade of hydronephrosis is correlated with the extent of cortical damage [3]. 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 [4]. Whenever hydronephrosis is diagnosed on USS, other imaging modalities are often used to evaluate renal function, the degree of obstruction or vesico-ureteralhral reflux. USS is an ideal technique to follow the degree of hydronephrosis over time or the response to treatment.

2. INTRAVENOUS UROGRAPHY

Intravenous urography or intravenous pyelography (IVU) 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 examination is currently contraindicate when creatinine levels exceed 2.0 mg/dL [5]. 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 for 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 [6-8]. 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 should be considered [9-11]. 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 [12, 13]. 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 CT and 3D reconstruction software. Differently from IVU which only acquires images in the antero-posterior straight or oblique 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 test 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 (14). In these cases the small size and poor function of the ectopic moiety make diagnosis difficult by IVU.

4. 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 and concerns about its nephrotoxicity have been recently raised [15]. The development of the uro-MRI technique has gained an increasing role for the technology in the evaluation of hydronephrosis and urinary tract anomalies in as an alternative to IVU. MRI usefulness in the diagnosis of ectopic ureter has recently been described [16-18].

Figure 3 a : MRI diagnosis of ureteral ectopia

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

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 [19, 20]. Diuresis renography with bladder drainage is recommended when obstructive uropathy is suspected [21]. Renal scintigraphy may be useful in the evaluation of ectopic ureters associated with hypoplastic kidneys [22].

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***]

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

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B2. IMAGING OF THE LOWER URINARY TRACT

Imaging of the lower urinary tract (LUT) has a long tradition in the management of urinary incontinence, particularly in female patients. The techniques have changed, 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.

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 wave offollowing technological development.

In males the purpose of voiding cystourethrography has been mainly to locate infravesical obstruction although it may play a role in the management of post-prostatectomy incontinence [1]. In children the diagnosis and classification of reflux and diagnosis of posterior urethral valves have been the primary goals [2]. The severity of the vesicoureteric reflux on one side determines the development of contralateral reflux and indicates a poorer resolution rate for the reflux [3].

Positive-pressure urethrography has been designed only for the diagnosis of female urethral diverticula, it was shown to be more sensitive than voiding cystourethrography [4-6] although MRI is the gold standard to diagnose diverticula and assess their anatomical relation to the surrounding structures [7, 8].

I. X-RAY IMAGING

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 have been abandoned. The same applies to outcome research in urinary incontinence where restoration of normal anatomy does 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 interest in 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 cystou-rethrography has been mainly to locate infravesical obstruction [1, 9]. The diagnosis and classification of reflux and diagnosis of posterior urethral valves in children have been the primary goals [2]. In a study comparing cystourethrography with direct radionuclide voiding cystography and voiding urosonography with contrast medium were compared. Voiding sonography and direct radionuclide voiding cystography were shown to be the most sensitive [10].

2. BACKGROUND

History and methodology of cystourethrography in females had been reviewed by Olesen [6]. The technique is now over 70 years old. Voiding cystou-rethrography with lateral projection was first done by Mikulicz-Radecki in 1931 [11]. The use of a metallic bead to identify the urethra was introduced by Stevens and Smith in 1937, and in 1956 Ardran, Simmons and Stewart reported on a cinematographic technique with contrast media also in the vagina and rectum [12, 13]. 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 sixties and seventies [14-18].

3. 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 the lack of quantitative information. Achieving a quasi-physio-logical 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 [11]. 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 is 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 and leak point pressure measu-rements [19, 20]. However, in voiding cystou-rethrography 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 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 [11]. Squeezing can demonstrate pelvic floor awareness and contraction [21].

4. COMBINED IMAGING AND URODYNAMICS

Videourodynamics has been by some regarded as the “gold standard” in the evaluation of lower urinary tract dysfunction [21]. Reproducibility of the combined examination has not been assessed and further the

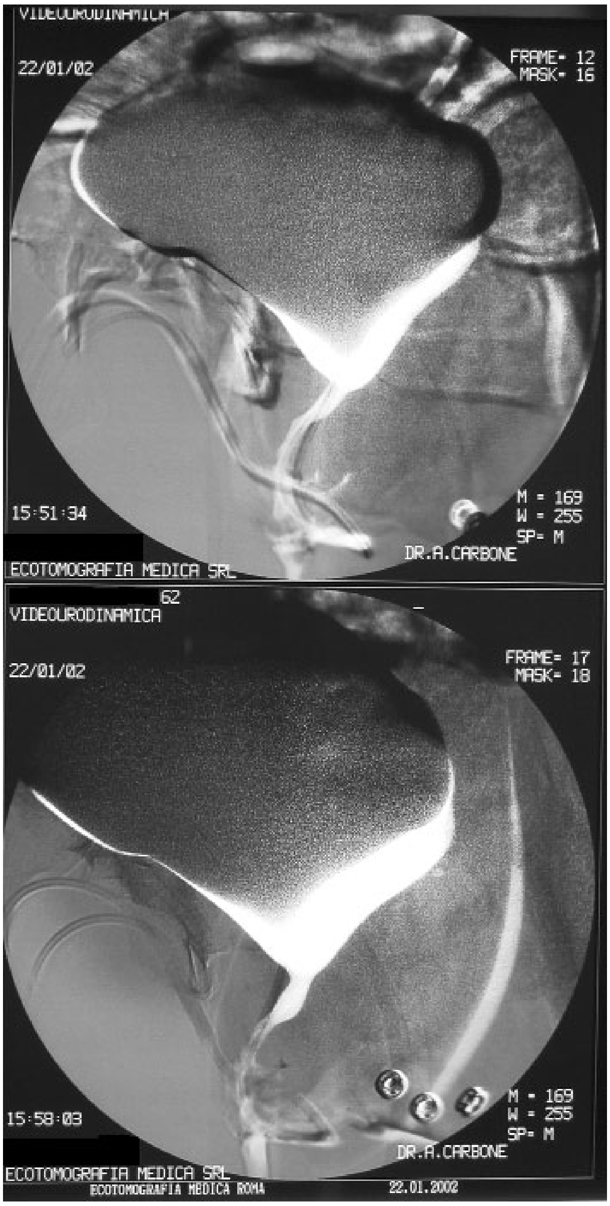


Figure 4 : VCUG with digital substraction (courtesy of Dr Carbone, Rome, Italy)

radiation dose has to be considered [13, 18, 22-24]. One study has attempted to compare videourodynamics with saline cystometry [21]. 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 or urethral diverticula, urethral stenosis and vesicoureteric reflux [1, 9, 12]. 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 [11, 16, 25, 26].

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 sphincter denervation bladder neck at rest and detrusor-external sphincter dyssinergia [27].

Neurogenic patients show severe bladder trabeculation with diverticula and pseudodiverticula, pelviureteric reflux, widening bladder neck and proximal urethra; 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 [28-30]. Urodynamic parameters in children do not discriminate between those with or without vesicoureteral reflux thus videourodynamics have been considered essential. Additionally children with non-neurogenic voiding dysfunction are found to have a number of abnormalities with videourodynamics [31, 32]. Indications for videourodynamics include previous continence and vaginal surgery, neurological disorders and suspicion of urethral diverticula.

5. 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 urethral hypermobility in a modern view of female stress urinary incontinence and this contributed to the gradual abandoning 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 lady women 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 [33]. Cut off values were usually 115° or more [34, 35];

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 [35];

3. The urethropelvic (UP) angle 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° [11];

4. Symphysis orifice (SO) distance 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 descen t [11];

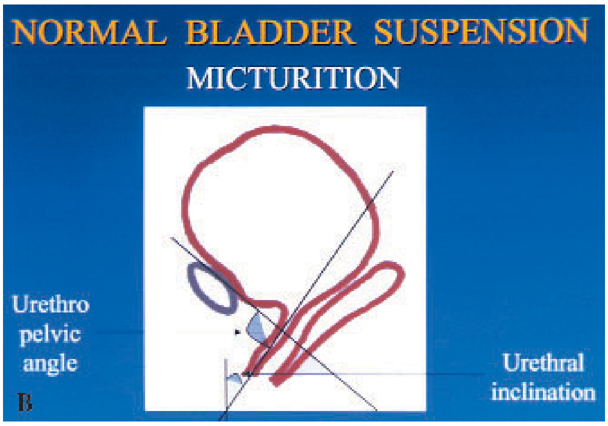
5. The urethral axis at rest (UAR) and during straining (UAS) (**Figure 6**)

Funnelling 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 [34].

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 funnelling of the bladder base at rest or with coughing. The insufficiency can be graded 1-3, which corresponds to Green's type I descent [11, 36]. The supportive defect is supposed to be in the fascial and ligamentous system and their abnormal detachments (eg., paravaginal defects).

Posterior bladder suspension defects (**Figure 8**) are defined as a posterior-inferior bladder displacement and a UP of less than 70° [11]. It corresponds to Green's type II [37]. 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 be close to normal suggesting a relation between the correction of the defective bladder support and cure [37]. A more structured definition of cystocele (ranked by height in centimetres) was also obtained, adding to the



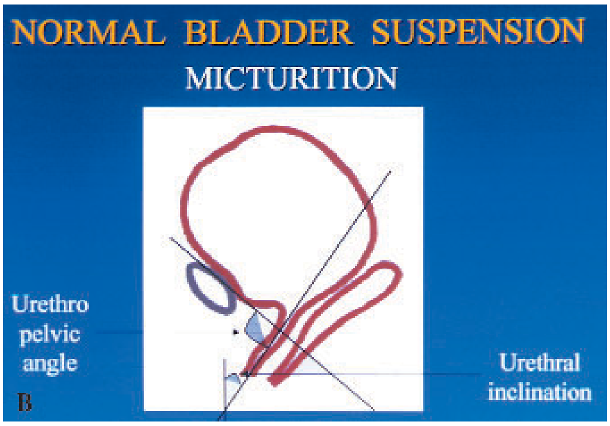


Figure 5 : Female Cysto-urethrography 1a: normal appearance on coughing, straining and squeezing b: normal appearance on voiding

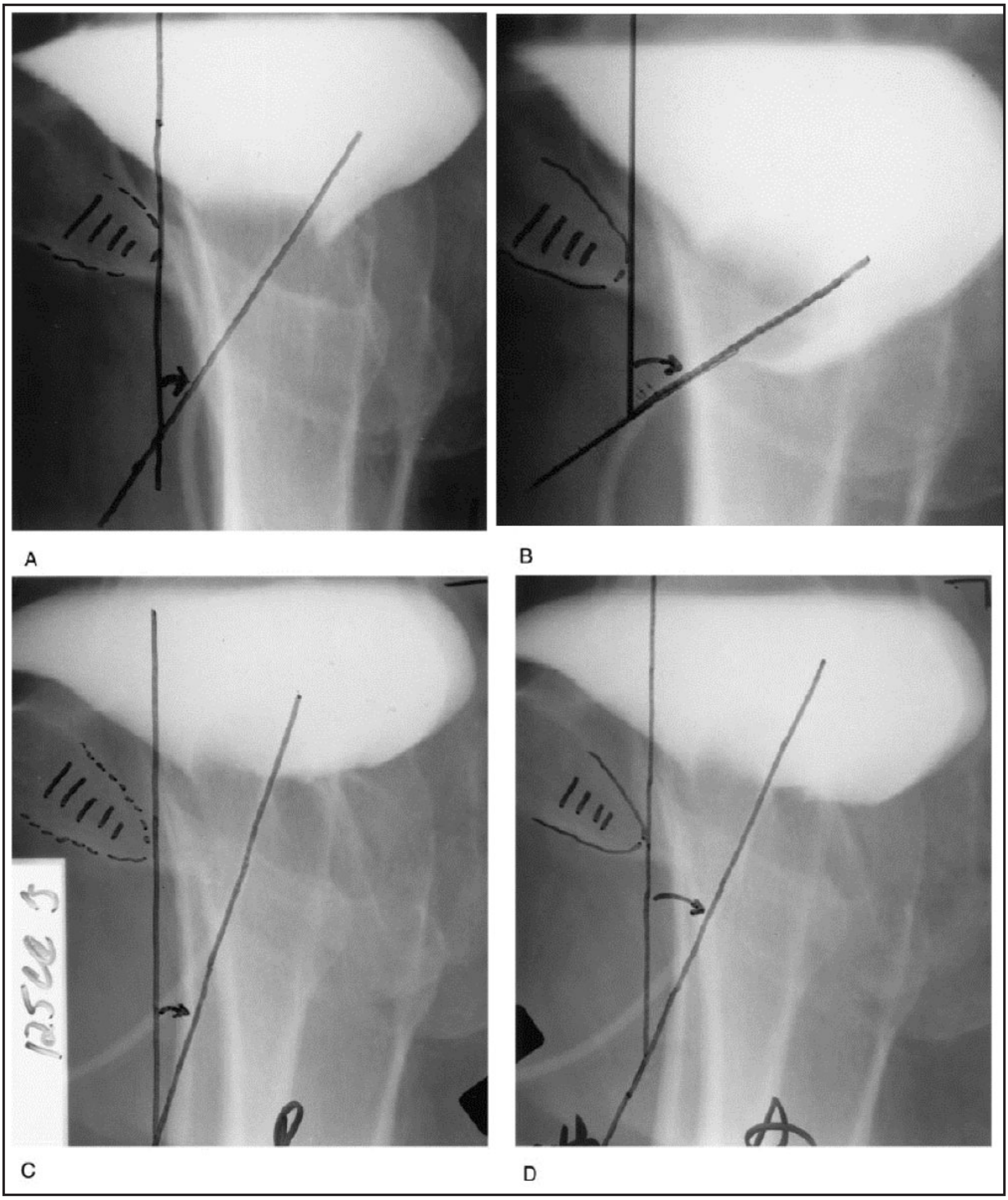


Figure 6 : Example of standing, lateral views on VCUG with 125 mL of contrast within the bladder. (A) Preoperative UAR. (B) Preoperative UAS. (C) Postoperative UAR. (D) Postoperative UAS. The urethral angle is calculated from a reference line drawn through the inferior portion of the pubic symphysis.

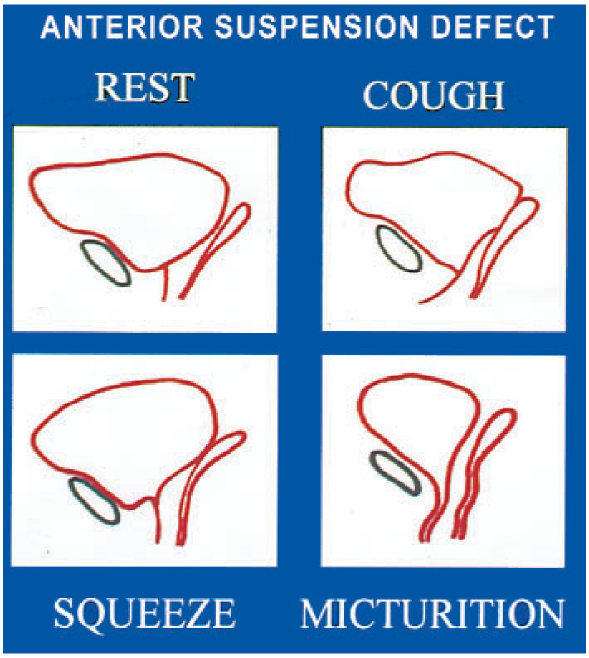


Figure 7 : Female Cysto-urethrography. Anterior bladder suspension defect

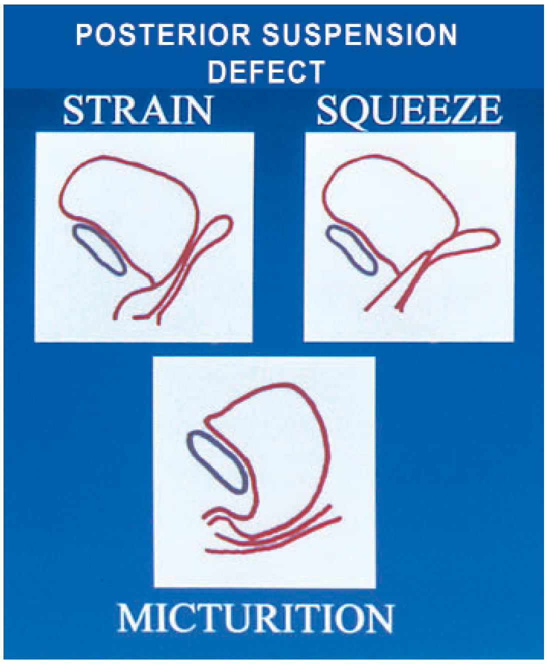


Figure 8 : Female Cysto-urethrography. Posterior bladder suspension defect

emerging data that the reliability of the pelvic organ prolapse quantification (POP-Q) system (POP-Q) increases when measurements are performed in a more upright position [37].

6. REPRODUCIBILITY

The observer variation has been evaluated in four university uro-gynecological units (**Table 1**) [21, 34, 38, 39]. The inter-observer agreement was 43-79% and the intra-observer agreement was 53-99%. These figures are in the same range as has been found for other diagnostic tests [40].

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 ones 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. Unfortunately 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, and therefore, comparison between different materials are difficult [40].

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 although new promising data have been published [35, 37, 41-43]. The specificity of 5 radiological parameters on static bead chain cystourethrography was 44-76% and the sensitivity 53-100% [43, 44]. Neither was the degree of stress incontinence correlated to the type or degree of suspension defects [21, 38, 45]. The positive and negative predictive values for a bladder suspension defect were 0.70 (95% C.I.: 0.62-0.78) and 0.52 (95% C.I. 0.41-0.63) respectively on voiding colpo-cystourethrography [36, 46]. In a later publication on 159 women, positive and negative predictive values of 0.56 and 0.74 were obtained [43]. Evaluation of the 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 9^{th} 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

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 incontinenceurgency 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 incontinenceurgency incontinence 6 observers on type of descent	43-60% kappa 57-98%	72-99% kappa 20-39%
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 [34]. 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 [20];

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 [39].

4: voiding colpo-cystourethrography at rest, coughing, with holding and voiding. Possible diagnoses were: normal appearance and anterior or posterior descent respectively [38];

5: standing voiding cystourethrography, urethral angle was measured ate rest (UAR) and during straining (UAS) [37].

significant. A similarly significant difference was found in patients with moderate to grade 3 cystocele and urethral hypermobility (at least 5 cm descent of the 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-matched) with patients suffering SUI showed a significant difference of UAR and UAS at diagnosis while similar values were found after surgery (**Figure 9**). This was similar to 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.

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

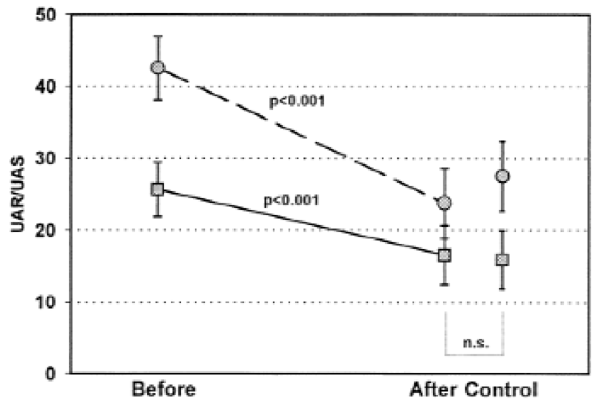


Figure 9 : Mean 6 95% confidence interval for UAR (squares) and UAS (circles) before and after surgical correction compared with age-matched controls. Difference from "before" to "after" was significant for both surgical groups; difference between "after" and "control" was not significant.

papers suggested the inability of the technique to distinguish postoperative failures from success [11, 21, 40, 42, 44, 47-50].

7. COMPARISON OF CYSTOURETHROGRAPHY AND ULTRASONOGRAPHY

The development of USS techniques for the evaluation of the lower urinary tract raised the question of the relationship of X-ray versus USS imaging. Static bead chain cystourethrography has been compared with transrectal and perineal ultrasonography and voiding colpo-cystourethrography has been compared with perineal ultrasonography [44, 45, 51, 52]. The findings correlated well regarding bladder beck 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 [9]. Simple and extensive funneling is more easily imaged in upright patients during cystourethro-graphy than in the supine position frequently used for ultrasound studies [28].

8. COMPARISON OF CYSTOURETHROGRAPHY AND MRI

The introduction of MRI in the assessment of the LUT required an adequate comparison of this technique with standard X-ray imaging. The comparison of cystourethrography and colpocystourethrography with dynamic MRI showed comparable data on bladder neck position and cystocele extension [53, 54]. Although there is an obvious concern about the fact that dynamic MRI is usually performed with the patient lying in a dorsal lithotomy position, comparison of standing and lying colpocystou-rethrography did not showed any significant difference [54].

CONCLUSIONS

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 deficiencies and possibly if new procedures are evaluated for the ability to restore this deficiency.

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

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***].

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)

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II. ULTRASONOGRAPHY

1. BACKGROUND

X-ray imaging has been used for decades in the evaluation of the lower urinary tract; the contrast agents are used to visualize the bladder and a bead chain can help to outline female urethra. Dynamic cystograms, were used to classify female urinary incontinence, the technique was gradually abandoned for its poor accuracy in diagnosing the condition, its little impact on patient management and poor correlation with treatment outcome [1].

Ultrasonography has been used in the evaluation of urinary incontinence as early as 1980 [2]. In the late eighties and nineties of the previous millennium, the quality of ultrasonography greatly improved as well as its availability. Various new developments, such as the use of contrast medium, colour Doppler, 360 degree transducers and three-dimensional imaging have been introduced and have been instrumental to a more widespread use of ultrasonography in the evaluation of pelvic floor disorders.

A number of studies have reported good correlations between ultrasonography and x-ray in the evaluation of urinary incontinence [3-10]. In particular, the position of the bladder neck at rest and during Valsalva manoeuvre has frequently been compared, and all authors agree on a good correlation. Some authors even found a better accuracy for the ultrasonographic method [6], especially in obese women [3]. Ultrasonography is cheaper than X-ray imaging, it is often preferred by physicians because the imaging studies can be performed in their own office as part of the physical examination and it is also more acceptable to patients because of the lack of for radiation exposure.

2. TYPES OF ULTRASONOGRAPHY

Different imaging windows have been used, such as abdominal, transvaginal, transrectal, perineal and transurethral. Synonyms for perineal access are transperineal, introital, labial or translabial access. Abdominal ultrasonography is general not considered to be helpful in pelvic floor imaging because of the acoustic shadow caused by the pubic bones. All types of access have the potential risk of interference with the existing anatomy. With vaginal ultrasonography this risk is probably highest [11], although this has also been denied [12]. Most recent studies report on perineal ultrasonography that allows the visualization of all three compartments in one image.

The development of three-dimensional ultrasonographic systems has brought a new dimension to pelvic floor imaging. Three-dimensional ultrasonography was first described for the female urethra in 1999 [13] ; the three-dimensional image can either be evaluated as a separate entity on the screen, or in combination with each of the two-dimensional planes from which it is derived (**Figure 1**). These three two-dimensional planes are the sagittal, coronal and axial. Three-dimensional images are built up as a rendered image of a self defined region of interest, major advantages over 2D imaging include the possibility to review the acquired images from any investigator and the ability to analyse the acquired volume through any plane (likewise CT scans or MRI) (**Figure 2**) so that, for example, the levator ani muscle can be easily visualised. Four-dimensional imaging, i.e. real-time three-dimensional imaging, incorporates the enormous improvement in speed of three-dimensional systems over the last few years and it makes three-dimensional assessment of the dynamic relation of the pelvic organs on Valsalva manoeuvre and pelvic floor contraction possible.

2. STANDARDISATION

No consensus has been reached as to the standardisation of image orientation. Some prefer orientation with cranial structures above (**Figure 3a**) [14] whereas others prefer presentation of the cranial parts below (**Figure 3b**) [15]. All authors agree that the symphysis pubis, and its inferior border in particular, is a well recognizable and fixed reference point. This point can be used in the evaluation of the various aspects of relevant structures at rest and during dynamic imaging. In general, ultrasonographic studies are performed in the supine position (**Figure 4**). Small differences between the supine and standing position of the patient have been documented, although these differences disappeared during a Valsalva manoeuvre [16]. Only a few studies have been performed in the standing position [17]. There is no clear consensus on the amount of bladder filling, some authors prefer significant bladder filling, others prefer a nearly empty bladder because an empty bladder seems to descend more on Valsalva manoeuvre compared with a full bladder [18, 19]. Attempts to standardize Valsalva manoeuvre, ideally with intra-abdominal pressure measurements, has not been widely accepted [20]. In a recent study [17], a peak flow meter has been used, where women were asked to “huff” maximally and to reach the same force during a number of “huffs”. It has been shown that the mobility of the bladder neck differs between coughing and Valsalva manoeuvre [21]. Co-activation of the pelvic floor muscles during Valsalva manoeuvre has been

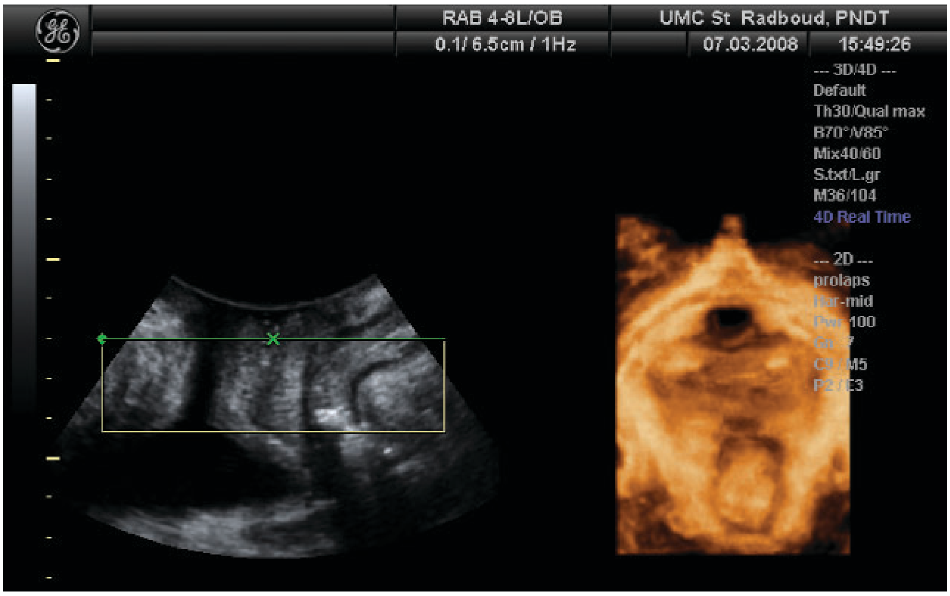

Figure 1 : Perineal midsagital two-dimensional view and three-dimensional rendered image. Normal anatomy.

Figure 2 : Perineal midsagital two-dimensional view. Normal anatomy of the levator ani muscle.

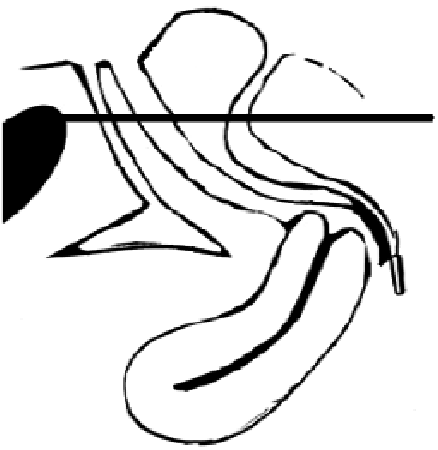

Figure 3a : Perineal midsagital two-dimensional ultrasound view on three compartments and horizontal reference line according to Dietz.

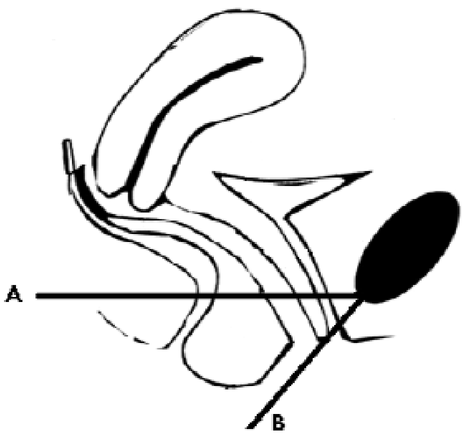

Figure 3b : Perineal midsagital two-dimensional ultrasound view on three compartments and reference lines according to Tunn and Schaer. A= horizontal reference line B= central line of the symphysis as reference line for bladder neck descent.

Figure 4 : Perineal ultrasound examination in the supine position.

documented and is one of the reasons for the lack of standardization [21].

4. THE URETHRA AND BLADDER NECK

When collagen fibres and muscle fibres are located parallel to the ultrasound beam, the structure becomes hypoechoic. These same structures will become hyperechoic, however, when the fibres are located perpendicular to the beam. On two-dimensional ultrasonography, this may result in variable images of the urethra, since the echogeneity of the structures depends on the position of the transducer in relation to the urethra. This may produce confusing images, especially in the dynamic process of pelvic floor contraction and Valsalva manoeuvre. In the midsagittal plane on perineal ultrasonography, and with normal anatomical position of the urethra at rest, the internal sphincter and inner mucosal layer of the urethra will appear hypoechoic (Figure 1), these structures cannot be distinguished from each other on ultrasonography. In the midsagittal plane and with normal anatomical position of the urethra at rest, the striated external sphincter or rhabdosphincter will appear hyperechoic, and can hardly be distinguished from the surrounding structures. It will, however, be easily visible as a hyperechoic circular structure in the axial plane as seen on three-dimensional ultrasonography. The rhabdosphincter has been found to be thinner dorsally [13], and both ventrally and dorsally [22] by various authors and more difficult to distinguish from the internal sphincter ventrally and dorsally compared with laterally [23].

With the use of ultrasonography, thickness and length of the urethral sphincter muscle can be measured and urethral volume calculated [15, 23, 24]. Some make use of intra-urethral ultrasonography for this purpose, [25] others use two- or three-dimensional ultrasonography of the urethra [13, 22, 26, 27]. Comparison of transvaginal and transrectal approach showed a lower degree of urethral compression with the latter approach [22, 28]. Ultrasound measurement of female urethra has been found to be reproducible [13, 27]. Sphincter volume may differ significantly when 2D or 3D imaging is used [27]. Urethral volumes, measured by 3D ultrasonography, were positively correlated with the actual volumes in cadavers [26]. A significant and positive correlation between rhabdosphincter volumes and symptoms and signs of urinary incontinence has been reported [13]; correlations with the urethral pressure profile (UPP) have been found [23, 24, 26, 29] but these data could not be reproduced [30]. Ultrasonography imaging during micturition has been explored with the aid of a remote control systems [31].

The use of intra-urethral ultrasonography with rotating probes (360°) has been proposed by various authors although no particular advantages over perineal US could be identified [25, 32-35].

The advantage of preoperative and intraoperative three-dimensional ultrasound scanning in women with urethral diverticula has been outlined by Yang et al. [36, 37].

5. BLADDER NECK

The bladder neck and proximal urethra are easily visible on all types of ultrasonography without the need for catherization (Figure 1). Measurements are usually taken at rest, during straining (Valsalva manoeuvre), and sometimes during a cough and squeeze. The position and movements are measured in relation to the lower margin of the symphysis pubis. The difference between rest and strain is referred to as the bladder neck descent (the distance between the bladder neck and a horizontal line through the lower end of the symphysis pubis) (**Figure 5**). On Valsalva manoeuvre the bladder neck rotates in a posterior and inferior direction under the symphysis pubis. The axis of the urethra in relation to a vertical or horizontal line can be measured in degrees and provide the degrees of urethral rotation ((hyper) mobility). Other parameters are the posterior urethrovesical angle and the anterior urethrovesical angle.

A number of studies have validated the use of ultrasonography in the assessment of the position and mobility of the bladder neck and proximal urethra. Good results for this validity testing have been reported although the clinical value of such measurements is still elusive [5, 12, 38-40]. Normal values of bladder neck mobility have not been defined, since there is a great range in mobility even in young nulliparous women. In one study amongst nulliparous continent women of approximately 20 years of age, the bladder neck descent varied between 1mm and 40mm [41]. Others [38] found an average descent of 15 mm on Valsalva manoeuvre and 8 mm on a cough. Brandt et al. have found an average bladder neck descent of

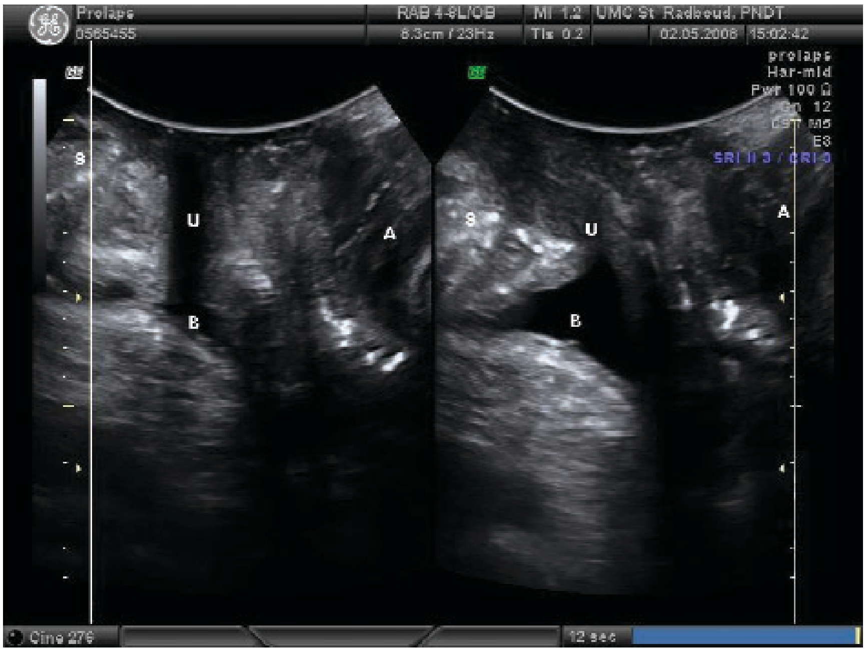

Figure 5 : Perineal midsagital two-dimensional view at rest and on Valsalva maneuvre. Bladder neck descent. (S= symphysis pubis; U= urethra; B= bladder; A= anal canal.)

only 5 mm in 16 year old girls [42]. Racial differences have been demonstrated, with white women having a greater bladder neck mobility compared with black women [43]. Genetic determination of bladder neck mobility has been suggested [44].

Numerous studies have found greater bladder neck mobility in parous compared with nulliparous women [12, 30, 45-47]. Bladder neck hypermobilty, however defined, is considered to be related to stress urinary incontinence [15, 30]. A large number of studies have correlated ultrasonographic findings with urodynamic parameters [47-56]). Specificity and sensitivity of ultrasonography for the diagnosis of stress incontinence were 83 and 68% in one study [50] and 92 and and 96% in another study [57].

One research group has specifically investigated simultaneous perineal ultrasonography and urethrometry. They were able to demonstrate that the variations in urethral pressure were caused by the activity of the urethral sphincter as well the pelvic floor muscles [58]. The contractions from the urethral sphincter are always fast contractions. Some studies have used ultrasonography in an attempt to optimize patient management, but despite the abundant literature on the use of ultrasonography in the work up in women with urinary incontinence, disappointedly, a clinical advantage in terms of patient outcome has not been studied up till now [59, 60].

Urethral funnelling can be observed on ultrasonography (**Figure 6**) particularly wih the use of contrast agents. It is a typical finding in women with stress urinary incontinence but can be seen in asymptomatic women as well [61-63]. In a study on stress incontinent women, funnelling was found to be present in nearly all women [62, 64]. Urinary incontinence can be demonstrated by the use of colour Doppler of the urethra [65, 66]. Colour Doppler has, furthermore, been used to visualize the periurethral vasculature and differences have been described between continent and incontinent women [67, 68] and before and after estrogen supplementation in postmenopausal women. Doppler velocimetry has recently been used in a study on the vascularisation of the levator ani musculature and a correlation has been found between the absence of an end-diastolic shift and the presence of stress urinary incontinence [69].

6. DETERMINATION OF THE POST VOID RESIDUAL URINE AND BLADDER WALL THICKNESS

Ultrasonography is the gold standard technique for measuring bladder volume and post-void residual urine [70-74]. Ultrasonographic data have been compared with residual volumes obtained by in-and-out catheterization under ultrasound control and were found satisfactory. However, Khan et al. have challenged the methodology of these studies and have found deficiencies in all reports on the topic [75]. A simple formula often used is [Height * Width* Depth](cm) * 0.7= Volume (ml) in which the factor 0.7 is the correction for the non circular shape of the bladder.

Automated ultrasound systems for measuring bladder volume and post-void residual have been developed and found to be more accurate than standard ultrasound measurements, furthermore they can be safely used by health care providers with no training in ultrasound imaging and by the nursing staff [76]. These machines are widely used and are, in general, experienced as reliable enough for clinical use, however, in case of ascites [77] or an ovarian cyst [78] for example, the estimated urinary volumes can be

Figure 6 : Perineal midsagittal two-dimensional view. Urethral funneling.

incorrect. Recently the normal values for the post void residual urinary volumes in asymptomatic women have been presented; in 60 year old women, the median residual volume was 19 ml, and 95% of women had a post void residual volume of less than 100 ml [71].

Ultrasound measurement of bladder wall thickness (BWT) and ultrasound estimated bladder weight (UEBW).

Ultrasound measurement of BWT was first proposed as a non-invasive method for diagnosing infravesical obstruction in children [79]. More recently, BWT has been used to predict the outcome of children with primary nocturnal enuresis [79-81]. BWT has also been proposed as a risk factor for upper urinary tract deterioration in children with myelodysplasia [82]. Measurement of BWT was also proposed to diagnose bladder dysfunction (DO and detrusor hypocontractility versus normal detrusor function) in children with urinary tract infection [83, 84]. Additional parameters such as the bladder wall thickness index (length x width x depth of the bladder at full bladder/average BWT) were proposed and a nomogram for the paediatric population provided [85].

In the adult population, higher BWT values have been measured in men than in women. Thickness may certainly differ depending the measurement technique; values of 3.3 ± 1.1 mm and 3.0 ± 1.0 mm, respectively were reported by Hackenberg and co-workers [86]. Oelke confirmed a significant difference between male and female detrusor thickness (1.4 versus 1.2 mm, respectively) [87]. A small increase of detrusor hypertrophy with age has been reported in both genders [86].

In men, measurement of bladder wall thickness proved to be the most sensitive parameter (outperforming uroflowmetry) to diagnose BOO in patients suffering LUTS [88, 89].

Transvaginal ultrasound was first proposed in 1994 for the measurement of BWT in women with bladder volume of less than 20 ml. A significant difference was shown in patients with DO and USI (6.7 ± 0.6 versus 3.5 ± 0.6 mm, respectively). Low intraobserver and interobserver variability were measured: 0.02 mm in both cases with a 95% confidence interval of -0.22 to 0.18 and -0.32 to 0.35 mm, respectively [90].

In 1996, Khullar and co-workers showed how ultrasound measurement of BWT is a sensitive method for diagnosing DO in symptomatic women without bladder outlet obstruction with 94% of women with BWT greater than 5 mm having involuntary detrusor contractions on videocystourethrography or ambulatory urodynamics [91]. In 2002, the same group showed no overlap in the 95% confidence intervals of BWT was shown in patients with DO and USI in women with storage symptoms, confirming the potential of this parameter for diagnosing DO [92]. In 2003, a study on ultrasound cystourethrography in women confirmed a significant association between age and intravesical pressure at maximum flow with BWT [93].

Methodological and technical issues in the ultrasound measurement of bladder wall thickness and weight remain open and constitute a major limitation for a more widespread use of these parameters. In 2005 Chalana and co-workers published an early report on automatic measurement of the ultrasound-estimated bladder weight from three-dimensional ultrasound. An average value of 42 ± 6 g was measured in healthy male subjects. A standard deviation of 4 g was seen among measurements performed in the same subject at different bladder volumes (200 to 400 ml) [94]. Further research in this area is certainly needed and further improvement in the accuracy of automated systems is eagerly awaited.

Although data published in the peer review literature on this subject are quite consistent, two discordant papers were recently published from Australia. Blatt and co-worker showed uniform values of BWT among men and women with non-neurogenic voiding dysfunction suggesting this parameter cannot be used to diagnose storage or voiding dysfunction [95]. A retrospective study on women undergoing translabial ultrasonography suggests a significant association between BWT and DO although a low diagnostic accuracy was shown for the diagnosis of DO which could be due to the fact that translabial ultrasound is unreliable [96].

The association between detrusor hypertrophy and bladder dysfunction (DO and BOO) is a well established fact in Urology. Ultrasound measurement of BWT and UEBW is an interesting alternative approach that may avoid invasive urodynamics in some patients. The development of automated ultrasound systems for measuring UEBW is instrumental to foster further research in this area, particularly in the management of patients with LUTS and in the evaluation of bladder response to pharmacologic treatment.

7. PELVIC FLOOR MUSCLES

Ultrasonography can be used to assess pelvic floor muscles and their function. Contraction of the pelvic floor results in displacement of pelvic structures that can easily be imaged on ultrasound (**Figure 7**) such as the cranial lift of the urethra in relation to the symphysis pubis during a maximal squeeze [16, 97] but also the dimensions of the genital hiatus or the posterior ano-rectal angle can serve this purpose [98]. Comparison with traditional measurements of pelvic floor muscle strength has been performed [97], and good correlations with palpation and perineometry have been found [99, 100]. Ultrasonography has been used to evaluate the effects of pelvic floor muscle training. A higher resting position of the bladder neck and a reduction in the rotational excursion of the urethra during Valsalva manoeuvre has been found with training [101]. Another research group has reported that the thickness of pelvic floor muscles increased after training [102]. A number of studies have assessed healthy female volunteers to establish normal values [41, 102], and one study has specifically compared elite athletes with normal volunteers [103]. Measurements of the levator ani muscle, with the use of two-dimensional imaging, has recently been described, and although direct comparisons to three-dimensional ultrasonography are lacking, the acquired data were comparable [104].

Almost half of women are unable to perform an optimal contraction of the pelvic floor muscles. Ultrasonography can be used in pelvic floor training to provide women a visual feedback of their exercise [16, 105]. In one study, 57% of the women who were not able to perform a proper pelvic floor contraction, were able to do so with the help of visual biofeedback of ultrasonography [16]. Whether this form of biofeedback results in better outcomes from pelvic floor physiotherapy is not known. The contraction of the pelvic floor muscle just before and during a cough, “the knack”, can also be visualized [106]. It has been demonstrated that the knack can significantly reduce urethral mobility during a cough.

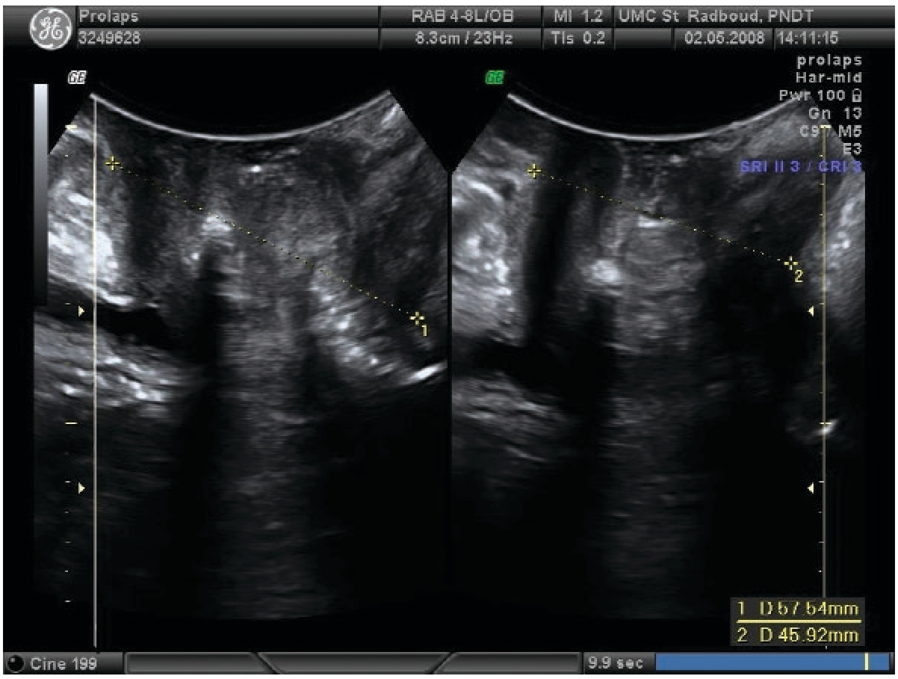

Figure 7 : Perineal midsagital two-dimensional view at rest and on contraction. Levator contraction with ventro-cranial displacement of the urethra. Measurement of minimal dimension of genital hiatus (from symphysis pubis to levator ani muscle)

Direct measurement of the pelvic floor muscles is possible with the use of two and three-dimensional perineal ultrasonography. An alternative technique makes use of a 360 degree rectal probe intravaginally (**Figure 8**) [104]. Most studies, however, have used three-dimensional perineal ultrasonography for this purpose [17, 98, 103, 107, 108]. The thickness of the muscles as well as the hiatal area can be measured. Hiatal dimensions and pelvic floor muscle thickness have been extensively validated and have good test-retest and inter observer characteristics [17].

The pelvic floor muscles were found thinner in women with pelvic organ prolapse [15, 104, 109] and with urinary incontinence [110], whereas their genital hiatus was found larger [111]. Well trained women have thicker pelvic floor muscles compared with controls [103], and Chinese women had thinner muscles compared with Caucasian women [108]. In nulliparous Chinese women, the anterior/posterior hiatal diameter was significantly increased in women with a higher body mass index [108].

Pelvic floor biomechanics were investigated with ultrasound using the position of the bladder neck in combination with continuous vaginal pressure measurements [112, 113]. A novel biosensor was used to measure the force as well as the displacement of the pelvic floor during contraction [114]. Another research group has inserted a water filled plastic bag to study the shape of the vagina during contraction [115]). Others [116] have assessed elasticity by means of the correlation of the dynamic dimensions of the hiatal circumferences and direct palpation of the muscles.

Figure 8 : Intravaginal 360 degree ultrasound imaging. Levator ani muscle, urethra and anal sphincter complex.

8. LEVATOR TRAUMA

Avulsion of the levator ani muscle from the symphysis pubis is known to occur in up to 36% of parous women [59, 117]. The integrity of the attachment of the pelvic floor muscle to the symphysis pubis can be visualised (Figure 2 and 9a). This is best evaluated on a pelvic floor contraction, since detachments are better visualized when the muscle is retracted away from the symphysis, and the potential gap between muscle and bone increases. Another marker of the detachment of the muscle is the loss of the typical H shape of the vagina in the axial plane, with the upper arms of the H hanging aside after detachment (**Figure 9a, 9b**).

It has been shown that the detachment of the levator ani muscle from the symphysis pubis is associated with pelvic organ prolapse with an odds ratio of six [118] especially of the anterior and central compartment [119]. This is similar to results from MRI studies, where it has been shown that the risk of pelvic organ prolapse further increases when the levator injury goes together with vaginal architectural distortion [120, 121]. Although these defects have recently been identified during labour, it is not known whether there is any reasonable (preventive) treatment for these women [118, 122]. There is an increase of the occurrence of levator muscle trauma with maternal age at first delivery [123]. There was a strong correlation between the presence of levator muscle avulsion and poorer muscle strength [124]. It has, however, been shown that the correlation between the clinical assessment (palpation of the muscle) and three-dimensional ultrasonographic assessment of muscular defects was only poor [125], as well as the intero-bserver repeatability of the palpation of defects [126]. A quantification method for levator muscle defects on ultrasonography (tomographic ultrasound imaging) (Figure 9a and 9b) has been described [107].

Another parameter, which has been found to be related to the severity of pelvic organ prolapse, was the size of the inner circumference at minimal hiatal dimension of the levator ani muscle on Valsalva manoeuvre [104, 107, 118]. The area of the levator hiatus on Valsalva manoeuvre ranges from 6 to 36 cm^2 in nulliparous women, with an outlier of almost 50 cm^2 in a young nulliparous athlete [103, 111]. An area of more than 30 cm^2 , 35 cm^2 and 40 cm^2 on Valsalva manoeuvre has been described as mild, moderate and severe ballooning of the genital hiatus respectively (**Figure 10**) [127]. The assessment of the levator hiatus has been shown to be a reproducible measurement [17, 117], whereas the reproducibility was less for muscle

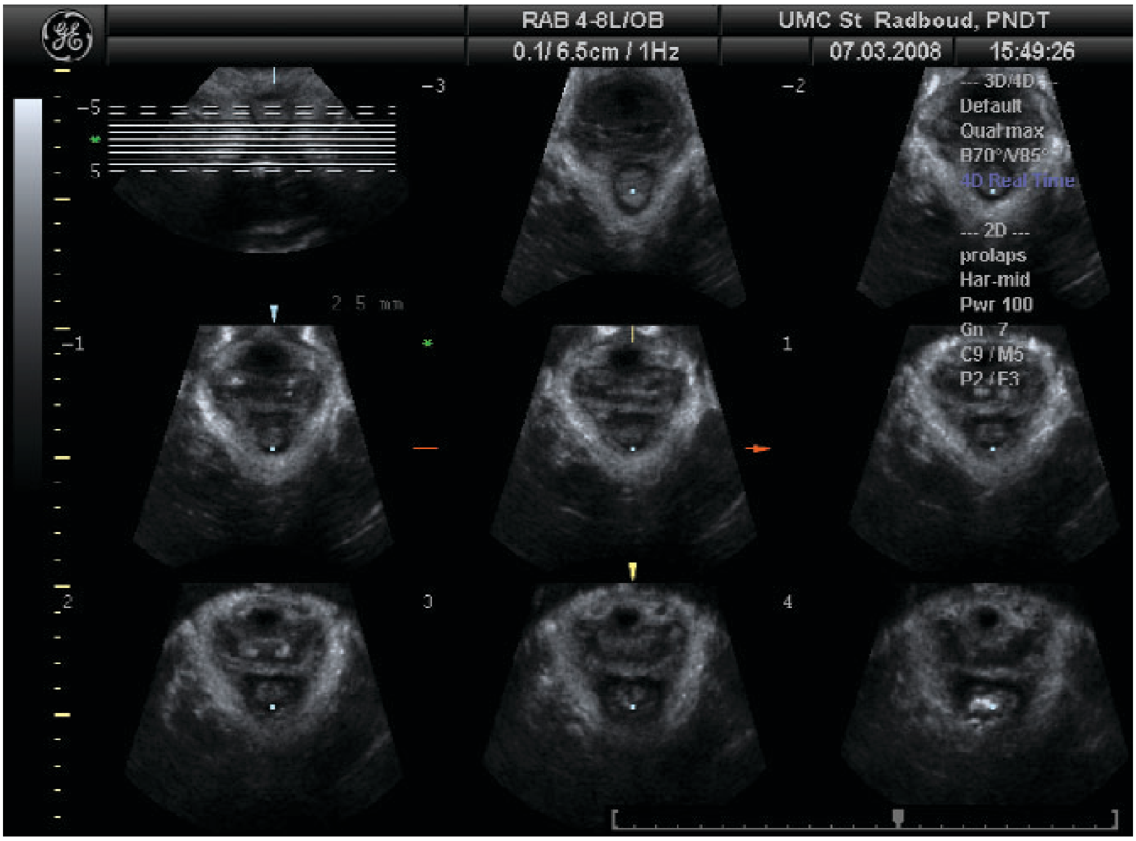

Figure 9a : Tomographic ultrasound imaging (TUI) in oblique axial plane. Normal attachment of the levator ani muscle.

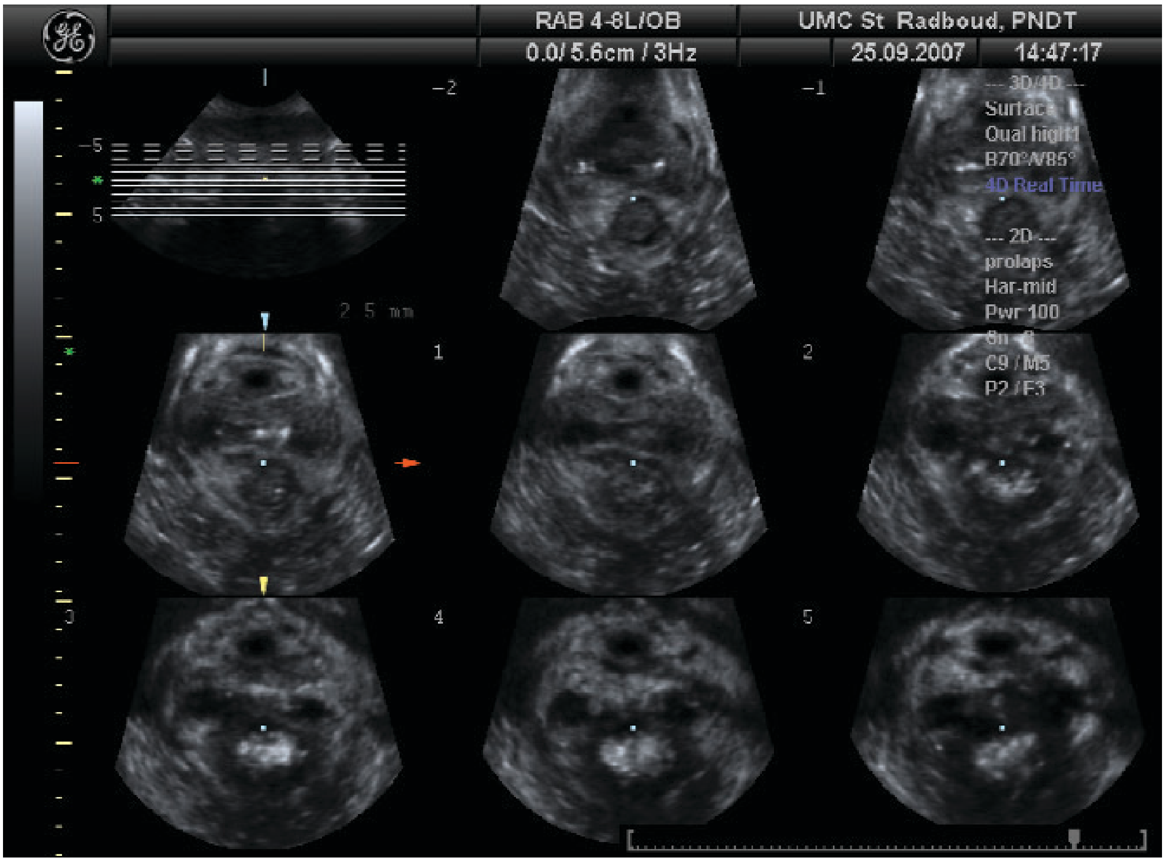

Figure 9b : Tomographic ultrasound imaging (TUI) in oblique axial plane. Both-sided avulsion of the levator ani muscle from the symphysis pubis.

diameter measurements [17, 98, 111]. Comparisons of the hiatal diameters and hiatal area as measured by three-dimensional ultrasonography and MRI revealed good correlations, especially for the measurements at rest. The correlation for hiatal diameter at Valsalva manoeuvre was lower, which is most likely due to the difficulty to reach the correct plane of the levator ani muscle on MRI [128].

The presence and clinical relevance of paravaginal defects represent a controversial issue amongst urogynaecologists, and there is a lack of scientific proof for the concept. In a study by Reisinger et al., an echogenic layer in the lower anterior vagina, which was thought to be a part of the endopelvic fascia, could be identified reproducibly in nulliparous and parous women by transrectal three-dimensional ultrasonography [129]. According to more recent insights, however, previously described paravaginal defects with loss of the H-shape of the vagina in the axial plane on three-dimensional ultrasonography [124, 130, 131] are likely to represent the detachment of the levator ani muscle from the symphysis pubis [132].

9. PELVIC ORGAN PROLAPSE

In cases of mild and moderate pelvic organ prolapse, perineal ultrasonography can be used, for the investigation of the prolapse. Ultrasonography should, however, only be used in addition to the patients history and clinical examination. In cases of severe pelvic organ prolapse, ultrasonographic assessment is impracticable due to transducer dislocation by the prolapse.

The ultrasonographic imaging of the anterior compartment (i.e. bladder, bladder neck and urethra) is the easiest to perform, and the majority of scientific studies deal with this compartment (**Figure 11**). Correlations with clinical examination [133, 134] are also highest for this compartment. Reproducibility of ultrasonographic imaging of prolapse in the anterior compartment were shown to be good [133]. This reproducibility has not been studied for the other two compartments until now.

In studies amongst 83 and 117 women with the uterus in situ, the uterus could be visualized on perineal ultrasonography in 82% and 97% of cases, respectively (**Figure 12**) [134, 135].

A number of studies have focused on the posterior compartment [136-144]). The distinction between enterocele (**Figure 13**) and rectocele (**Figure 14**) is known to be difficult on clinical assessment. In these cases, two-dimensional ultrasonographic imaging in the midsagittal plane can be helpful. The ultrasonographic visualisation of an enterocele has been confirmed with defecography as well as intraoperative findings [136]. It has not been shown, until now, however, whether this extra ultrasonographic investigation indeed leads to superior clinical outcomes of prolapse surgery.

In a study on ultrasonography of the posterior compartment a differentiation between true rectocele, enterocele and perineal hypermobility has been made [139]. Intussusception can also be visualised on ultrasonography [145]. The true rectoceles were diagnosed in case of a sharp discontinuity of the rectovaginal septum, with herniation of the rectal wall through this discontinuity and with a depth of at least 10 mm (**Figure 15**). Perineal hypermobility and an enterocele was seen as a descent of the rectovaginal septum or abdominal content on Valsalva manoeuvre respectively, below a horizontal line through the inferior margin of the sympysis pubis (see below for more information on these measurements). Ultrasonographic staging was significantly correlated with clinical staging and the presence of symptoms of obstructed defecation [15, 140]. In one third of the patients with clinically diagnosed rectocele, however, no ultrasonographic abnormality could be found. As far as interrater reliability was concerned, two expert ultrasonographists have reached moderate to good interrater reliability for the detection of a rectovaginal septum defect, descent of rectal ampulla, and the depth and width of a rectocele [139].

In one study, rectocele and perineal hypermobility were present in nulliparous women in 12 and 13% respectively the significance of these findings has not yet been determined [141].

The posterior anorectal angle, which is the angle between the anal canal and the posterior rectal wall, can be measured at rest and under dynamic circumstances such as straining and squeezing. A number of studies have compared these findings with defecography and found in general a good correlation [143, 144, 146].

10. QUANTITATIVE ASSESSMENT OF PELVIC ORGAN PROLAPSE

In the quantitative assessment of prolapse in the various compartments, a reference line, such as the hymen in POPQ, is needed. For ultrasonography, a horizontal line drawn from the inferior margin of the symphysis pubis is the most widely used reference line for the purpose (Figure 3a). A disadvantage of this line is that only one fixed point through which the reference line is drawn is available, and the horizontal line may thus change with the rotation of a handheld transducer. The effect of rotation is obviously increasing with the distance from the fixed point, and consequently is greatest in the posterior compartment [134]. Although this problem has been overcome in research settings with the use of motion tracking systems, at the moment this is not a realistic option for routine use in clinical practice [147]. For quantitative assessment of rectoceles, the depths of the rectocele as measured

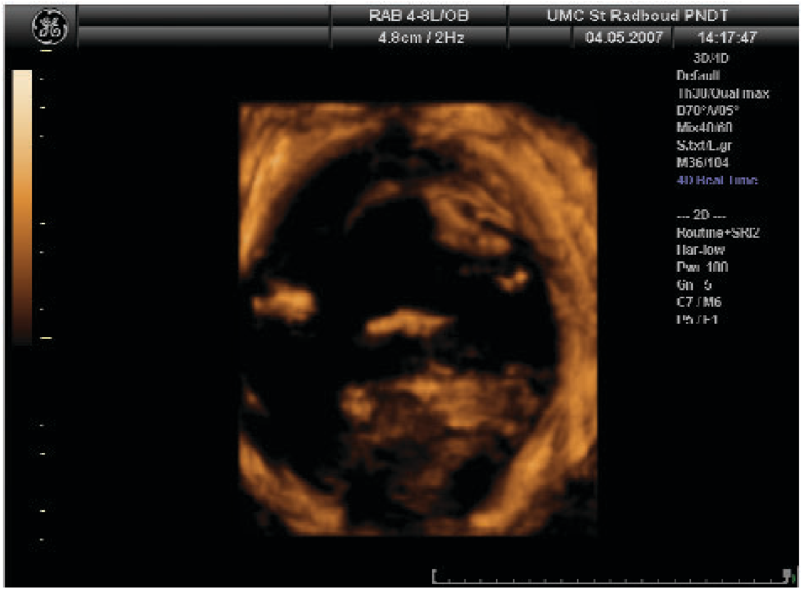

Figure 10 : Perineal three-dimensional rendered image. Ballooning of the genital hiatus.

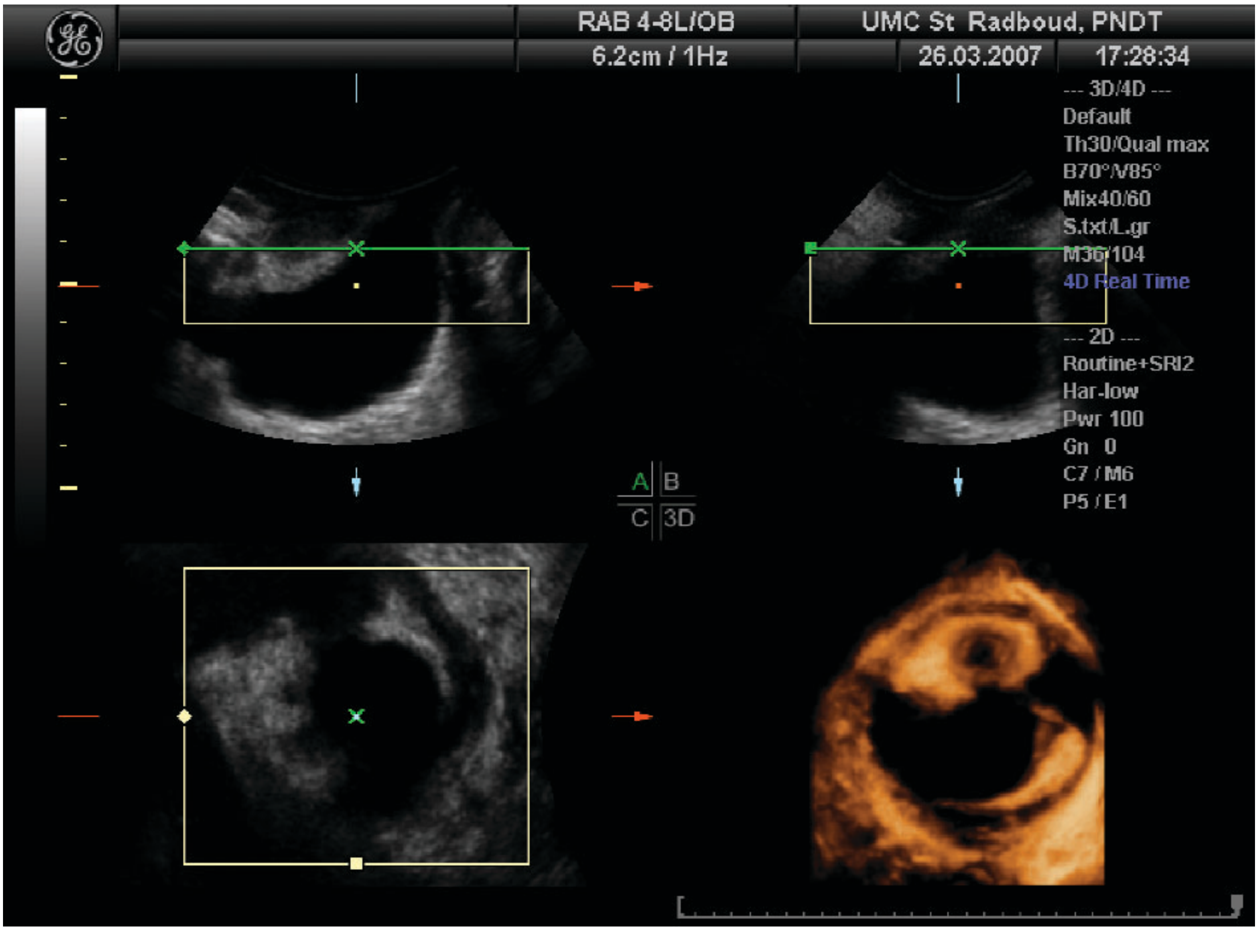

Figure 11 : Perineal midsagital [left upper], coronal [right upper] and axial [left lower] two-dimensional view and three-dimensional rendered image [right lower] .Cystocele.

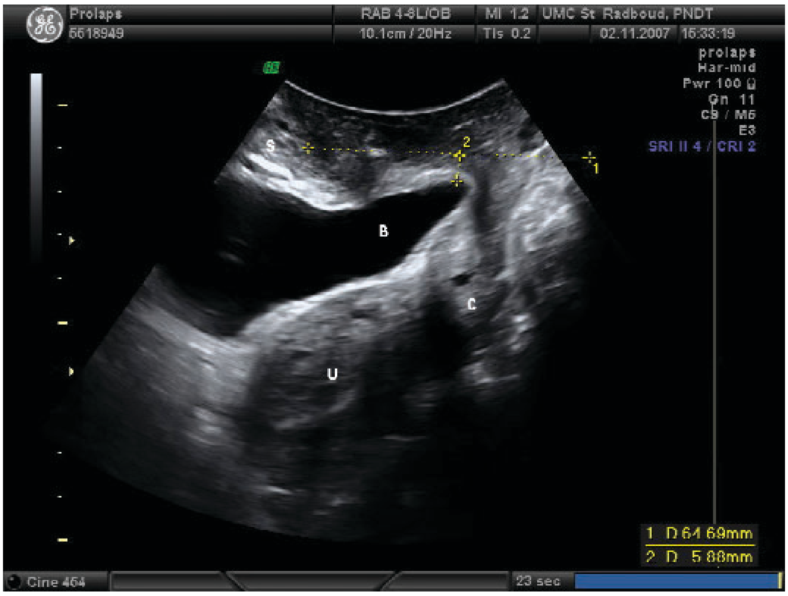

Figure 12 : Perineal midsagital two-dimensional view. Cystocele and descending uterus. (S= symphysis pubis; B= bladder; U= Uterus; C= cervix.)

Figure 13 : Perineal midsagital two-dimensional view and three-dimensional rendered image. Enterocele. (S= symphysis pubis; B= bladder; E= enterocele; R= rectum; A= anal canal.)

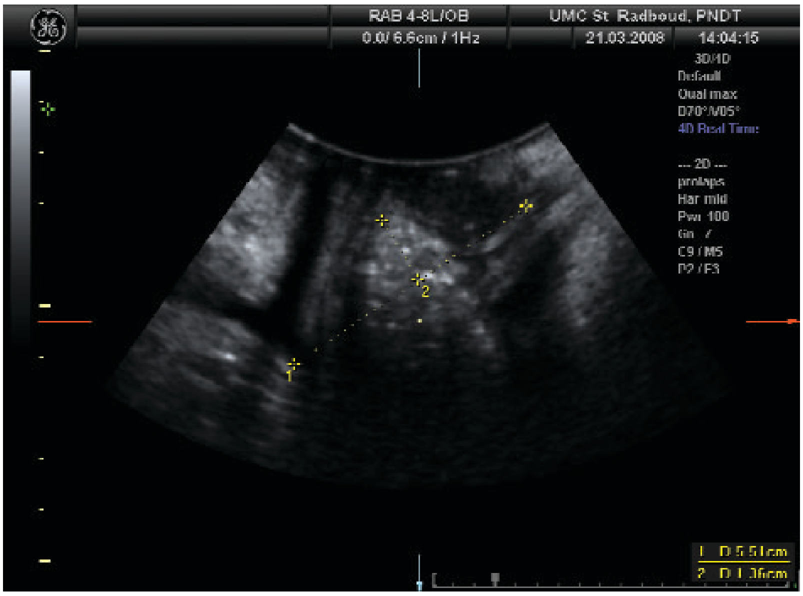

Figure 14 : Perineal midsagital two-dimensional view. Measurement of the depth of the rectocele, perpendicular to a straight line through the anterior border of the anal sphincter complex, i.e. 14 mm.

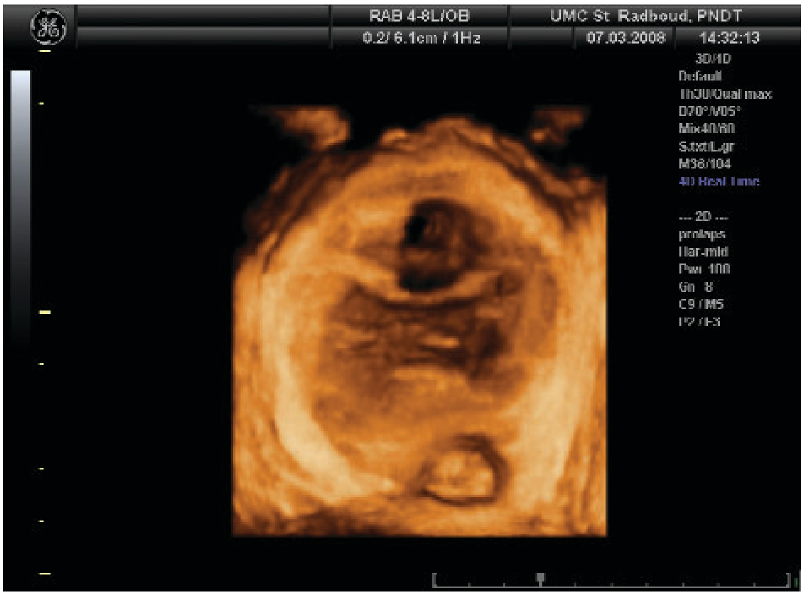

Figure 15 : Perineal three-dimensional rendered image. Polypropylene mesh (TVT-O) after one-sided incision of the tape.

in relation to a line through the anterior anal canal, may be more useful as compared with the descent in relation to the horizontal reference line [148].

Since pelvic organ prolapse can be visualised well with the use of ultrasonography, it raises the question whether this assessment modality is superior to others, such as clinical examination. In a recent study on the relationship between prolapse symptoms and the most dependent point of the prolapse on POPQ and on ultrasonographic assessment, POPQ performed better in the prediction of prolapse symptoms with increasing stages of prolapse [148]. In a previous study, where only women with a single compartment prolapse were studied, the area under the receiver operating curve was, however, as good as 0.86 and 0.82 for the anterior and posterior compartment respectively [149]. In both studies the cut-off value for symptomatic prolapse averaged 15 mm below the horizontal reference line through the symphysis pubis.

As far as dynamic MRI and X-ray defecography are concerned, there are only a few studies available as yet, on comparisons with ultrasonography. For enterocele detection in women with obstructed defecation, perineal ultrasonography has been compared with X-ray defecography, but not with the clinical findings [143]. In the women in whom enterocele had been detected by either method, the enterocele was detected by both ultrasonography and X-ray in 71% of women. In this study, perineal ultrasonography showed more severe stages of enterocele compared with X-ray defecography. In another recent study from a different research group, X-ray defecography has been compared with perineal ultrasonography using a vaginal probe in women with impairment of the posterior pelvic floor. Good to excellent concordance has been found for the assessment of the anorectal angle, rectocele and intussusception. The authors claimed, however, that rectoceles with a depth less then 20 mm could not be detected on ultrasonography [138], which is discordant with most other publications on the topic and as well as the authors' experience.

11. ULTRASONOGRAPHY IN RELATION TO PREGNANCY AND DELIVERY

Vaginal childbirth is commonly accepted as the major risk factor for the development of pelvic organ prolapse later in life. In nulligravid women, however, a wide variation in pelvic organ descent has been shown for all three compartments [114, 135, 150-152]. In a study on 169 women who underwent ultrasonography during and after pregnancy, a significant increase in pelvic organ mobility (downwards displacement) has been found in all three compartments [153]. The increase in mobility was significantly correlated with the length of second stage of labour and the mode of delivery. The highest mobility was found in women who underwent an operative vaginal delivery, but no association was found with the length of gestation at delivery, with the length of the first stage of labour, and with birth weight, although birth weight reached borderline significance. In a similar study, focussing on the posterior compartment in 52 nulliparous pregnant women, 8 women developed de novo true rectoceles, and the descent of the rectovaginal septum increased with 22 mm for the entire group, which was statistically significant [154]. On the other hand, in a study amongst 207 women, of whom half of the women had a clinically diagnosed rectocele, no relation has been found with (vaginal) parity, and only a weak correlation has been found with age for a posterior vaginal wall prolapse as assessed with ultrasonography [139]. This suggests that the effect of vaginal parity on pelvic organ descent, is most evident in the anterior and central compartment, and may have another pathophysiology compared with the posterior compartment [153]). Concerning bladder neck descent, it has been shown that the first delivery caused the most marked changes compared with the subsequent deliveries, with the most marked changes with forceps delivery [155].

Another interesting point of view came from two different research groups, who have reported that an increased antenatal ultrasonographic bladder neck descent was associated with normal vaginal delivery [156, 157]. Furthermore, vaginal delivery was strongly associated with a larger, and more distensible antenatal levator hiatus [156]. The underlying reason remains hypothetical, but more antenatal laxity of the structures may allow for a smoother delivery. Women with increased bladder neck mobility, however, also have a increased risk of de novo urinary incontinence post partum [20].

Avulsion of the levator ani muscle from the symphysis pubis, as outline above, is typically found in vaginally parous women only (Figure 9b) [117, 119, 158]. It has, furthermore, been shown that a higher maternal age at first vaginal delivery is strongly related to an increased risk of these avulsions [117, 158]. These avulsions are again associated with an increased risk of urinary incontinence and more severe stages of prolapse later in life.

12. PELVIC FLOOR SURGERY

Ultrasonography has been used during anti-incontinence surgery with the aim of obtaining optimal results from surgery, for example during Burch colposuspension [159, 160]. On an individual basis, the bladder neck was lifted between 1 mm and 10 mm. The authors have obtained excellent results with a 94% continence rate after 1 year, but unfortunately no control group was incorporated in the study.

13. SLINGS AND MESHES

Monofilament meshes, for example polypropylene meshes, are easier to visualise on ultrasonography compared with multifilament meshes, such as IVS [161]. Ultrasonography has been widely used to localize the exact position of tension free midurethral tapes (Figure 15) [156, 162-165]. The tape is generally easily visible as an hyperechogenic structure under the urethra and is easy to recognize, which is in contrast with the poor visualisation on MRI [166]. Exact midurethral position of the tape is not essential for proper function [167]. Despite the fact that the tape was located in the midurethra in only two-third of cases, this had no relation to postoperative continence status [168]. During Valsalva manoeuvre, the tape moves in a semicircle movement around the inferior margin of the symphysis pubis [169]. This results in a position closer to the symphysis, which consequently leads to a certain degree of mechanical compression during Valsalva manoeuvre. Another mechanism of action is kinking of the urethra around the tape [170]. A number of studies have studied transobturator tape and compared these with retropubic tapes [161, 171-174]. Two studies could not detect any differences between the two types of tape [161, 174], whereas in the other two studies [171, 173], subtle differences with no apparent clinical consequences were found. No study has found a clear correlation between cure of stress incontinence or post-operative voiding troubles and the position of the tape.

Recently, ultrasonographic localization of polypropylene mesh as used in prolapse surgery has been described (**Figure 16 and 17**) [175]. These meshes are usually easily visible on ultrasonography. It appears that the ultrasonographic appearance of the mesh is significantly shorter than the size at implantation. It is unclear whether this is due to shrinkage of the mesh or represents difficulties in visualizing the full extent of the implanted mesh.

Perineal ultrasonography can, furthermore, be helpful in the assessment of recurrences after mesh implantation. The differentiation between recurrent herniation and the detachment of the mesh arms from the pelvic sidewall for example, will aid in the better understanding of the mode of action of these meshes [176].

14. BULKING AGENTS / INJECTABLES

Periuretral bulking agents/injectables, such as microparticulate silicone (Macroplastique), various gels (e.g. Durasphere, Zuidex) and collagen, can be visualized by imaging techniques. For MRI, an overview of appearances of periurethral bulking agents is already available [177]. On ultrasonography, the injectables appear hypoechoic after injection, and become more hyperechoic over time due to dehydrogenation. Good intra-observer variability of repeated measurements of periurethral collagen volumes have been found [178].

The location in relation to the bladder neck and a circumferential distribution of collagen injectables around the urethra, as well as the height and volumes of the injected periurethral collagen bumps, were associated with the treatment success of periurethral bulking agents [178-180]. Although the volume range was wide, a collagen volume of 2.8 cc on three-dimensional ultrasonography has been assessed as optimum volume from a continence point of view. Poon et al. have published a decision tree, in which a combination of the patients´ symptoms after collagen injection and the configuration and volume of the periurethral collagen on three-dimensional ultrasonography, assist in the decision for further treatment of women with intrinsic sphincter deficiency [178]. In this algorithm, women with asymmetric deposition and/or low collagen volumes were offered further treatment with injectables.

Figure 16 : Perineal midsagital two-dimensional view. Polypropylene mesh of the anterior vaginal wall (Prolift anterior).

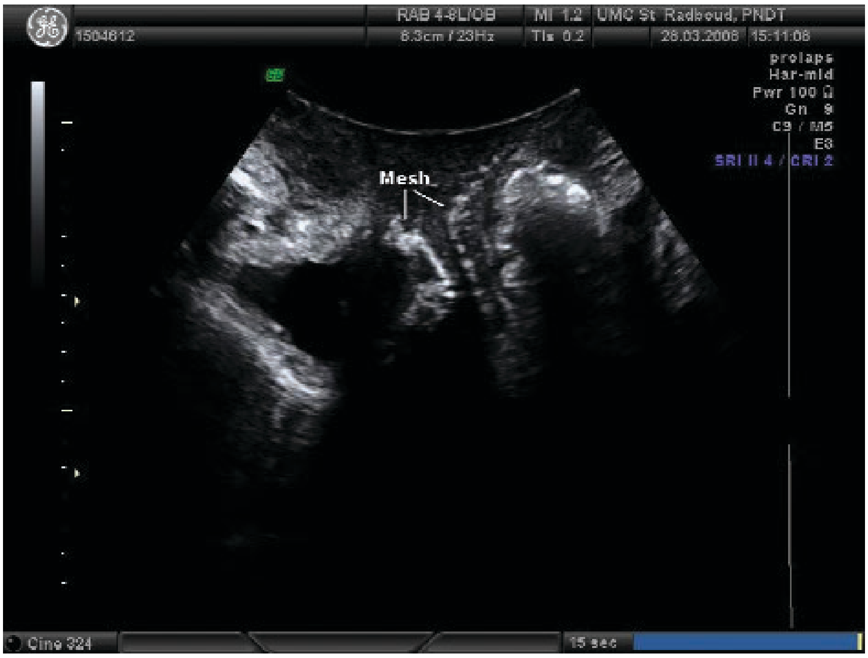

Figure 17 : Perineal midsagital two-dimensional view. Polypropylene mesh of the anterior and posterior vaginal wall (Prolift).

Ultrasonography has not only been used for follow-up, but also during placement of periurethral injections. Transurethral ultrasonography-guided injection of autologous stem cells has been used in women and men with stress urinary incontinence.

The technique allowed precise injection of the myoblasts directly into the rhabdosphincter, and was more effective in the resolution of incontinence compared with urethroscopic guided collagen injectables in the submucosa in a randomized controlled trial [181, 182]. The use of stem cells in the management of urinary incontinence is of great interest although the subject remains controversial and confirmatory studies are eagerly awaited.

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III. MRI

1. BACKGROUND

The role of MRI in evaluating pelvic floor disorders continues to evolve. This technique provides unparalleled images of pelvic floor muscles, connective tissue, and organs. In addition to the detailed static picture of the pelvic organ support system anatomy, MRI can also reveal the downward movement of each pelvic compartment during increases in abdominal pressure. Advances in MRI equipment and software have significantly improved image quality and provides ever more detailed pictures of anatomy and function. At present active investigation is ongoing to try to see if and how this imaging might result in a better understanding of these diseases.

One proposed rationale for the use of MRI in the evaluation pelvic floor disorders 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 and that imaging can provide information to extend what can be determined on physical examination [1]. Furthermore, it has been suggested that 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 of 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 ioniszing radiation [8-17]. MRI 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.

Proof that MRI has value will eventually need to come from increased operative success rates. It is possible that better documentation of preoperative and postoperative anatomy could allow us to seek reasons for of operative failure. Because MRI provides a detailed picture of a woman's pre-operative anatomy, once operative failures are discovered, it would be possible to look back at images from women with successful and unsuccessful operations to seek anatomical explanations for failure. This chapter provides a current view of where we are in evaluating the role of MRI in understanding the cause and treatment of pelvic organ prolapse.

2. METHODOLOGY

a) Conventional MRI

Standard MRI consists of two dimensional image acquisitions. Usually conventional T1 images and spin echo T2 weighted images are obtained and specifically proton density T2 weighted scans provide excellent soft-tissue definition (**Figure 1**). 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]. Recent improvements in Magnet strength and instrument refinement produce remarkable images.

b) Ultra fast image acquisition and MRI sequences

It is possible to see pelvic organ movement during Valsalva using very fast single-shot MRI sequences allowing excellent visualization of the pelvic floor in women [14,15,22-23]. These sequences images allow a series of images to be obtained approximately once per second, either by acquiring 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 centred 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 apnea with the patient relaxed and during various degrees of progressive abdominal straining (Figure 2).

During a typical study two sets of images are obtained. The first set consists of static sagittal and para-sagittal

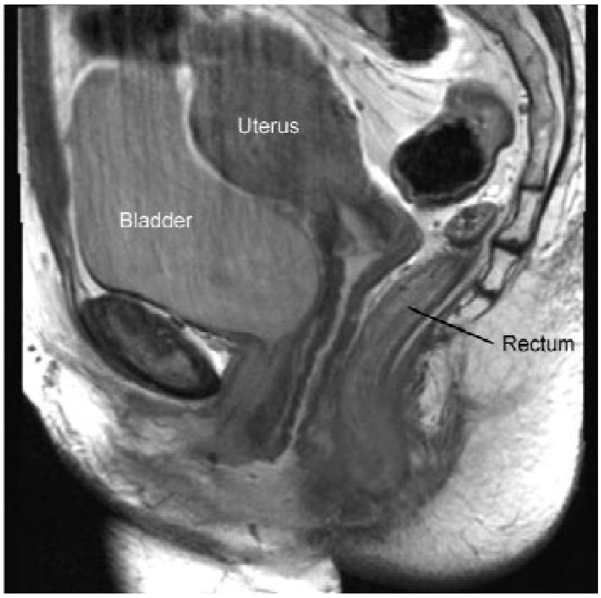

Figure 1 : Sagittal mid pelvic section showing anatomical detail visible in static images made with Proton Density sequence.

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 1). The perineal membrane 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 2 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.

c) Three dimensional MRI

Three dimensional (3-D) MRI provides great detail of the bony and muscular pelvic structures (**Figure 3**). 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°.

3. NORMAL PELVIC ORGAN SUPPORT

Static, dynamic and three-dimensional MRI studies of normal subjects have improved our understanding of normal pelvic anatomy [24-26]. The use of MRI to image the pelvic floor musculature has also contributed greatly to our understanding of pelvic floor dysfunction [19, 21, 27]. MRI 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 [27, 28]. 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. Studies are usually done with the patients supine and so the anatomy as it is seen in the standing position is not generally possible. Upright static and dynamic MRI are possible, but are used mostly as a research tool because they are 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.

4. PELVIC ORGAN PROPLASE

MRI has proven to be a key assessment for understanding pelvic organ prolapse; a problem that arises from damage to connective tissue, muscles, and nerves that are invisible on standard radiography. With the advent of ultrasound and especially MRI 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.

a) Normal Pelvic Floor Functional Anatomy

1. MRI OF THE NORMAL PELVIC ORGAN SUPPORT STRUCTURES

MRI in pelvic organ prolapse requires that the specific structures involved are identified and their normal

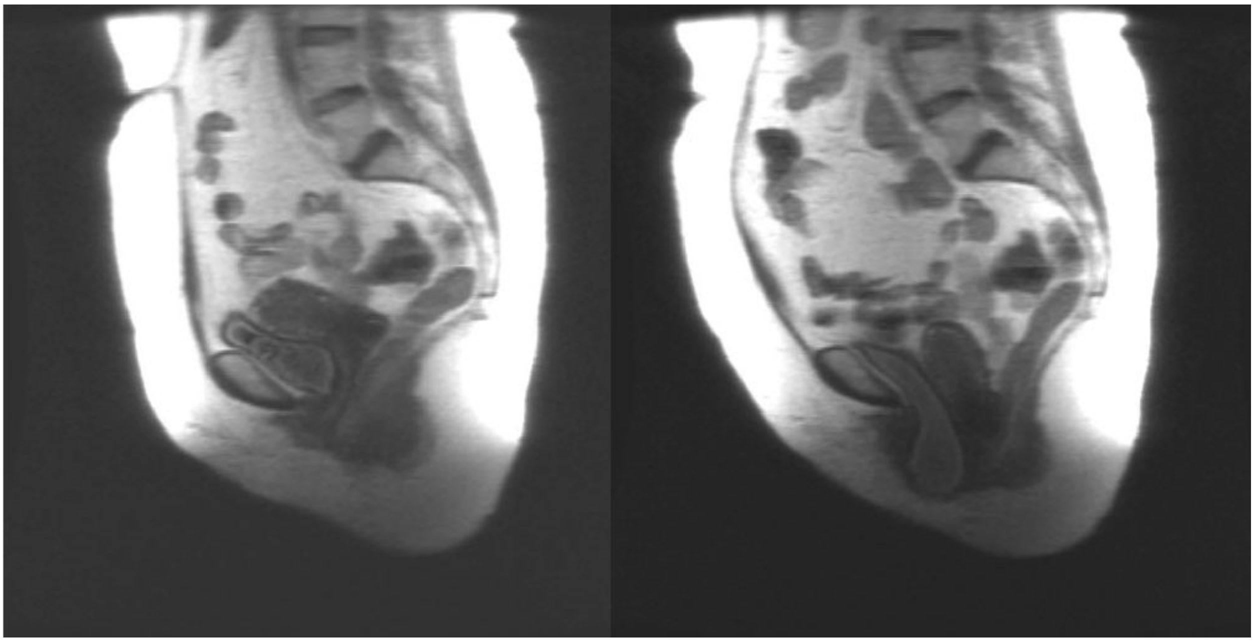

Figure 2 : The rest and strain image taken from a mid-sagittal dynamic MRI sequence revealing cystocele and uterine descent using SSFSE sequence.

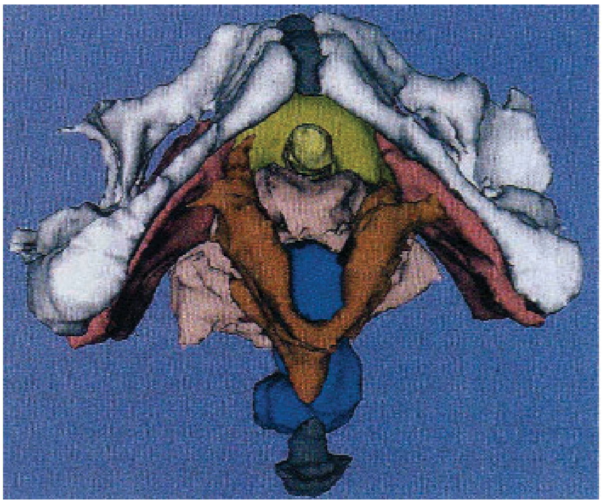

Figure 3 : Pelvic Organs as seen from caudal on a three-dimensional reconstruction from Magnetic resonance images. Copyright Mosby Inc.

variations described (**Figure 4**). Tan [21] demonstrated that the anatomy of the female pelvic floor with endovaginal MRI. Ten healthy nulliparous volunteers (age, 22-26 years) underwent MRI with an endovaginal coil. Pelvic floor structures such as the pelvic diaphragm and the urogenital diaphragm were well depicted as were urethral supporting structures—the peri-urethral and paraurethral ligaments—were visualized. The zonal anatomy of the urethra was clearly visible. The endovaginal MRI findings in the volunteers correlated with the endovaginal MRI findings and gross anatomy in the cadavers. Chou [30] developed a systematic method for analyzing the normal MRI location and appearance of structural features involved in urethral support. Multiplanar proton density MRI 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.

Tunn et al [32] 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 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 et al [33] found that in 80 healthy women, the uterosacral ligaments exhibited greater anatomic variation than their name would imply.

It has long been recognized that the pelvic floor is greatly distorted in cadavers where loss of muscle tone and pressures caused during embalming distort pelvic floor topography. Otcenasek et al have recently used MRI of a normal nulliparous woman to establish geometry and then added details from dissection to produce an anatomically based topographically normal

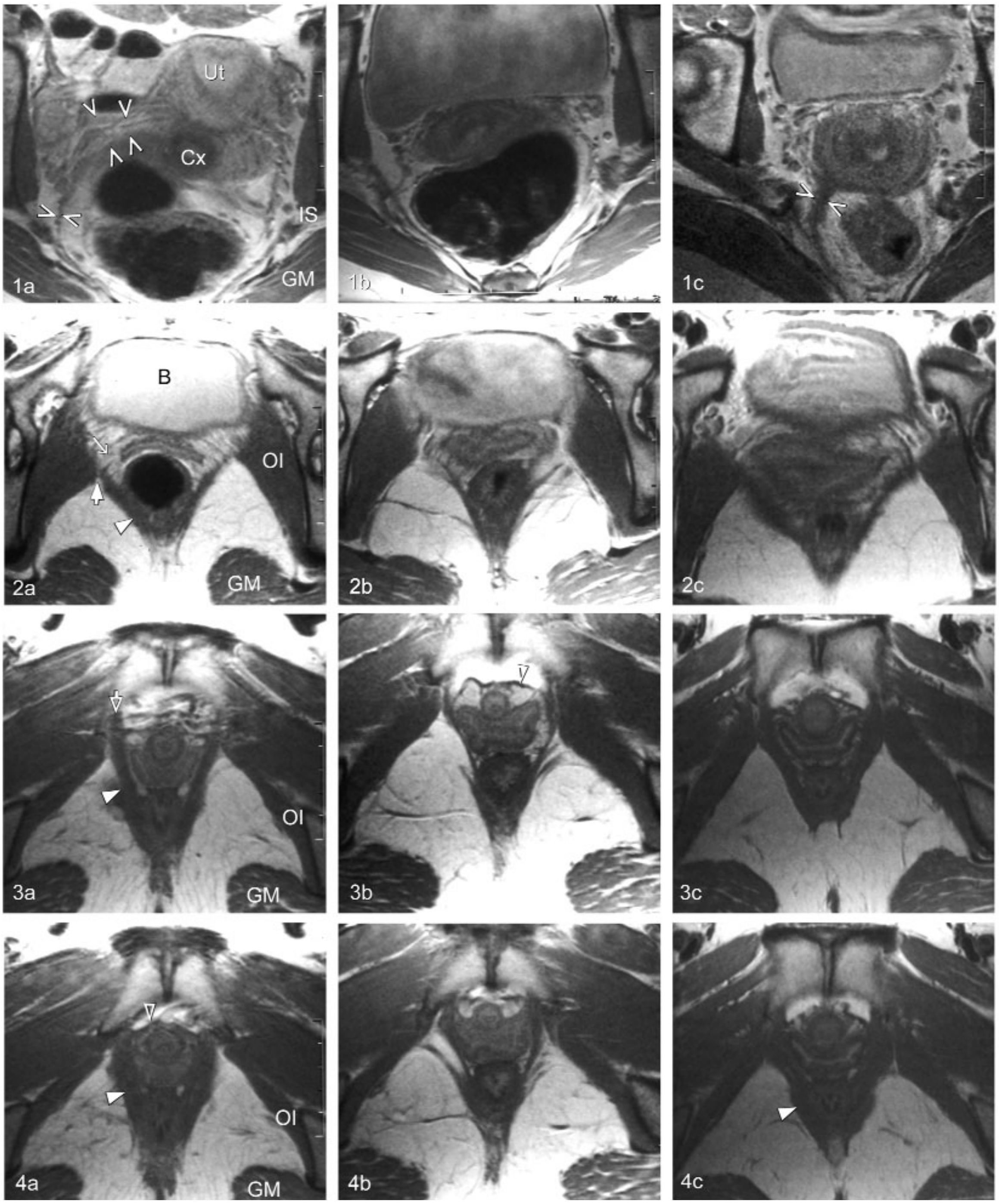

Figure 4 : Axial images according , in 22-year-old (A, D, G, and J), 24-year-old (B, E, H, and K), and 34- year-old (C, F, I, and L) nulliparous women without urogynecologic problems. A-C, Level of cervix (Cx) and ischial spine (IS); uterus (Ut) with bright endometrium is also seen. Paracolpium and parametrium suspend (open tips) vagina and cervix from lateral and posterior pelvic sidewall. Smooth muscle of uterosacral ligament (open tips) is best seen in C. GM, Gluteus maximus muscle. D-F, Level of bladder (B) base. Upper vagina between bladder and rectum (R) and its attachment to pelvic sidewall by vascular and connective tissue mesentery (small arrow) are seen. Levator ani muscle (iliococcygeal part, filled arrowhead) arises from arcus tendineus of levator ani muscle (filled arrow). OI, Obturator internus muscle. G-I, At level of proximal urethra, levator ani muscle (pubovisceralis part, filled arrowhead) arises from pubic bone (open arrow). Pubovesicalis muscle (open arrowhead) is clearly seen in H. Vessels (white gap) are visualized between smooth muscle layer of lateral vaginal wall and levator ani muscle at this level. J-L, At level of middle urethra, pubovesicalis muscle is seen as shown in J (open arrowhead). Vessel layer (white gap) between lateral vaginal wall and levator ani muscle (filled arrowhead) has disappeared; direct connection between vagina and levator ani muscle is seen at this level. Small white gap in levator ani suggests fascia between puborectalis and pubococcygeal muscles (especially in J and L). From Tunn et. al. 2001. [31]

3-D model that displays the features of pelvic floor anatomy (**Figure 5**) [34] .

2. Levator ani muscle functional anatomy

Recent work has extended our understanding of normal levator ani muscle anatomy. Guo and Li [35] studied MRI and CT images obtained at rest in 22 male and female volunteers and 10 cadavers. They described levator shape by dividing it into a transverse portion and a vertical portion. The anterior transverse portion was found to be basin-shaped; the middle transverse portion was funnel-shaped, while the posterior transverse portion was dome-shaped. The puborectalis was found to be a u-shaped muscle outside the vertical portion. Detailed information about the specific levator ani muscle subdivisions has also been studied. Margulies et al [36] have used detailed MRI images to visualize the specific origins and insertions of the five Terminologia Anatomica-listed levator ani components: pubovisceral (pubovaginal, puboperineal, and puboanal), puborectal and iliococcygeal portions of the levator ani muscle muscles in 80 nulliparous women with normal pelvic support. In the axial plane, the puborectal muscle can be seen lateral to the pubovisceral muscle and decussating dorsal to the rectum. The course of the puboperineal muscle near the perineal body is seen best in the axial plane. The coronal view is perpendicular to the fibere direction of the puborectal and pubovisceral muscles and shows them as “clusters” of muscle on either side of the vagina. The sagittal plane consistently demonstrates the puborectal muscle passing dorsal to the rectum to form a sling that can consistently be seen as a “bump.” This plane is also parallel to the pubovisceral muscle fibere direction and shows the puboperineal muscle. Ultrasound has also been useful in evaluating levator ani muscle morphology. Similarities and differences between MRI and 3-D ultrasound have been studied recently [37] in a group of 27 nulliparous asymptomatic young women. Levator hiatal dimensions were measured and were data acquired at rest, on maximum Valsalva and maximum pelvic floor contraction. Interobserver repeatability was fair to excellent for all parameters measured with both methods. Moderate-to-substantial agreement between methods was shown for all tested parameters (intraclass correlation coefficients 0.587-0.783). There was a systematic but non-significant difference between methods, in that measurements on Valsalva tended to be larger for MRI, and the poorest agreement

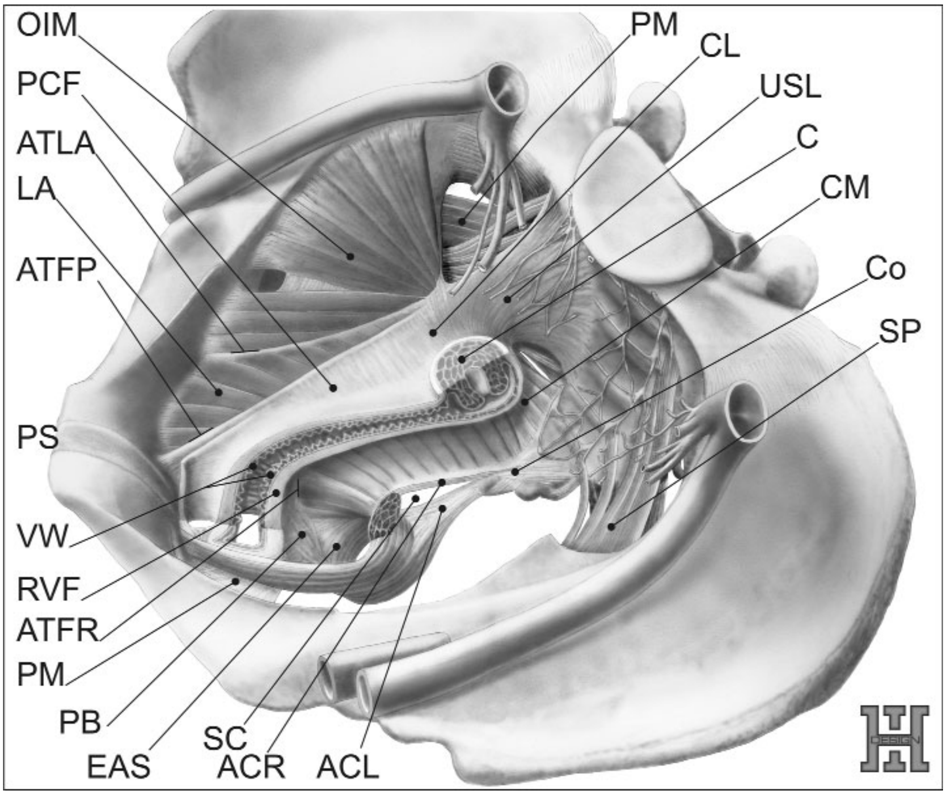

Figure 5 : Left lateral view from above the female pelvis. The vagina, endopelvic fascia, and levator ani muscle are cut in the sagittal plane. Urethra, urinary bladder, and rectum have been removed. OIM, obturator internus muscle; PCF, pubocervical fascia; ATLA, arcus tendineus levator ani; LA, levator ani muscle; ATFP, arcus tendineus fasciae pelvis; PS, pubic symphysis; VW, vaginal wall; RVF, rectovaginal fascia; ATFR, arcus tendineus fasciae rectovaginalis; PM, perineal membrane; PB, perineal body; EAS, external anal sphincter; SC, space of Courtney; ACR, anococcygeal raphe; ACL, anococcygeal ligament; PM, piriformis muscle; CL, cardinal ligament; USL, uterosacral ligament; C, cervix of the uterus; CM, coccygeus muscle; Co, coccyx; SP, sacral plexus. Illustration: Ivan Helekal. [34]

(intraclass correlation coefficient 0.587) was found for hiatal area on Valsalva. This demonstrates substantial similarity between the two methods for these assessments (**Figures 6-7**).

3. Functional MRI

Functional MRI of the brain has recently been used to better understand central control of pelvic floor muscles. Kuhtz-Buschbeck et al [38] used functional MRI to identify cortical and subcortical regions involved in voluntary pelvic floor muscle control. During pelvic muscle contraction they found a strong and consistent recruitment of the supplementary motor area (SMA), with foci of peak activity located in the posterior portion of the SMA, suggesting that this region is specifically involved in voluntary pelvic floor muscle control. Further significant activations were identified bilaterally in the frontal opercula, the right insular cortex and the right supramarginal gyrus.

These may reflect the attentive processing and evaluation of visceral sensations. Weaker signals were detected in the primary motor cortex (M1) and the dorsal pontine tegmentum. Similarly Seseke et al [39] in a study of 11 healthy women found that relaxation and contraction of pelvic floor muscles induced strong activation patterns including frontal cortex, sensory-motor cortex, cerebellum, and basal ganglia. Furthermore, well-localized activations in the pontine micturition centere and the periaqueductal gray were identified.

4. Pathophysiology

i) Levator ani muscle defects muscle bulk

Although it has long been known that birth is highly strongly associated with pelvic organ prolapse, proof of a specific injury that occurred at birth and was associated with prolapse later in life had not been found. Recent MRI studies have demonstrated that the type of LA injury seen after vaginal birth is highly strongly associated with pelvic organ prolapse. In [40] a case-control study with group matching for age, race, and hysterectomy status 151 women with prolapse (cases) were compared to 135 controls with normal support (controls). Magnetic resonance imaging was used to grade muscle defects on each side from 1 to 3 (with 0 designating normal muscle (**Figure 8**).

Defect severity for a woman was then classified by adding the scores for the two sides together to make a score from 0 to 6. These were then classified as “major” (4 to 6), “minor” (1 to 3), or no defects (0) in the levator ani muscles. Cases (n=151) were more likely to have major levator ani defects than controls (55% compared with 16%), but equally likely to have minor defects (16% compared with 22%) as seen in **Figure 9**. These defects had functional consequences. Women with defects generated less vaginal closure force during a pelvic muscle contraction than women without defects (2.0 Newtons compared with 3.1 Newtons) and women with prolapse also generated less vaginal closure force during pelvic muscle contraction than controls (2.0 Newtons compared with 3.2 Newtons), whereas the genital hiatus was 50% longer in cases than controls (4.7+/-1.4 cm compared with 3.1+/-1.0 cm). This confirmed earlier uncontrolled observations made with ultrasound [41] of urogynecologic patients with ultrasound.

This added new information concerning specific muscle defects to previous studies of muscle bulk. It is important to distinguish between muscle thickness and muscle damage. A woman with a normally thin but intact muscle may have less muscle substance than a woman with naturally bulky muscles who has a defect that has involved 25% of her muscle bulk. The issue of muscle damage is relevant to seeing who is injured while that of muscle bulk, with the capability of the muscle to close the hiatus. Loss of muscle bulk in women with pelvic floor dysfunction was studied by Hoyte et al [42]. They studied two- and 3-dimensional MRI comparison of levator ani structure, volume, and integrity in women with prolapse and stress incontinence 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, ($P = 0.003$), and levator shape (90%, 40%, and 20% dome shaped; $P < 0.005$). This studiyes 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. Later in a similar design, they used a novel thickness mapping [43] to studyied MRI datasets from 30 women were studied: 10 asymptomatic, 10 with urodynamic stress incontinence, and 10 with pelvic organ prolapse. They found thicker, bulkier anterior portions of the levators in asymptomatic women, compared with women with prolapse or urodynamic stress incontinence while the more posterior portions of the muscle were not affected.

Hsu and colleagues quantified levator ani muscle cross-sectional area as a function of prolapse and muscle defect status [44]. They selected thirty women with prolapse and 30 women with normal pelvic support. For each of the two groups, 10 women were selected from three categories of levator defect

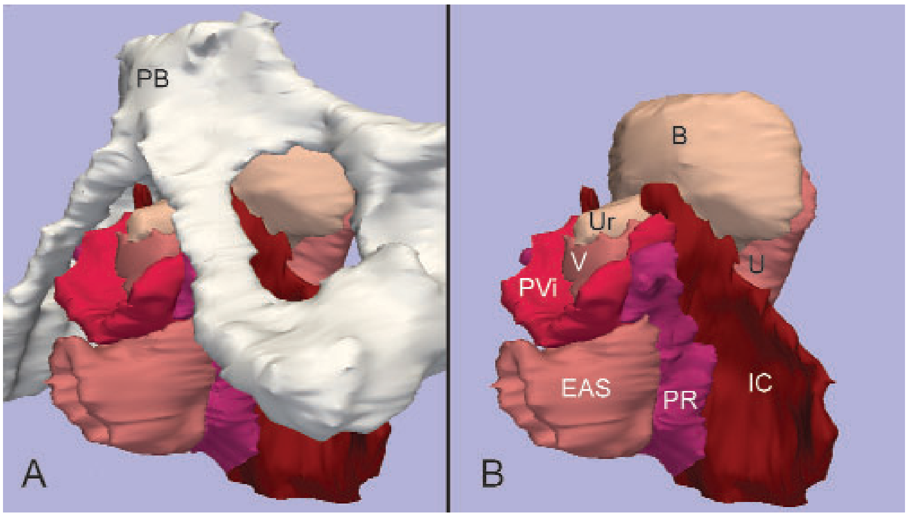

Figure 6 : Three-dimensional model of levator ani subdivisions including the pubic bone and pelvic viscera. This model was created by using the magnetic resonance images shown in Figures 2, 3, and 4. The pubovaginal, puboperineal, and puboanal muscles are all combined into a single structure, the pubovisceral muscle. Inferior, left 3-quarter view. B. The same model without the pubic bone. PB, pubic bone; V, vagina; U, uterus; Ur, urethra; B, bladder; IC, iliococcygeus muscle; PR, puborectal muscle; PVi, pubovisceral muscle; EAS, external anal sphincter [36].

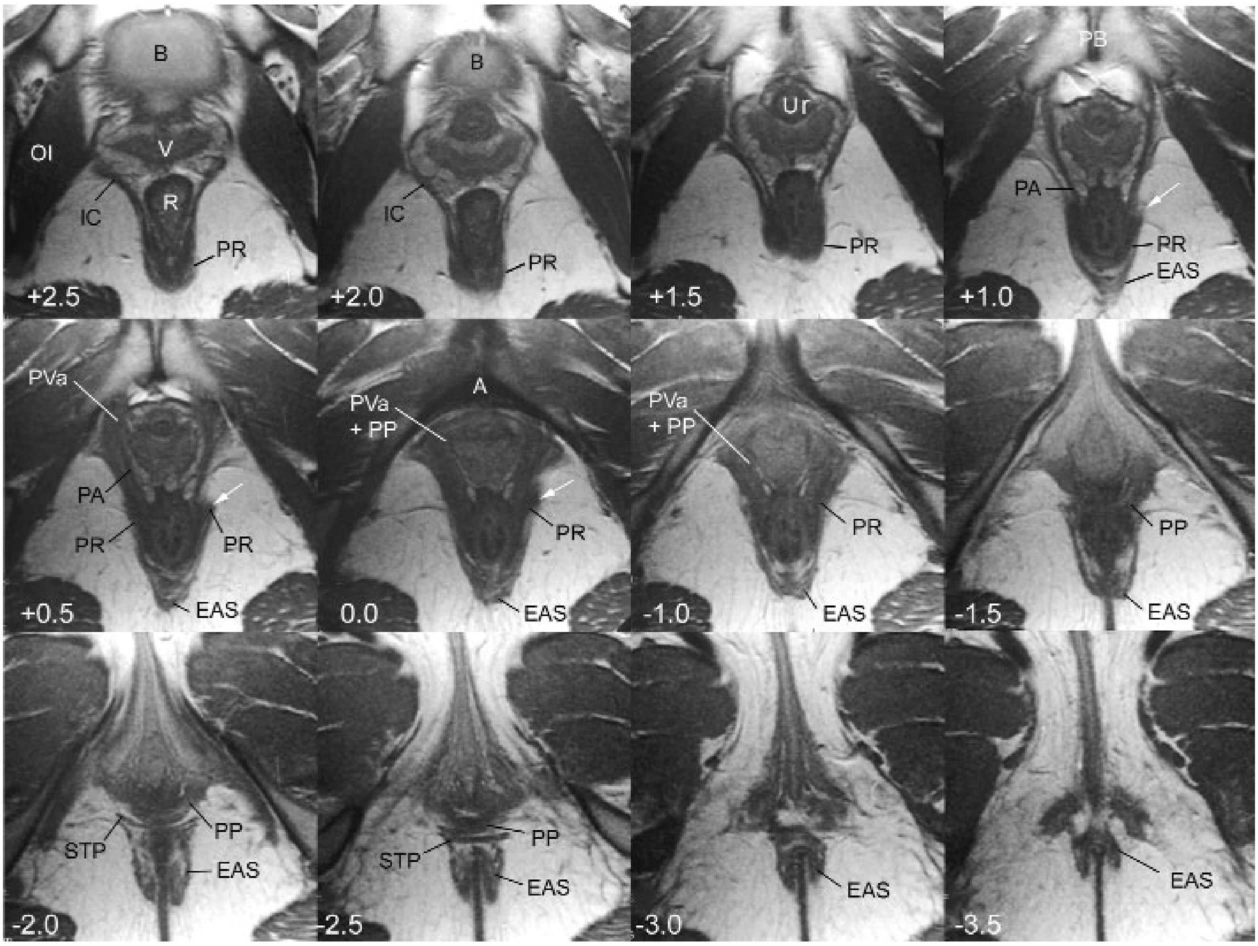

Figure 7 : Axial scan of 25-year-old nullipara showing subdivisions of the levator. Level of scan in centimeters relative to the arcuate pubic ligament (A) is indicated in lower left corner with positive numbers cranial to the ligament and negative numbers caudal. Additional abbreviations: PP, puboperineal muscle; PVa, pubovaginal attachment; PA, puboanal muscle; OI, obturator internus muscle; STP, superficial transverse perineal muscle; R, rectum. White arrows indicate puborectal muscle progression [36].

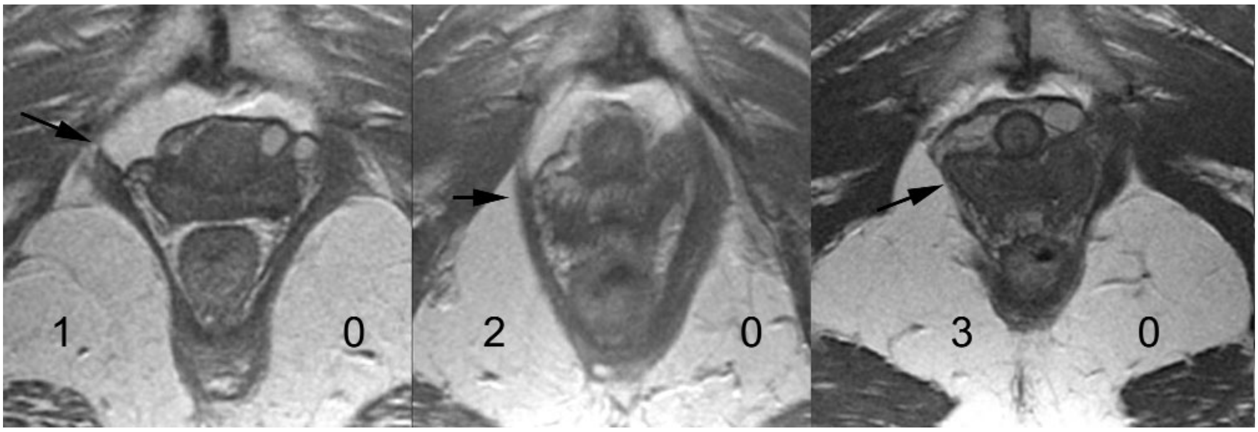

Figure 8 : Examples of grades of defects in the pubovisceral portion of the levator ani muscle in axial magnetic resonance images at the level of the mid urethra. These were selected to illustrate degrees of defects in individuals with a normal contralateral pubovisceral muscle. The score for each side is indicated on the figure, and the black arrows indicate the location of the missing muscle. A. A grade 1 defect; B. A grade 2 defect; and C. A grade 3 defect [40].

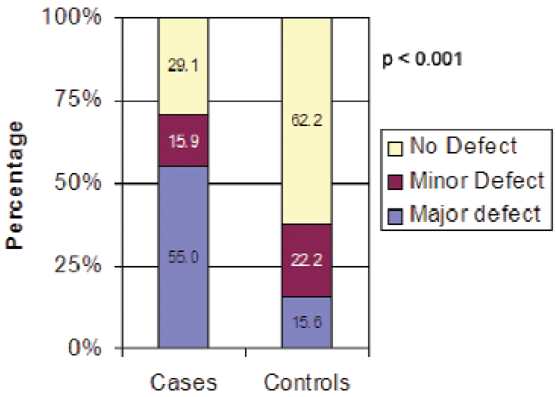

Figure 9 : Percentages of cases and controls with no defects, minor defects, and major defects; P≤.001 [40].

severity: none, minor, and major identified on supine magnetic resonance scans. They calculated muscle cross-sections perpendicular to the muscle fibre direction of the pubic portion of the levator ani muscle based on 3-D reconstructions made from proton-density MRI. The ventral component of the levator muscle of women with major defects had a 36% smaller cross-sectional area, and women with minor defects had a 29% smaller cross-sectional area compared with the women with no defects (P < 0.001). In the dorsal component, there were significant differences in cross-sectional area according to defect status (P = 0.03); women with major levator defects had the largest cross-sectional area compared with the other defect groups. For each defect severity category (none, minor, major), there were no significant differences in cross-sectional area between women with and those without prolapse. This indicates that women with visible levator ani defects on magnetic resonance imaging have less muscle ventrally compared with women with intact muscles. Women with major levator ani defects had larger cross-sectional areas in the dorsal component than women with minor or no defects indicating that compensatory hypertrophy may occur in this area.

ii) Identifying the injury zone within the levator ani muscle most often involved by injury

The specific anatomical location of these injuries has been studied in several ways. Otcenasek and colleagues [45] created two 3D computer models of the female pelvic floor, one of a healthy nulliparous woman and the other of a woman with bilateral puborectal muscle avulsion after vaginal delivery based on magnetic resonance imaging examinations. They found that the damage affected the pubic origin of the muscle and that this structurally altered the support to the whole endopelvic fascia and destabilized both the anterior and the posterior vaginal walls. Margulies [46] extended these findings by examining a unique set of 14 women who had significant muscle on one side that allows normal muscle and damaged muscle to be compared in the same individual. This allowed the anatomical connections affected by defects the pubovisceral portion of the muscle to be studied using 3-D reconstructions of the levator ani muscles the normal side in each woman could be compared with the side with muscle damage. It was shown that the injury involved the muscle's origin from the posterior pubic bone. The insertion points of the missing muscle involved its connections with the vaginal wall, perineal body, and the space between the internal and external anal sphincter. It was accompanied by distortion of the surrounding connective tissue with lateral spilling of the vagina towards the obturator internus muscle in 50% of women. The defect was right sided in 71% of patients. In a separate study quantifying the amount of muscle lost in these types of injury, Chen [47] found that the average difference between the normal side and the defective side was up to 81% at locations nearest the pubic origin. Almost all of the volume difference (13.7%, P=0.0004) was attributable to a reduction in the pubic portion (24.6%), not the iliococcygeal portion of the muscle (**Figure 10**).

iii) Changes in the hiatus size and levator plate angle with prolapse

The levator ani muscles constant activity closes the genital hiatus. In addition to evaluating defect status and muscle bulk, MRI has revealed changes in the levator hiatus and angle of the levator plate (that midline portion of the muscle between the anus and the coccyx) whose angle is presumed to be influenced by muscle action. Hsu and colleagues [48] studied 68 women with pelvic organ prolapse and 74 normal controls. During Valsalva, controls had a mean levator plate angle of 44.3 degrees. Cases had 9.1 degrees (21%) more caudally directed levator plate angle compared to controls (53.4 degrees vs. 44.3 degrees), 15% larger levator hiatus length (7.8 cm vs 6.8 cm), and 24% more caudal perineal body location (6.8 cm vs 5.5 cm).

Increases in levator plate angle were correlated with increased levator hiatus length (r = 0.42) and perineal body location (r =.51). Ansquer and colleagues [49] sought to see if hiatus dimensions parameters varied with the degree of prolapse present in 40 patients referred for evaluation prior to genital prolapse surgery. They found that greater bladder neck descent at straining was correlated with the larger levator plate angle at rest, hiatus length at rest and at straining. Uterine cervix descent at straining was correlated with increased hiatus length and width at straining, and greater levator plate angle (p=0.007) at straining. Paradoxically anterior rectal bulging at straining was inversely correlated with the hiatus width at rest (p = 0.04).

Perineal descent and localized outward bulging of the during Valsalva was evaluated by Gearhart and colleagues [50]. In this study, dynamic magnetic resonance imaging of symptomatic patients with pelvic floor prolapse demonstrated unsuspected levator ani hernia. Eighty consecutive patients with pelvic organ prolapse, faecal and/or urinary incontinence, or chronic constipation were evaluated. Twelve patients (15 percent) were found to have unilateral (n = 8) or bilateral (n = 4) levator ani hernias on dynamic magnetic resonance imaging. No one specific symptom was directly associated with the presence of a levator ani hernia. Perineal descent on physical examination was associated with the finding of a levator ani hernia in nine patients. At present, the clinical implications of these hernias remain to be determined.

b) 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 [51]. There are changes observed in the levator ani and pelvic floor musculature immediately after delivery that appear to change over time. Boreham [52] evaluated the normal visibility of the levator in postterm nulliparas using 3-dimensional (3-D) magnetic resonance. They studied 84 nulliparas and found that LA insertion into the symphysis was visible in 93%, and the iliococcygeus muscle assumed a convex shape (arch) in the 92%. Mean LA volume was 13.5 (3.7) cm^3. Interestingly there was a positive association between LA volume and higher fetal station increasing BMI. Tunn evaluated the changes that occur after delivery studying patients on postpartum day 1 and compared the MRI images to those obtained at 1, 2, and 6 weeks and 6 months after delivery [53]. They 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 [54] 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.

The relationship between delivery method and levator anatomy, has been studied. Baytur et al evaluated pelvic floor anatomy seen in MRI scans and muscle function after childbirth in young women who were recruited into 3 groups: 1. elective, prelabour caesarean delivery (n =12); 2. vaginal delivery (n = 15); and 3 age-matched nulliparas as controls (n = 13) [55]. Descent of the bladder and cervix on straining was greater in the subjects who delivered vaginally than in the caesarean delivery and nulliparous groups. There was a positive and significant correlation between the duration of labour and the area of the levator sling and also between birth weight and the descent of the cervix on straining.

In a study that evaluated changes in the levator ani muscles among primiparous women, DeLancey [56] studied 80 nulliparous asymptomatic women, 160 vaginally primiparous women half of whom had new stress incontinence after their first birth. A visible defect 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. In a further study of this cohort they [57] evaluated obstetric factors associated

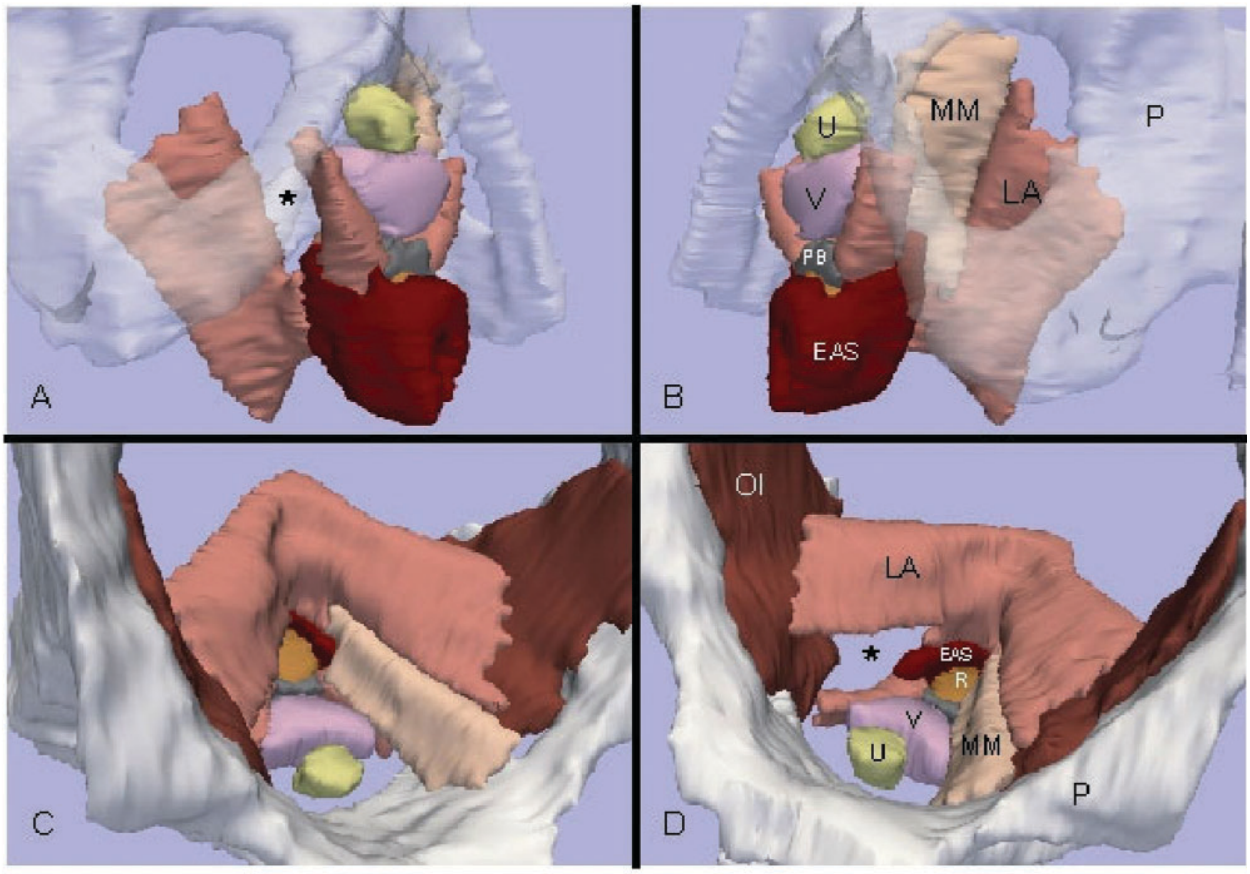

Figure 10 : Three-dimensional model generated from the axial MR scans shown in Figure 1. A, and B, Oblique right and left inferolateral views, similar to the dorsal lithotomy position, are shown. In these panels the pubic bone is semitransparent and the obturator internus muscle is not shown. C, and D, Oblique right and left views peering over the pubic bone and down to the pelvic floor are shown. The urethra, vagina, and rectum have been truncated so as not to obscure the views of the levator muscles. EAS, external anal sphincter; LA, levator ani; MM, mirror image of the missing muscle; P, pubis; PB, perineal body; U, urethra; V, vagina. The missing muscle in A and D is denoted (asterisk) [46].

with development of levator ani injury after first vaginal birth. There were increased odds ratios for levator defect were found: forceps use 14.7, anal sphincter rupture 8.1 and episiotomy 3.1 but not vacuum delivery 0.9 epidural use 0.9 or oxytocin use 0.8. Women with levator injury were 3.5 years older and had a 78-minute longer second stage of labour. Differences in gestational age, birth weight, and head circumference were not statistically significant. The traumatic nature of these lesions has been supported by Dietz [58] who has reported the specific findings in a woman at vaginal delivery with a visible tear who had persistent evidence of muscle injury at 6 months on imaging. Excellent prospective information about damage is also available from 3-D ultrasound although this imaging modality is outside the topic covered by this chapter [59].

Danneker [60] studied women who experienced spontaneous vaginal delivery (n = 26) and compared them with women delivering by vacuum extraction (n = 49) and a control group that consisted of healthy nulliparous volunteers (n = 20). Significant differences for individual POPQ component measurements were noted for points Aa and Ba, TVL, and GH (spontaneous delivery versus control) and in addition for Ap, Bp, and D (vacuum extraction versus control). Significant differences for MRI measurements were observed for the position of bladder base, bladder neck, posterior fornix of the vagina, anorectal junction, hiatus perimeter and depth of rectocele.

Branham and colleagues [61] assessed postpartum changes in the levator ani muscle related these changes to obstetric events in 45 primiparous women and 25 nulliparous women comparing their status at 6 weeks to that at 6 months after delivery. The occurrence of muscle abnormality at any of the 4 sites (pubovisceral or iliococcygeal; left and right) was considered as abnormal. In those subjects recovering to normal magnetic resonance by 6 months an average of nearly 60% increase in right puborectalis muscle thickness compared with that seen at 6 weeks indicated the extent of the injury. Subjects with injury to both the “puborectalis” and iliococcygeus at 6 weeks did not recover to normal at 6 months, whereas those with injury only to the puborectalis tended to have normal magnetic resonance images at 6 months.

Younger white primiparous women had a better recovery at 6 months than older white women.

5. MRI AND BIOMECHANICAL INVESTIGATION OF THE PELVIC FLOOR

Dynamic MRI has allowed specific mechanistic hypotheses to be tested. Summers and colleagues [62] evaluated whether the degree of anterior compartment (bladder) and apical compartment (cervix) prolapse are correlated are related at maximal Valsalva. They studied 153 women with a complete spectrum of pelvic support loss from normal support to stage 4 prolapse using dynamic magnetic resonance scans taken during Valsalva. They found that there was a strong correlation (r^2 = 0.53) between prolapse of the how far the bladder base and of uterine cervix , were below normal with was r^2 = 0.53 indicating that slightly over half of the observed variation variation in anterior compartment support may be explained by apical supportsupport. Further analysis in the same patients to evaluate what other factors might be associated with cystocele size [63]. Anterior vaginal wall length, location of distal end of the vaginal wall and the curvature of the anterior wall were measured during maximal Valsalva. Vaginal length was the strongest secondary factor determining 30% of the variation after apical descent was taken into account. This finding that a longer vaginal wall was associated with increasing cystocele size was unexpected, but seems consistent with clinical observations.

MRI has also allowed anatomically based biomechanical models to be constructed. Simulations performed with these models have demonstrated important interactions between muscle and connective tissue in providing for anterior vaginal wall support [64]. MRI has also been used as a basis for biomechanical analysis by allowing construction of finite element analysis [65,66] and has allowed for capture of 3D shape variation of the levator ani during straining for studying dynamic shape changes of 3D structures where complete volumetric imaging is prohibited by the inherent temporal resolution of the scanning technique [67]. Research is just beginning on evaluating changes that can be seen in the vaginal wall and support tissues. Hsu et al. for example used axial magnetic resonance imaging to test the null hypothesis that no difference exists in apparent vaginal thickness between women with and those without prolapse [68]. They found that vaginal thickness is similar in women with and those without pelvic organ prolapse. However, the vaginal perimeter and cross-sectional areas are 11% and 20% larger in prolapse patients respectively. These techniques should provide objective evidence of changes in the tissues involved in pelvic organ support.

a) Racial differences in pelvic dimensions

There has been interest in racial differences in the occurrence of pelvic floor dysfunction. Several groups have evaluated differences in the bony pelvisc and the levator ani muscles between women from different races [69-71]. In a study by Handa et al, 59 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) and a shorter obstetrical conjugate (odds ratio 0.2) were found to be associated with pelvic floor dysfunction. Hoyte and colleagues compared pelvic morphology between asymptomatic African-American and white nulliparous women in 3-D reconstructions from resting supine T2-weighted MRI images in 12 African-American (AA) and 10 white American (WA) women without pelvic floor dysfunction [70].

They found that levator ani volume was significantly greater in the AA compared to the WA group (mean = 26.8 vs. 19.8 cm3, P = .002). The levator-symphysis gap was smaller in the AA (left-18.2, right-18.8 mm) versus the WA group (22.4, 22.6 mm, P = .003, .048) on the left and right. Significant differences were also seen in bladder neck position, urethral angle, and the pubic arch angle. In another study Downing et al compared levator and obturator thickness between asymptomatic black and white nulliparas using three-dimensional (3D) MRI colour mapping [71]. Using 3D color-mapped MRI of pelvic muscles in 22 similar nulliparas black (n=12) and white (n=10) women they found that levator thickness was significantly greater in blacks bilaterally yet obturator internus muscle thicknesses were similar. Handa et al used static and dynamic MRI to compare dimensions of the bony pelvis and soft tissue structures in a sample of African-American and white women [72]. They included 104 primiparous women with an obstetric anal sphincter tear, 94 who delivered vaginally without a recognized anal sphincter tear and 36 who underwent by caesarean delivery without labour. They found that the pelvic inlet was wider among 178 white women than 56 African-American women (10.7+/-0.7 cm compared with 10.0+/-0.7 cm, P<0.001). The outlet was also wider (mean intertuberous diameter 12.3+/-1.0 cm compared with 11.8+/-0.9 cm, P<0.001). There were no significant differences between racial groups in interspinous diameter, angle of the subpubic arch, anteroposterior conjugate, levator thickness, or levator hiatus. A broader group of races was studied by Rizk et al who studied dynamic pelvic floor and bony pelvis morphologic condition with MRI in asymptomatic multiethnic nulliparous young volunteers from 5 ethnic groups (n=11 x 5 volunteers: Emirati, other Arab, Filipino, Indian/Pakistani, and European/white volunteers), with the white volunteers as the reference group [73].

The white volunteers were significantly taller (P <0.0001) than the other women. Their levator hiatus was significantly longer than the Emirati women (P=0.03) and wider than the Filipino women (P=.04). The bladder neck descent on straining was also significantly greater than the other groups (P <0.00001). The white women also had the longest transverse diameter of the pelvic inlet (P=0.002). Their sagittal outlet diameter was significantly longer than the Emirati and Arab women (P=0.02), and their interspinous diameter was significantly longer than the Arab women (P=0.002).

1. MRI FOR CLINICAL EVALUATION OF PROLAPSE

There is growing experience with evaluating in the interpretation of MRI images of pelvic organ prolapse.the type and size of prolapse visible in MRI. Several ways in which this might enhance patient care and treatment outcome are under investigation.

2. ENTEROCELE

Enterocele can be seen during MRI [74,70]. In the past enteroceles 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 [75]. 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 MRI 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 11**). Neither instrumentation nor invasive procedures are required. Similarly, Lienemann et al., using MRI with opacification of organs with ultrasound gel, showed that MRI had a much higher sensitivity for detection of enteroceles when compared to physical exam and dynamic cystoproctography [76]. Whether or not this technique alters clinical outcome remains to be seen.

b) 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.

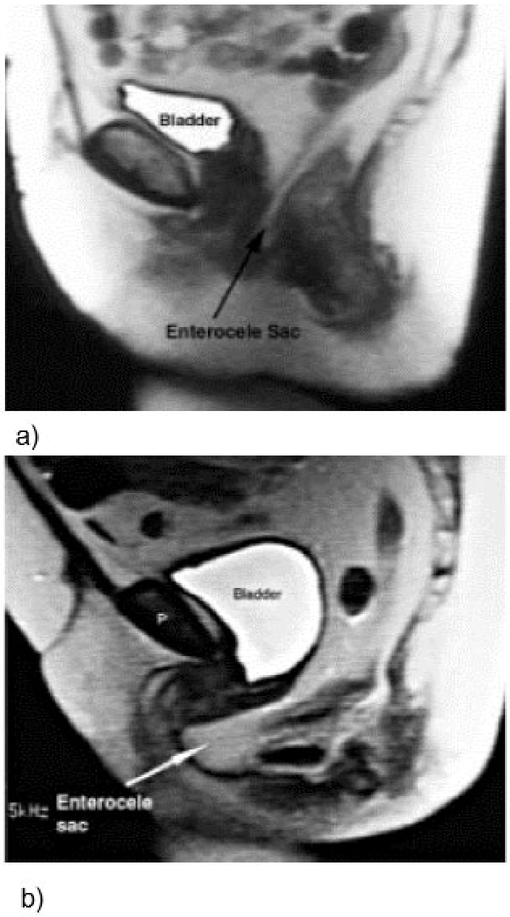

Figure 11 : Pelvic floor MRI: Enterocele at rest a) and during Valsalva b).

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 12 a, b** show an MRI of two patients with grade 2 and 3 cystocele, respectively.

Other uses of MRI can also be helpful in documenting the status of pelvic organ support as part of a program to assess operative efficacy [77,78] and differentiating such problems as Müllerian remnant cysts from cystocele [79].

c) 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, 80,81]. 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

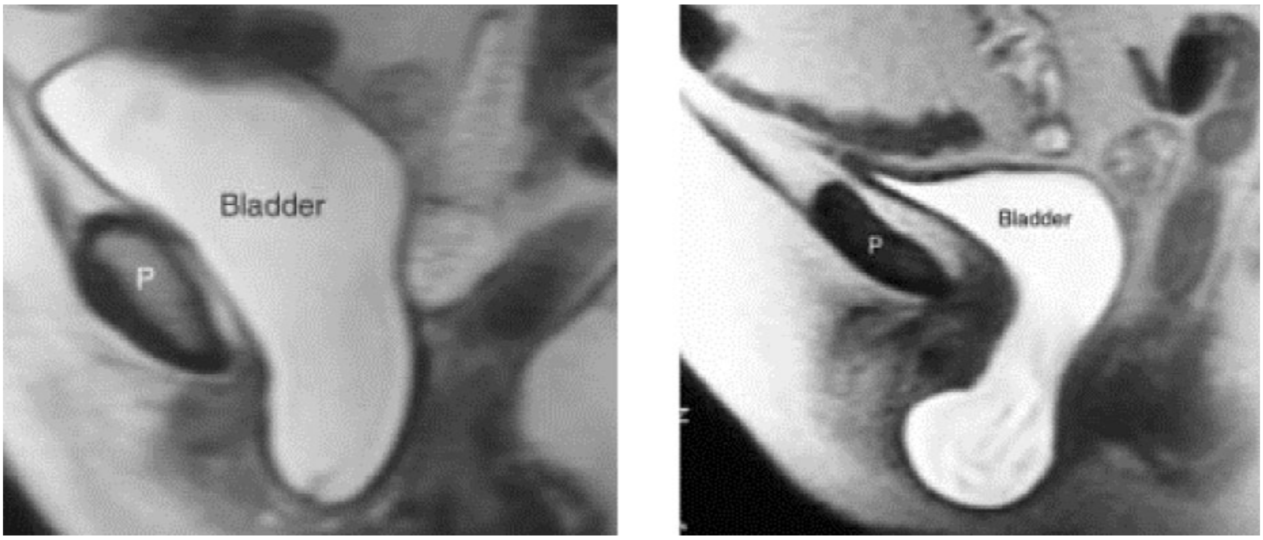

Figure 12 : Pelvic floor MRI: grade 2 (a) and grade 3 (b) cystocele

enterocele from a high rectocele. **Figure 13** 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 be 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. In complex situations such as rectal intussusception [82] by distinguishing mucosal from full-thickness descent MRI can provide important information. MRI defecography also shows movements of the whole pelvic floor.

In this study, 30% of the patients studied were found to have associated abnormal anterior and/or middle pelvic organ descent that would not necessarily be seen in traditional evacuation proctography (unless opacification of vaginal, bladder and intestine are carried out).

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. Rectocele 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.

d) Uterine Prolapse

Although uterine prolapse is easily diagnosed on physical examination MRI is an excellent modality to permanently record the structural relationships with the bladder and rectum present in patients with uterine prolapse (**Figure 14**). 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, tumours, Nabothian cysts. etc.), but also ovarian pathology (cyst or mass) which is essential information in may sometimes prove useful if these problems have not been picked up on physical examination is helpful information in determining if a vaginal of abdominal hysterectomy is indicated. In addition, MRI provides information on the presence or absence of cystocele, rectocele, urethral hyper-mobility and urethral diverticula, and evaluates for ureteral obstruction [9-10, 13-15, 83]. Gousse et al. reported a sensitivity of 83%, a specificity of 100% and a positive predictive value of 100% when comparing dynamic MRI 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].

e) Grading of pelvic floor relaxation

A number of studies have described reference values for grading 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

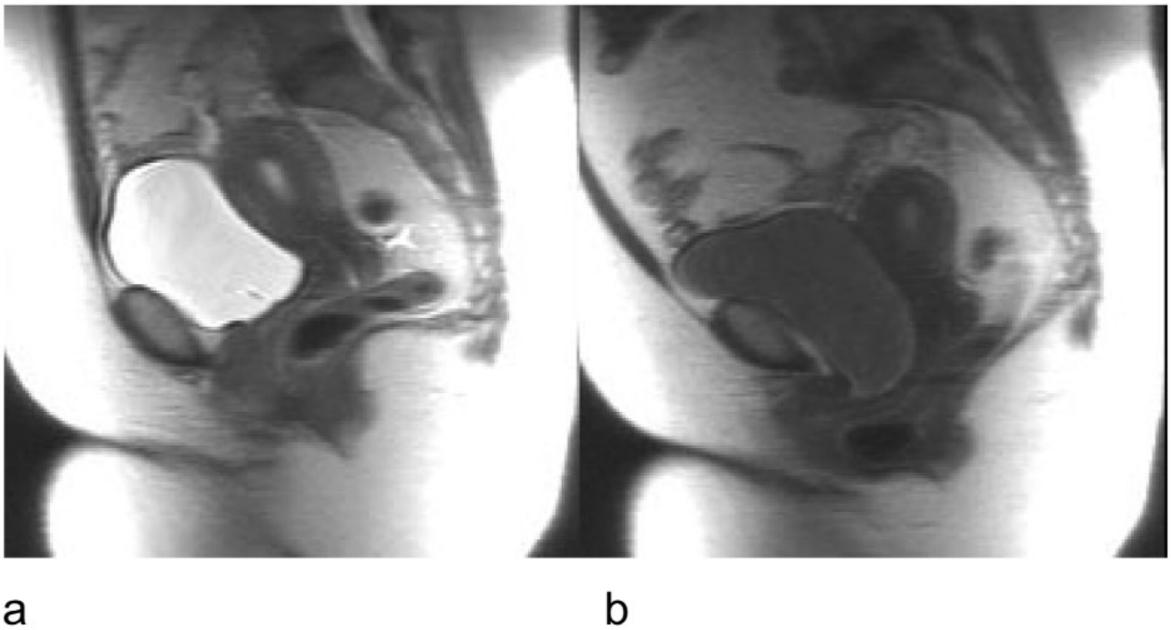

Figure 13 : Resting (a) and straining (b) midline sagittal section showing a rectocele that traps intestinal contents.

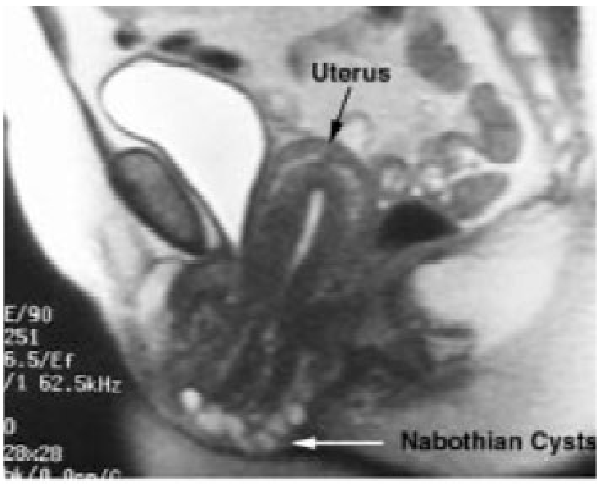

Figure 14 : Pelvic Floor MRI: Uterine Prolapse

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 et al [84] assessed a new technique of grading pelvic organ prolapse by using dynamic MRI with the clinical staging proposed by the POP-Q system [85]. In a cross-sectional study, 20 patients with pelvic organ prolapse underwent dynamic MRI 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 MRI 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 [74] also used MRI to evaluate functional disorders of the 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 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 tocannot be determined.

Table 2. Grading of hiatal enlargement, pelvic organ prolapse and pelvic floor descent 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

Deval [85] compared dynamic MRI with physical examination as an alternative to dynamic cysto-proctography for the evaluation of pelvic floor prolapse. Pubococcygeal line and puborectalis muscle were the references points. The grading system is based on the degree of organ prolapse through the hiatus and the degree of puborectalis descent and hiatal enlargement. They also used, the mid pubic line 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.

More recently Etlik [86] studied 46 patients who were known to have pelvic prolapses from their vaginal examination and thirty women who underwent vaginal examination and shown not have pelvic prolapse served as a control group. Physical examination and MRI findings were very concordant in the diagnosis of pelvic prolapse and statistical correlations in the stages of prolapse between both of the methods were significant for anterior and middle compartment ($P<0.01$), as well as for posterior compartment ($P<0.05$).

6. ASSESSING TREATMENT OUTCOME

a) Pelvic Organ Prolapse operations:

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. [87] 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 [42]. Similar studies will be needed in order to better evaluate the structures important for pelvic support and, continence as well as the effects of surgical interventions. Sze [88] used MRI to study vaginal configuration on MRI after abdominal sacro-colpopexy 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. Similarly Rane [89] used MRI to compare the vaginal configuration on MRI following transvaginal sacros-pinous fixation (SSF), posterior intravaginal slingplasty (PIVS) (infracoccygeal sacropexy) and sacrocolpopexy (SCP) and was able to demonstrate significant improvements in the restoration of vaginal configuration were achieved in patients and differences between the procedures in final anatomy.

Boukerrou [90] used MRI scans to compare outcomes of 1) abdominal (Sacral cervicopexy), 2) vaginal hysterectomy with paravaginal repair, sacrospinous suspension and posterior colporrhaphy and 3) sacrospinous suspension and posterior repair without paravaginal suspension demonstrating objective effectiveness provided by these three techniques. The correction provided by the vaginal route resulted in a return of the bladder and the vaginal apex to their normal positions, which clearly demonstrates the short-term effectiveness of these surgical suspensions. In addition they confirmed that vaginal shortening and postoperative change in vaginal orientation were not present postoperatively.

Relationship between assessment of surgical correction studied with MRI and symptoms have been studiedreported. Gufler [91] studied 15 patients with uterovaginal prolapse and 15 asym-ptomatic 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. Huebner et al assessed symptomatic changes after anterior levatorplasty with morphologic changes visualiszed by magnetic resonance defecography [92]. They were able to demonstrate that anterior levatorplasty improved quality of life in patients with symptomatic rectocele and that correction of rectocele is accurately documented by magnetic resonance defecography, however only moderate correlation between morpho-logic and clinical improvements was observed.

b) Pelvic Floor Muscle Exercises

Studies have also been conducted concerning the effects of pelvic floor muscle training on the pelvic floor [93] demonstrating reduced levator ani surface area and volume encircled by the levator ani muscle at rest and during contraction. The fact that muscle morphology might be affected by training was investigated by comparing elite athletes to normal women. finding significant differences in the cross-sectional area and width of the pelvic floor muscles, measured in the line of the anal canal between athletic group and the controls [94]. These types of studies are being facilitated by improved techniques of aligning contracted and non-contracted muscle [95]. Assessment of techniques to evaluate structure and function has recently been reviewed [96].

7. COMPARISON OF MRI WITH OTHER EXAMI-NATIONS AND ASSESSMENT OF RELIABILITY

In the evaluation of incontinence and simple low-grade cystoceles, the studies of choice in the past have been the voiding cystourethrogram (VCUG) and urodynamics. VCUG is useful in determining the severity of cystocele, evaluating for urethral hypermobility, and SUI, and documenting PVR [6]. In addition to the above information, the evaluation of high-grade cystoceles should also provide information on concomitant pelvic floor prolapse and the presence or absence of urinary retention and ureteral obstruction [9-10, 13-15, 83]. Gufler et al. compared chain cystourethrography with dynamic MRI [83]. 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 [83].

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, 89, 92,93]. These studies fail to detect up to 20 percent of all enteroceles [83, 97-99]. 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 from enteroceles, thus allowing adequate surgical planning and safer planes of dissection [14, 15, 18, 76]. Although a recent study found that multiphasic MRI with opacification of organs and multiphasic fluoroscopic cystocolpoproctography had similar detection rates for enterocele [97], 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, 75, 98].

In the evaluation of rectoceles, evacuation proctography has been used to diagnose enteroceles, rectoceles, perineal descent and rectal intussusception. Dynamic contrast roentography or fluoroscopic cystocolpoproctography have also been used [4. 80,81, 97,100] 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 [18]. Other investigators have also shown that triphasic dynamic MRI and triphasic fluoroscopic cystocolpoproctography have similar detection rates for rectocele [97]. Recently, upright dynamic MRI defecating proctography has been reported [101]. 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 include anismus, intussusception, and others, and may be too invasive to justify their routine use in the evaluation of rectocele.

Kaufman [102] 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 MRI, dynamic cystocolpoproctography, and subsequent multidisciplinary review and operative repair. Physical examination, dynamic MRI, 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 for 41 percent of patients. Dynamic MRI was the only modality that identified levator ani hernias. Dynamic cystocol-poproctography identified sigmoidoceles and internal rectal prolapse more often than physical examination or dynamic MRI. Whether this type of imaging creates measurably better outcomes remains to be seen. Singh et al [103] showed 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 the area of the genital hiatus could be assessed quantitatively on magnetic resonance images. Torricelli [74] studied ten healthy volunteers and 30 patients with suspected pelvic floor deficiency with and without pelvic organ prolapse. They compared MRI findings with findings on pelvic examination. They found good concordance between physical examination and MRI 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 [104] 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 routine evaluation of patients with [uncomplicated primary] pelvic organ prolapse; however data concerning the causes of prolapse are rapidly accumulating and this may change soon. It can provide useful information concerning complex prolapses and can be used in difficult cases. **[Level of evidence 3, Grade of Recommendation C]**

SUGGESTED RESEARCH AREAS

1. Studies that identify specific defects in the connective tissue and the muscles of the pelvic floor that correlate these findings with the clinical presentation in prolapse are needed.
2. Additional studies comparing MRI of healthy volunteers and patients with pelvic organ prolapse are needed to better evaluated the anatomic changes involved in pelvic floor prolapse.
3. Quality control in MRI, including: what maneuversmanoeuvres are required to produce a maximal prolapse during MRI, standardisation of bowel conditions, degree of bladder filling, pushing instructions, etc.)

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B.3 SPECIAL ISSUES

I. POST-VOID RESIDUAL

1. BACKGROUND

Post-void residual urine (PVR) is defined as “the volume of urine left in the bladder at the end of micturition [1]. Evaluation of PVR prevalence in women with symptomatic pelvic floor dysfunction suggests that 81% have a post-void residual of 30 ml or less [2]. This is not significantly different from asymptomatic perimenopausal and postmenopausal women in whom 15% of subjects had a PVR greater than 50 ml [3]. If symptoms can not predict elevated PVR, a urogenital prolapse beyond the hymen seems to be associated with incomplete bladder emptying [4]. Among patients with symptoms of overactive bladder, age older than 55 years, prior previous incontinence surgery, history of multiple sclerosis and vaginal prolapse stage 2 or greater, were found to be independent predictors of elevated PVR [5]. Similar data were obtained by Fitzgerald in patients with urgency incontinence, the presence of pelvic organ prolapse ≥stage 2, symptoms of voiding difficulty and absence of stress incontinence symptoms predicted 82% of patients with elevated PVR [6]. Higher prevalence of post-void residual was found in patients with stress urinary incontinence with 35.5% of women had a PVR >50 ml suggesting they have some degree of voiding dysfunction [7]. Although elevated PVR and bacteriuria are common among elderly residents in nursing homes, no association between the two was observed in a Swedish study [8]. Analysis of elderly patients with urinary incontinence failed to identify any significant association between PVR and any other clinical or urodynamic parameter [9]. 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 [10].

PVR is often considered a safety parameter, that needs to be monitored in the follow-up of medical or surgical management of urinary incontinence. A number of studies have addressed the effect of antimuscarinic treatment in men with symptoms of overactive bladder to rule out the old dogma that banned the use of these drugs in elderly men. Actually, all published data suggest that antimuscarinic treatment is safe also in men with benign prostatic enlargement and no significant change in PVR values was found in active treatment groups compared to placebo [11, 12]. In male patients with bladder outlet obstruction, antimuscarinic treatment may result in a significantly larger PVR (25 vs. 0 ml) that seems to be of no clinical relevance and does not reflect in any higher incidence of adverse events [13].

Although the prevalence of incomplete bladder emptying among male and female patients with urinary incontinence and pelvic floor dysfunction is low, there is a general consensus that PVR should be measured in all incontinent patients [14].

2. MEASURING PVR

The measurement of PVR can be performed by invasive and noninvasive means. Invasive methods include: in-and-out catheterisation and endoscopy. Noninvasive means are transabdominal ultrasonography with real-time ultrasound or fully automated systems, and radioisotope studies. In-and-out catheterization has been considered for some time, 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 [15]. Stoller and Millard showed inaccuracies in 26% 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 those measurements that were found to be inaccurate [16]. 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 are usually performed with some kind of local anaesthesia and carry a small the risk of urethral damage and urinary infection.

Before the era of ultrasonography, PVR was measured non-invasively by the phenolsulfonphthaleine excretion test or with isotopes [17, 18].

In 1967, Holmes described the use of ultrasonography in the evaluation of bladder volume and this technique rapidly gained widespread acceptance as a satisfactory level of accuracy was demonstrated [19, 20]. 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**). Twenty-one different formulas have been proposed over the years making assumptions about bladder shape which have often been questioned [21]. Comparison of values of bladder volumes obtained using different formulas did not result in any significant difference amongst the various calculations [22]. At present, 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 [20, 21, 23-26]. False negative results are rare with PVR less than 20 ml [27]. Recently portable scanners were introduced, with automatic measurement of bladder volume. In a prospective comparison of one hundred measurements of PVR by portable ultrasound with measurements by catheterisation, the mean absolute error of the scanner was 52 ml [28]. For volumes below 200 ml and 100 ml, the error was 36 ml and 24 ml respectively. More recent studies suggest a good level of accuracy in both female and paediatric populations [29, 30]. 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 hours period. This was reported in men with BPH by Birch et al. and by Bruskevitz et al. [31, 32]. Griffiths et al. examined the variability of PVR among 14 geriatric patients (mean age 77 years), measured by ultrasound at three

Table 3. Comparison of different formulae to assess PVR by transabdominal ultrasound in 30 men with BPH scanned three times [32].

Author/reference	Method	Standard error	95% Confidence limits
Hakenberg et al [40]	625 x H x W x (D1+D2)/2	17.5	34.3
Poston et al [41]	7 x H x W x D1	20.0	39.2
Hartnell et al [42]	625 x H x W x D1	17.0	33.3
Rageth and Langer [43]	Nomogram based on areas	15.0	29.4

Modified from the Proceedings of the 4th International Consultation on Benign Prostatic Hyperplasia p. 205 different times of day on each of two visits separated by 2-4 weeks [33]. 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 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 reported the questionable value of PVR as an important outcome prognosticator in male patients with benign prostatic enlargement and benign prostatic obstruction [34-39]. The cause of PVR is probably mutifactorial, and no consensus exists on the relation of PVR, bladder outlet obstruction and detrusor contractility.

CONCLUSIONS

The knowledge as to the pathophysiology of PVR remains unclear. In patients with urinary incontinence, no consensus exists as to its value as a safety parameter and particularly its relation with upper tract dilation, 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 recommended method for assessing PVR because it is the least invasive and it 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 in and-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. Pathophysiology of PVR in male and female populations with UI;
2. Diurnal variation of residual urine in patients with UI;
3. Determination of the cut off value of significant residual urine in different patient populations with UI
4. Residual urine as a prognostic indicator of outcome in the treatment of incontinence

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II. OPEN BLADDER NECK AND PROXIMAL URETHRA AT REST

An open bladder neck and proximal urethra at rest is usually an unexpected observation of voiding cystourethrogram or pelvic floor ultrasonography and its significance remains doubtful [1]. A 21% prevalence in nulliparous asymptomatic women has been reported [2]. In the non-neurogenic population there is no pathophysiological correlation between such this and urinary incontinence, Digesu and co-workers reported a prevalence of 1:3 amongst females suffering LUTS. An open bladder neck at rest is not pathognomonic of sphincter incompetence although it is associated with USI [3]. In patients with stress incontinence, but also in asymptomatic women [4], funnelling of the internal urethral meatus may be observed on Valsalva (Fig. 5) and sometimes even at rest; funneling is often associated with leakage. However, funnelling may also be observed in urgency incontinence and cannot be used to prove USI. Marked funnelling has been shown to be associated with poor urethral closure pressures [5, 6].

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 neurological disease and is interpreted as a sign of internal sphincter denervation as occurs in 53% of patients with MSA [7]. Distal spinal cord injury has been associated with an open smooth sphincter area, but whether this is due to sympathetic or parasympathetic decentralisation or defunctionalisation has never been settled [8]. 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 [9]. In a review of 550 patients [10], 29 out of 33 patients with an open bladder neck had neurological 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 underactive bladder. Shy-Drager syndrome is a Parkinson-like status with peripheral autonomic dysfunction. Neurogenic detrusor overactivity is usually found in association with an open bladder neck at rest and a denervated external sphincter [11]. 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 [12]. 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 [13-16] although the possible role of parasympathetic innervation has been proposed by others [17, 18]. An open bladder neck at rest in children or in women without neurological disease can represent a different disorder, either related to a congenital anomaly or secondary to an anatomical pelvic floor defect. Stanton and Williams [19] 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 [20] 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-neurogenic 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 USI in later life.

Open bladder neck is a key point in defining type III stress incontinence according to the classification of Blaivas and Olsson [21]. 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 that 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 in controversial [22-24]. Skala and co-workers suggest that an open bladder neck at rest is associated with an increased risk of postoperative complications and failure after open colposuspension [25]. Further research in this area is required to confirm these data.

In conclusion, the diagnosis of open bladder neck at rest does not seem to be helpful to diagnose the underlying cause of urinary incontinence.

RECOMMENDATIONS

When observing an open bladder neck and proximal urethra at rest in male patients, 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

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III. FEMALE URETHRAL DIVERTICULA

The prevalence of urethral diverticula ranges between 1 and 6% with rates up to 10% in among symptomatic women from tertiary referral centres [1, 2]. The suspicion of a urethral diverticulum stems from LUTS or urethral masses on physical examination. Urethral masses include leiomyoma, vaginal cysts, malignancy, ectopic ureter, granuloma and urethral diverticula. The first case of female urethral diverticulum was reported in 1805 [3] . Since the report from Davis and Cian in 1956 [4] using positive-pressure urethrography (PPU), the diagnosis has become much more common even though, despite increased clinical awareness, this pathology continues to be frequently overlooked. Urinary incontinence is often associated with a urethral diverticulum. Incontinence may be a sequel to urine loss from the diverticulum itself with stress manoeuvres, USI or urgency incontinence [5]. Aldrige et al. [6]. 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 [7, 8]. 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 [4]. Two different models exist: the Davis-TeLinde and the Tratner catheter. Positive-pressure urethro-graphy (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.

The accuracy of a diagnostic test may depend upon the characteristics of the study population and conflicting data are often reported in the peer-review literature. Blaivas et al report a diagnostic accuracy of VCUG of 97% in a series of 66 patients and similar results (95%) were obtained by Ganabathi et al. [7, 9]. Less favourable results were reported by others. Comparison of VCUG versus PPU in the diagnosis of urethral diverticula showed a clear superiority of the latter with good consistency among different studies [10, 11]. In some patients, VCUG only delineated the lower part of the diverticulum [12]. Ultrasound sonography and MRI should be theoretically free of such false negative imaging. Chancellor et al. [13] 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 imaging 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 [14-19] (Figure 28 a,b). MRI is superior to VCUG or double-balloon urethrography, particularly in diagnosing diverticula with narrow, noncommunicating necks [15, 16]. 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 [17]. Endoluminal MRI is considered to be of particular importance in the diagnosis of circumferential urethral diverticulum, a condition that is relatively rare but the diagnosis may increase with the increased use of this imaging technique. Proper evaluation of diverticulum anatomy is essential in planning reconstructive surgery [1, 20]. MRI also proved to be useful in diagnosing inflammation and tumour of the diverticulum [21, 22]. Endoluminal MRI with either a vaginal or rectal coil, may provide even better image quality than simple MRI [18]. 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 [14]. 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. Diverticula ostia could not be identified by MRI study not withstanding the use of contrast material. Neitlich et al. [15] 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 al. [17], 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 not withstanding 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 [23].

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

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IV. IMAGING OF THE NERVOUS SYSTEM IN URINARY INCONTINENCE

1. LUMBOSACRAL SPINE X-RAYS

No significant update can be provided compared to the previous report of the 2005 [1]. In children with lower urinary tract dysfunction and urinary incontinence, the presence of a spinal dysraphism must be ruled out. Although in most of the cases abnormalities of the gluteosacral region and/or legs and foot are clearly visible, antero-posterior and lateral films of the lumbosacral spine have to be evaluated in order to identify vertebral 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 ruleusually found. 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. lumbo-sacral spine anteroposterior and lateral radiological evaluation (or MRI) is indicated. **(Level Evidence 3, Grade of Recommendation C)**

2. CT, MRI, SPECT and PET

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 to identifying the underlying CNS disease. These references have little impact on the daily practice although can he helpful in occasional difficult cases.

With regards to the clinical diagnostic use of CT or MRI, a few papers evaluated the role of fetal MRI imaging. Fetal MRI has higher contrast resolution than prenatal sonography and allows better identification of normal and abnormal tissue. Moreover, MRI can diagnose some abnormalities such as cerebral malformations and destructive lesions which can be occult on prenatal sonography, where the more anterior cerebral hemisphere cannot be properly evaluated due to reverberations by the overlying structures [2]. Common indications for fetal MRI include the evaluation of all the sonographically diagnosed abnormalities of ventriculi, corpus callosum, or posterior fossa, as well as all those fetuses at increased risk for brain abnormalities, such as in families with a history of a prior child or fetus with anomalies, genetic disorders, complications of monochorionic twinning, and maternal illness (such as maternal infection or major cardiac event). Moreover, with recent advances in fetal surgical techniques, fetal MRI is being increasingly used before surgical intervention [3]. The results of fetal MRI, whether verifying absence of abnormality, confirming sonographically detected abnormalities, or discovering additional abnormalities that were not apparent by sonography, have been shown to affect clinical decision-making during pregnancy, both by physicians and parents, resulting results in changes in pregnancy management in nearly half of cases [2]. With regards to myelomeningocele, prenatal ultrasound can easily identify the absence of posterior elements of the vertebral bodies at affected levels and extension of the subarachnoid space posteriorly through the bony spina bifida, as well as the frequently associated presence of small posterior fossa alteration and haerniation of cerebellar tissue into the cervical subarachnoid, which define the Chiari II malformation. However, fetal MRI can be a helpful adjunct when sonography analysis is limited, such as in cases of large maternal body habitus, oligohy-dramnios, low position of the fetal head, or when the fetal spine is positioned posteriorly with respect to the mother. Moreover, fetal MRI can be very useful to detect additional associated anomalies, such as callosal agenesis or hypogenesis, periventricular nodular heterotopia, cerebellar dysplasia, syringo-hydromyelia, and diastematomyelia [3]. If fetal surgery will be shown to improve long-term outcome, fetal MRI will surely become a routine examination for affected fetuses.

MRI is also recommended in children with anorectal abnormalities 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 [1]. Wraige et Borzyskowski suggested that spinal cord imaging should bhe considered in children in whom day-time 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 10 children with these symptoms had a spinal cord defect diagnosed on MRI [4].

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. A potential technical update might be the use of intrathechal contrast medium to perform cisternography and ventriculography contrast-enhanced MRI. Munoz et al., evaluated a series of 10 patients with complex cerebrospinal fluid diseases, where other imaging techniques had been unclear or inconclusive, performing MRI with intrathechal administration of gadopentate dimeglumine. In 8 out of the 10 patients, imaging findings influenced or changed the clinical decision-making program and the surgical planning [5].

Sharma et al. recently evaluated with MRI the surgical outcome in patients with spinal dysraphism. Specifically, MRI spectroscopy was used to evaluated the composition of cerebro-spinal fluid before and after surgery. Before surgery, high levels of lactate, alanine, acetate, glyceropho-sphorylcholine, and choline were observed in the cerebrospinal fluid of patients with spinal dysraphism, while these levels normalized postoperatively to those observed in control subjects. However, in those patients where cord retethering occurred, increased concentrations of lactate and alanine were found, suggesting that MRI spectroscopy might be a promising tool in the assessment of surgical outcomes in patients with spinal dysraphism [6].

Several papers refer tos the use of CNS imaging in clinical research of voiding dysfunction and patho-physiology. Positron emission tomography (PET) and functional MRI studies provided information on specific brain structures involved in micturitions in humans. During micturitions an increase in regional blood flow was shown in the dorsomedial part of the pons close to the fourth ventricle, in the pontine micturitions centercentre (PMC), in the mesencephalic periacque-ductal grey (PAG) area, as well as in the hypothalamus includinged the preoptical area [1].

A couple of significant original studies were have been published since the last International Consultation on Incontinence on the role of functional MRI in stress and urge urinary incontinence. Specifically, previous brain imaging studies showed that during pelvic floor muscle contraction there was activity in the superior medial precentral gyrus, anterior cingulate cortex (ACC), cerebellum, supplementary motor cortex (SMA) and the thalamus [7, 8]. Similarly, during anal spincter contractions multifocal cerebral activity was shown in the primary and secondary sensory/motor cortices, the insula as well as the cingulate gyrus, prefrontal cortex, and the parietooccipital region [9]. Di Gangi Herms et al. evaluated the neuroplastic changes of cortical representation of pelvic floor motor functions induced with pelvic floor muscle training (PFMT) by biofeedback in patients with SUI [10]. Specifically, the authors used functional MRI to evaluate 10 patients with stress urinary incontinence SUI before and after a 12-week PFMT with EMG-biofeedback program. In the MRI performed before the beginning of PFMT, the authors identified significant brain activation in superior lateral and medial precentral gyrus and the superior lateral postcentral gyrus, in the SMA, the left premotor area, and in the left and middle cerebellum, as well as in the insula as well asand in the ACC. In the MRI film after PFMT, less brain areas were activated, mainly the superior lateral and medial precentral gyrus, superior lateral post-central gyrus and the insula. In other words, after PFMT it was identified a more focused activation in the primary motor (superior lateral and superior medial precentral gyrus) and somatosensory areas, which is consistent with automatization automation of the relearned skillful behavior [10]. PFMT with biofeedback may improve muscular strength therefore enhancing support of the urethra and also optimize central muscular control of the pelvic floor, modulate bladder sensation, and reflect the emotional neutralization related to symptom reduction.

With regards to urge urinary incontinence, Tadic et al. reported a small study, which used functional MRI to investigate 11 patients with urge urinary incontinence and 10 healthy controls. Specifically, the connections of the right insula (RI) and anterior cingulate gyrus (ACG) to other cortical area were evaluated, based on the assumption that the two areas were among the most important regions of the supraspinal neuronal network controlling the bladder. In normal subjects, there were significant positive effective connections with many of the regions involved in supraspinal bladder control, including left insula and frontotemporal and parietal regions, thalamus, putamen and claustrum, posterior cortex, cerebellum, pontine micturition centre and mesencephalic periacqueductal grey. Vice versa, in the patients with urgency incontinence, significant negative connections to left parieto-temporal lobes, hippocampus, parahippo-campal gyrus and cerebellum were found, with few positive connections [11].

In subjects with normal bladder function, RI and/or ACG have been reconfirmed to have effective connections with many of the brain regions involved in bladder control such as the frontotemporal and sensorimotor regions, thalamus, putamen, cerebellum and midbrain, as well as to the posterior cortex, a region which may have a role in the control of bladder function. Vice versa, in the patients with urgency incontinence, the connections were shifted to an alternative complex of brain regions, such as left parieto-temporal lobes, parahippocampal gyrus and parts of cerebellum, which might represent expression of the recruitment of accessory pathways in order to control urgency and the voiding reflex as well as the emotional charge due to the abnormal sensation of urgency [11]. On the whole the data of these recently published studies have improved our knowledge of nervous functional anatomy related to vesicourethral function and dysfunction but, to date, have no clear clinical relevance.

In conclusion, central nervous system imaging is rarely indicated in urinary incontinence. Spinal cord imaging is recommended in cases 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.). Further improvements in the knowledge of the correlation between morphologic and functional evaluation of the CNS is foreseeable using present CNS functional imaging technology.

RECOMMENDATIONS

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

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V. ENDOSCOPY OF THE LOWER URINARY TRACT

I. BACKGROUND

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 rarely been based on evidence. There are five specific areas pertaining to urinary incontinence in which cystourethroscopy has been advocated:

1. Observation of the female urethral sphincter to assess its ability to close and coapt. Urethrocystoscopy has been advocated in the static state to assess 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 pipestem 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 be the cause of detrusor overactivity and urinary incontinence or may simply require treatment.
3. Search of extraurethral causes of urinary incontinence, such as vesico-vaginal fistula and ectopic ureter.
4. Intraoperative cystourethroscopy during correction of USI 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. Assessment of bladder outlet in males with urgency incontinence considered to be secondary to bladder outlet obstruction to appraise prostate morphology.

2. 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 SUI as a sluggish closure of the bladder neck and the appearance of the overactive 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 SUI 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 USI [3]. Of the 204 patients, 99 had USI. Urethroscopy was found to be an imprecise predictor of USI 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 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 SUI using urethroscopy [5]. They retrospectively reviewed the records of 263 women who had a diagnosis of USI. 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 concluded 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.

3. 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 SUI [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 SUI and detrusor overcativity [9].

Cystoscopy revealed no abnormalities amongst the 100 patients with USI. Fourteen of the 100 patients with detrusor overactivity had cystoscopic abnormalities, eg trabeculation, injected mucosa, sacculation, a bladder capacity of less than 100 cc. 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 overactive 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 haematuria [11]. They performed urinalysis, urine cytology, and cystoscopy on 128 women who presented with urgency incontinence and/or storage voiding symptoms. Of these, 68 patients had urgency incontinence, 35 of whom also had microscopic haematuria. One patient with urgency incontinence and haematuria was found to have a transitional cell carcinoma of the bladder. None of the patients with urgency incontinence (or storage symptoms only) and no haematuria were found to have significant cystoscopic findings. This would support the routine use of cystoscopy for patients with urgency incontinence only if haematuria is present.

4. 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 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.

5. 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.

6. EVALUATION OF THE MALE BLADDER OUTLET

Urgency 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 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 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 affected 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 (pressure-flow) 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.

7. EVALUATION OF URETHRAL SPHINCTER IN POST-PROSTATECTOMY INCONTINENCE

Iatrogenic UI in males usually occurs after prostate surgery for benign and malignant conditions. The pathophysiology of UI following transurethral surgery for BPH includes sphincter damage from extending the resection too distal, particularly in the ventral aspect of the sphincter where muscle fibres are more abundant. Endoscopy in post-TURP incontinence reveals insufficient closure at rest with tissue loss in the ventral aspect of the sphincter area, voluntary muscle recruitment is often good. The pathophysiology of UI in post-radical prostatectomy patients is unclear. Numerous studies investigated the relation between parameters of urethral pressure profile, morphology of the prostate apex and length of the external sphincter area to post-prostatectomy incontinence. Although the results of these studies suggest a relation between sphincter competence and UI, no consensus has been reached yet as to the gold standard test to be performed prior to surgery to assess the individual patient risk of incontinence.

Recently, Gozzi and Rehder suggested that post-radical prostatectomy incontinence may be related to prolapse of the sphincter complex and that repositioning of it by a transobturator sling may be successful. Pre-operative selection of surgical candidates for such intervention include endoscopy of membranous urethra testing whether manual push-up of the centrus tendineus perinei results in recruitment of the sphincter fibres comparable to a voluntary contraction. Contraction of the sphincter muscle upon repositioning in a more cranial position is used as an indication for a transobturator sling with the Gozzi and Rehder technique [22-24]. Further research is required to confirm such an interesting pathophysiological explanation of post-radical prostatectomy incontinence and to support the role of endoscopy in the evaluation of these patients.

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 urgency 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 urgency incontinence)

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C. IMAGING IN ANAL INCONTINENCE

I. BACKGROUND

Anal incontinence may result from anal sphincter weakness and/or rectal sensory disturbance. Imaging provides highly detailed evidence of changes to sphincter morphology. This started with the development of endoanal ultrasound (EAUS) in 1989, which soon became the gold standard[1] for demonstrating internal and external sphincters tears. Important early findings were the unexpectedly high incidence of occult sphincter damage following vaginal delivery[2], and an association between a history of obstetric trauma with faecal incontinence developing later at menopause. Parks' original work[3] had focussed on denervation and striated muscle atrophy as the main cause of faecal incontinence. One limitation of EAUS was in measuring the external sphincter thickness, and it was not until MRI with an endocoil for the anal canal was developed that highly detailed images of the striated sphincteric muscle to show thickness and fat replacement were possible, and external sphincter atrophy could be assessed by means other than EMG. Studies of rectal evacuation are performed mainly fluoroscopically, and give only a rough indication that the patient suffers from incontinence. They are used mainly to investigate difficult defaecation and rectal prolapse.

II. INDICATIONS

The role of imaging is largely to place patients into treatment defined groups, so the emphasis may change as new treatments evolve. Endosonography took over from EMG studies as the optimum method to select patients with sphincter disruption for surgical repair, and this remains its main indication. When to investigate for external sphincter atrophy is a more complex question. Endocoil MRI may be indicated prior to sphincter repair if there is any doubt as to the quality of the external sphincter. Biofeedback has become a popular first line treatment, and a recent study suggests that imaging has only a limited role in predicting success[4], which could have a negative impact on the utilization of imaging.

III. IMAGING MODALITIES

1. ENDOANAL ULTRASOUND (EAUS)

Several systems are available, and recently integrated 3D systems are available (B&K Medical, Sandoften 9, 2820 Gentofte, Denmark). US probes designed for transvaginal examination with endfire linear arrays may be used in women to image the sphincters from the perineum. Women should be examined prone with an endoanal system to minimise anatomical distortion.

The standard EAUS image of the anal canal is of 4 layers (**Figure 1**):

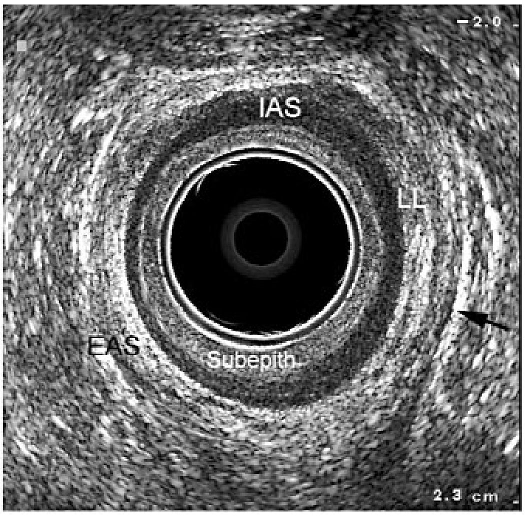


Figure 1 : Axial endosonography in the mid canal in a normal 38yr old female. Subepith: subepithial layer; IAS: internal anal sphincter; LL: longitudinal layer; EAS: external anal sphincter. The outer border of the external sphincter is defined by an interface reflection at the fat/muscle boundary (arrow).

1. The subepithelial layer is moderately reflective.
2. The internal sphincter is the most obvious landmark and is a well defined low reflective ring. The internal 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.
3. The longitudinal layer is a complex structure with a large fibroelastic and muscle component, the latter formed from the puboanalis as well as the longitudinal muscle of the rectum (**Figure 2**).
4. The external sphincter is better defined in men than women, where it tends to be less hyoechoic. It is distinguished mainly by interface reflections between muscle/fat planes either side (Fig 1). In women the external sphincter is shorter anteriorly than posteriorly, which must not be misinterpreted as a tear. The transverse perineii fuse anterior with the sphincter, whereas in men they remain separate.

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

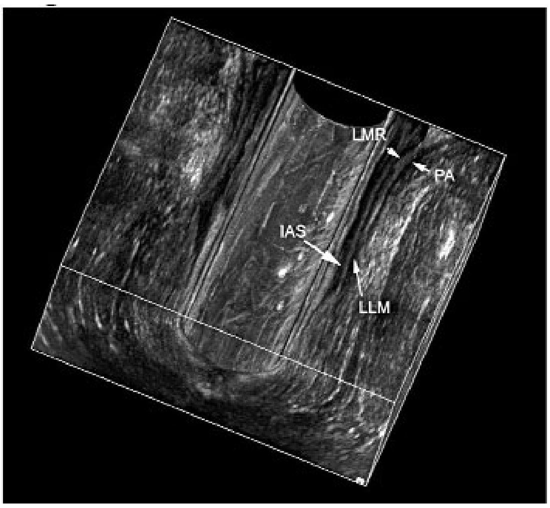


Figure 2 : 3D view of the anal canal in the mid coronal plane with some image manipulation to highlight the internal sphincter (IAS) and the longitudinal muscle of the rectum (LMR) joining the puboanalis (PA) to form the combined longitudinal layer muscle (LLM).

2. MRI

Dedicated endoanal coils are no longer available, so that much of the research using these cannot now be transferred into routine practice. However, image quality has improved dramatically with standard external coils, and MRI is particularly useful to show atrophy and tears outside the sphincter, such as the puborectalis [5].

The advantages of MRI are multiplanar imaging and that the difference in signal between fat and striated muscle allows precise measurement of external sphincter (**Figure 3**) thickness and estimation of fat replacement.

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 30mins before. The patient is seated sideways within the fluoroscopic unit on a radiolucent commode. Evacuation of the barium paste is recorded either on video or on cut film at 1 frame/sec using a low dose protocol. At rest the anorectal junction is at the level of the ischial tuberosities and the anal canal closed. 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. Intra-anal intussusception creates a thick double fold of rectum, which impacts into the anal canal on straining at the end of rectal evacuation. Rectal prolapse represents an extension of this process, with passage of the intussusception through the anal canal and inversion of the rectum (**Figure 4a-c**).

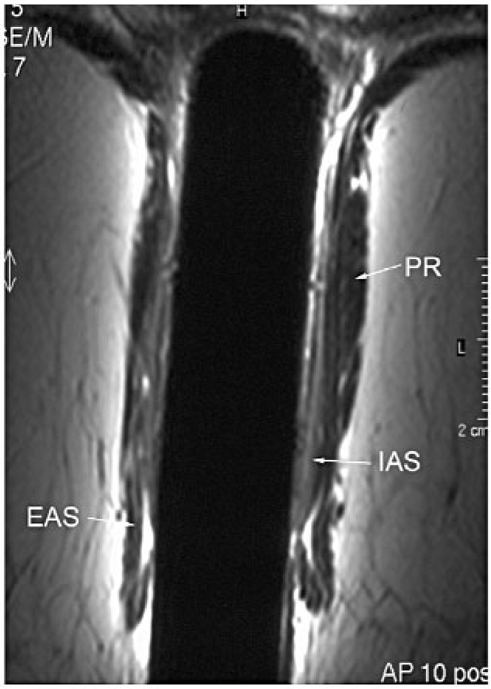


Figure 3 : Mid coronal MRI with an endocoil. The endocoil causes the central black void from absent signal. The smooth muscle of the IAS is of moderate signal intensity, and higher than the striated muscle of the PR and EAS. Note how well the striated muscle is demarcated by the high signal from the fat in the ischioanal fossae.

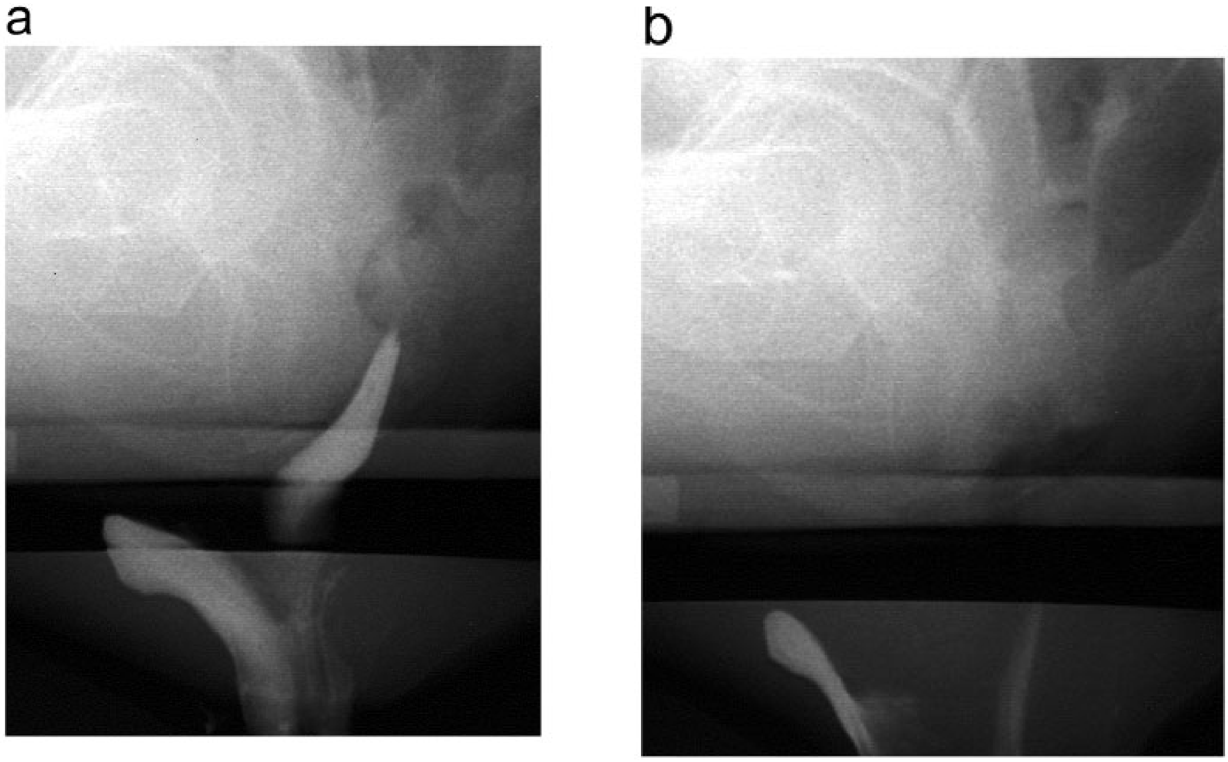
Dynamic examinations of rectal emptying may also be performed with MRI, though this is technically more difficult and perhaps not worthwhile unless a global view of pelvic floor prolapse is required, although it does eliminate any harmful radiation. A simpler method involves views during only rest and stress. This is useful to show bladder and uterovaginal prolapse as well as pelvic floor descent (**Figure 5a-b**), but gives limited information as to rectal function.

IV. SPHINCTERIC DISORDERS

1. THE INTERNAL ANAL SPHINCTER

Abnormalities of thickness have to be related to the patient's age. A sphincter less than 2mm thick in a patient more than 50 years of age is indicative of internal sphincter degeneration (**Figure 6**) and is associated with passive faecal incontinence.

Obstetric trauma to the internal sphincter parallels that of the external sphincter in extent, but should always be in the anterior half, so that any defect between 3 and 9 is due to some other cause.



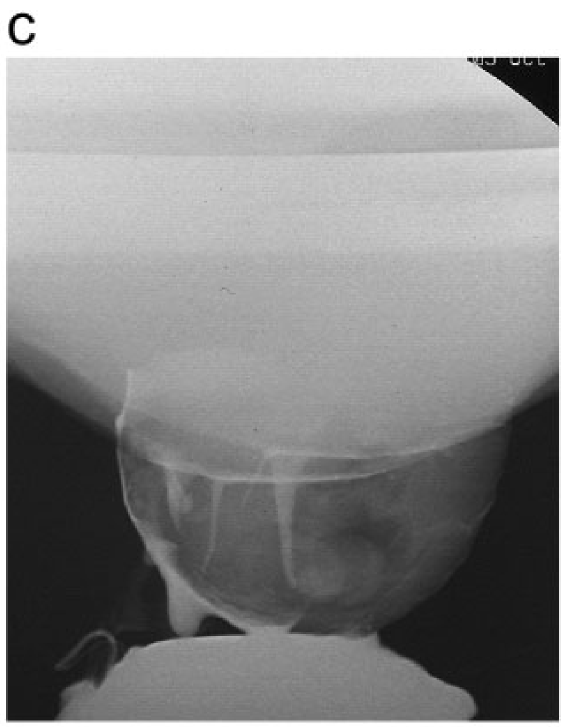


Figure 4 : Evacuation proctogram showing the development of rectal prolapse. Intussusception starts at the end of rectal emptying (a) and rapidly passes through the anal canal (b) to form the external prolapse (c).

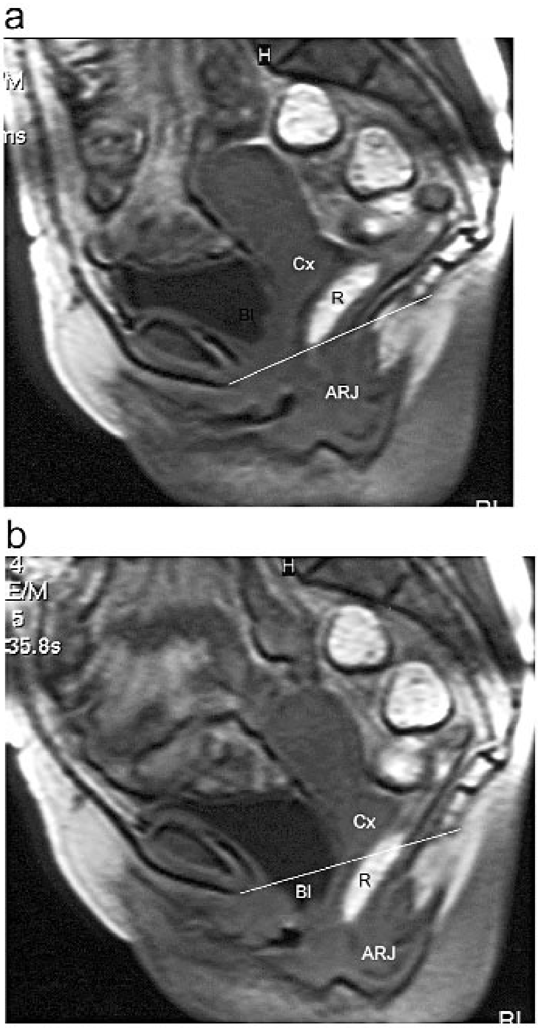


Figure 5 : Sagittal views from a dynamic MRI examination. The dotted line indicates the position of the pubococcygeal line. At rest (a) there is some descent as the anorectal junction (ARJ) is more than 1 cm below this. During pelvic stress (b) there is marked pelvic floor descent, with descent of the cervix (Cx) and bladder base (Bl).

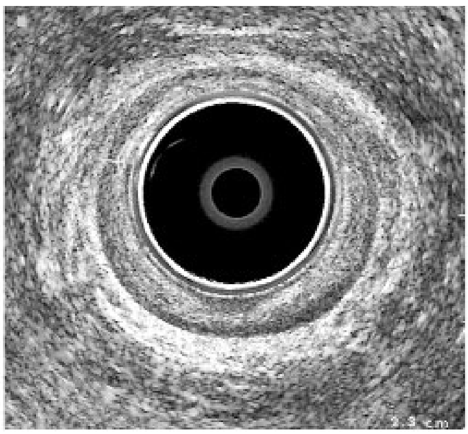


Figure 6 :Endosonography with an axial image in the mid canal of an elderly patient, aged 73yrs with passive faecal incontinence. The internal sphincter measures only 1.1mm (markers) indicative of internal sphincter degeneration.

Sphincterotomy may be more extensive than was planned, particularly in women, and 3D studies are especially helpful to assess the longitudinal extent of the defect. The length of the sphincter divided relates directly to the risk of incontinence[6]. Dilatation procedures are hazardous and may completely fragment (**Fig 7**) the internal sphincter.

2. THE EXTERNAL ANAL SPHINCTER

When striated muscle is stretched beyond the limits of its elasticity fibres rupture and heal with granulation tissue and eventually fibrosis. Most chronic tears are seen with scar formation, and present as a uniform area of low reflectivity distorting and obliterating normal anatomical planes (**Figure 8**). A key to the diagnosis is lack of symmetry with the anterior part of the external sphincter not fusing at 12 o'clock as the probe is moved slowly down the canal. This may also be seen on 3D studies in the coronal plane (**Figure 9**). Other perineal structures, such as the puboanalis and transverse perineii are frequently torn and distinguishing these tears from external sphincter trauma requires experience, and again may be helped by 3D multiplanar imaging. The distinction is important as tears of the puboanalis or transverse perineii are not associated with a significant fall in squeeze pressure[7], and it is only damage to the external sphincter that results in a significant change.

In healthy young adults a 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[8].

The outer border of the external sphincter is easier to see on MRI, but fibrosis is not so markedly different in signal from normal muscle, so that the conspicuity of tears may not be as obvious as with endosonography.

Atrophy is a more difficult problem. Determining the thickness of the external sphincter on EAUS depends on visualising its borders from interface reflections between the longitudinal layer on the inside and subadventitial fat on the outer border. As atrophy involves a reduction of muscle fibres and an increase in fat, the outer interface reflection is lost and the thickness of the external sphincter cannot be measured. Such loss of definition of the outer border of the external sphincter on endosonography has a positive predictive value of 71% for atrophy[9]. Using 3D EAUS and a grading system based on definition (**Figure 10**) and echogenicity of the external sphincter showed a comparable accuracy to endocoil MRI in detecting atrophy [10].

Pelvic floor descent at rest with the patient seated and impaired movement during pelvic floor contraction[11] (measured either on MR or EP) are good indicators of generalised pelvic floor weakness, and if the anal canal is open (**Figure 11**) this indicates

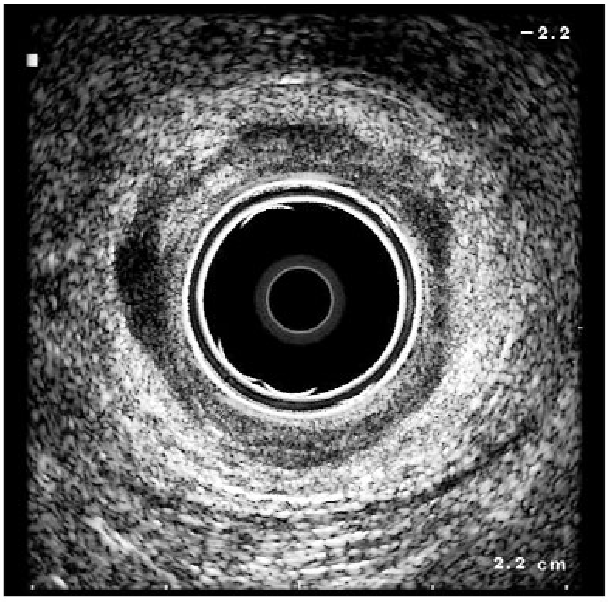


Figure 7 : Endosonography in the mid canal showing gross internal sphincter irregularity, typical of the "fragmented" appearance from trauma after an anal stretch procedure.

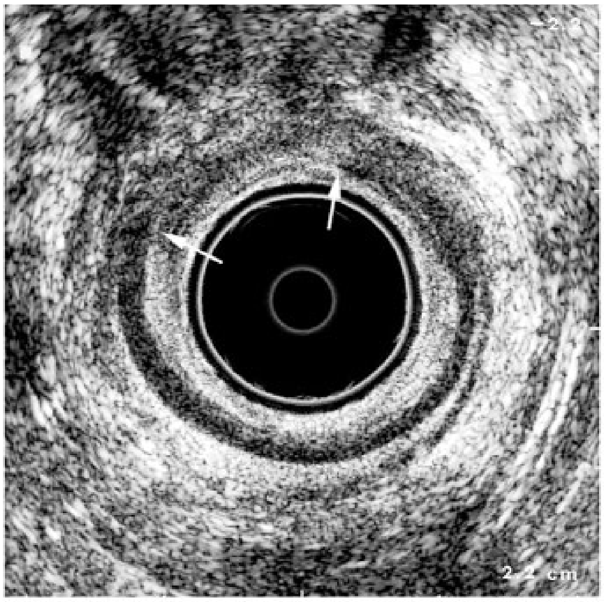


Figure 8 : Tears of internal and external sphincters (arrows) between 10 and 1 o'clock following a traumatic vaginal delivery.

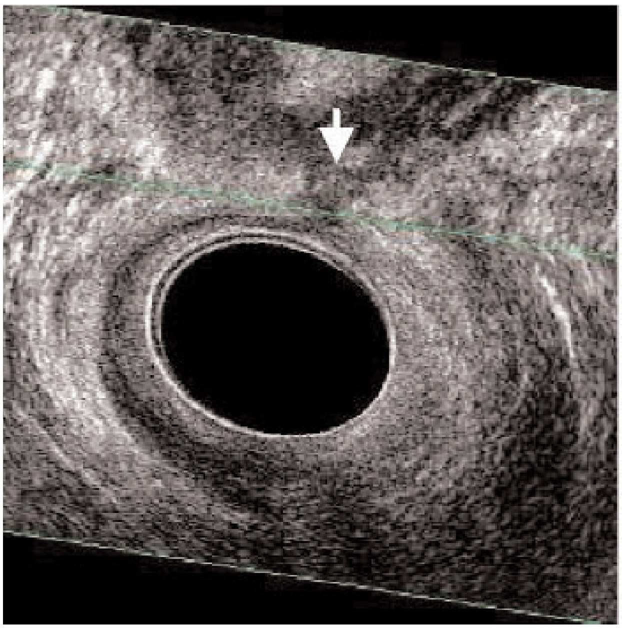


Figure 9 : 3D EAUS of a small tear to the external sphincter (arrow).

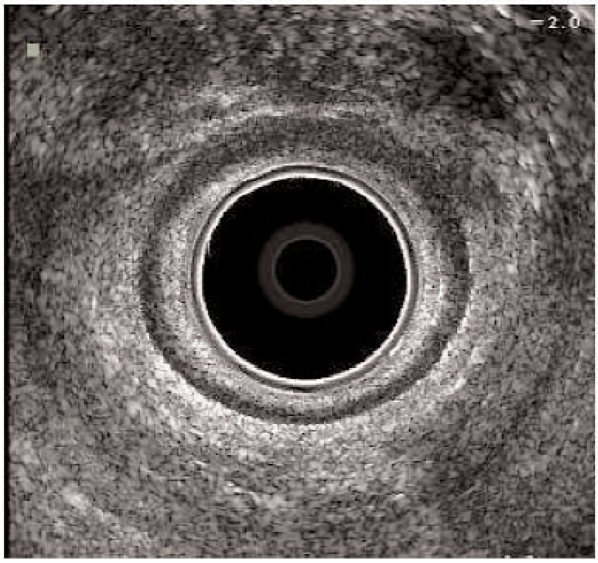


Figure 10 : EAUS showing a normal internal sphincter, but the external sphincter is not visible as it is echogenic and the interface reflections due to advanced atrophy.

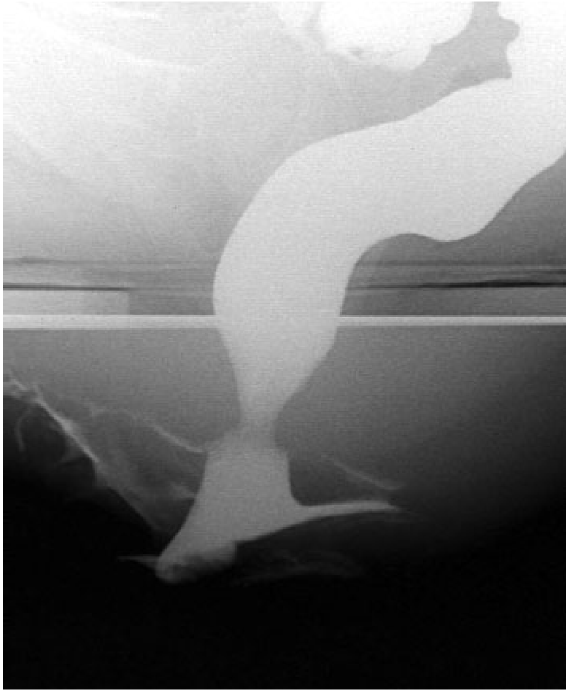


Figure 11 : Evacuation proctogram at rest. There is marked pelvic floor descent and the anal canal open indicating gross sphincter and pelvic floor weakness.

significant sphincter weakness. Most other findings, such as rectal prolapse, are really either secondary or associated with faecal incontinence, and EP is used to investigate these rather than the incontinence.

V. CONCLUSIONS AND RECOMMENDATIONS

Claims for superiority of one or other modality for the detection of sphincter tears probably depend largely on individual experience, but the cheapness and speed of endosonography makes this an ideal screening procedure to assess sphincter integrity.

Fluoroscopic studies have little role in faecal incontinence, unless there is an underlying rectal abnormality such as prolapse. Dynamic MRI studies have the added value of demonstrating prolapse in the rest of the pelvis, but apart from the lack of ionising radiation, has no real advantage for studying rectal function.

A leading issue is the significance of occult sphincter tears (diagnosed on endosonography but not apparent clinically) following vaginal delivery. Although these may be detected by careful examination immediately post partum [12], retrospective detection will still require EAUS. A meta-analysis of 717 vaginal deliveries 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 being due to a sphincter tear was 76.8-82.8% [13]. Recent studies confirm the strong relationship between obstetric sphincter damage and faecal incontinence [14,14], and its late onset [15,16]. Subsequent deliveries increase the risk of incontinence particularly if there has been a tear at the first delivery [17]. Tears that involve the internal sphincter increases the severity of incontinence [18].

A sphincter tear at EAUS is therefore an important finding, but how this is used to decide management a little more controversial. Sphincter repair has fallen out of fashion a little following the finding that results deteriorate over a few years [19], although a more recent study [20] suggests a better response.

EAUS therefore remains the first line imaging investigation for faecal incontinence, giving accurate information as to external and/or internal sphincter tears and the likelihood of atrophy. Dynamic studies of rectal evacuation are required only if there is some other problem suspected, such as prolapse. The advantages of using MRI are the lack of ionising radiation and a global view of the pelvic floor. Although imaging gives hard evidence of sphincter damage, this is really only part of a much more complex functional problem, and colorectal abnormalities may be just as important [11] with tears accounting for perhaps only 45% of incontinence [21].

RECOMMENDATIONS

- EAUS is the first line imaging investigation for faecal incontinence providing accurate information as to external and/or internal sphincter tears and the likelihood of atrophy. **[Level of Evidence 3, Grade of Recommendation C]**.
- Dynamic imaging of rectal function is required when rectal abnormalities such as prolapse are suspected **[Level of Evidence 3, Grade of Recommendation C]**.
- MRI offers no advantage over other imaging modalities except for the lack of ionising radiation and a global view of the pelvis **[Level of Evidence 3, Grade of Recommendation C]**.

SUGGESTED RESEARCH AREAS

MRI has allowed a much clearer understanding of pelvic floor anatomy, and this in turn has enabled the sonographic anatomy to be worked out. However, conflicting views remain when sonographic abnormalities are compared to function. Are clinical symptoms related to the size of a tears [22] or not [23]?

Problems after sphincter repair include:

- understanding the significance of the image soon after surgery [24],
- the value of manometry and imaging in assessing the repair [25],
- confirming that the length of the repair affects outcome [20].

Perhaps the most valuable aspect of MRI imaging is that gives a global view of the pelvis, capable of investigating urological, gynaecological and coloproctological problems at the same time. Many patients do not have faecal incontinence as an isolated symptom, but also have urinary or prolapse problems. The overview provided by imaging sets the way for a combined approach to the pelvic floor[26] and should be the prime area future investigation.

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D. PAD TESTING

BACKGROUND

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 and the technique was improved [3-8]. Walsh & Mills and Sutherst et al. introduced a more simple approach by estimating leakage by perineal pad weight gain [9, 10]. These tests were not standardised until Bates et al. described a "structured" one hour pad test which was endorsed by the International Continence Society in 1988 [11]. This test, however, was shown to have poor interdepartmental correlation and to be highly dependent on bladder volume [12, 13]. 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 [14].

I. DEFINITION

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.

INDICATION AND METHODOLOGY

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

II. OFFICE-BASED PAD TESTING

Pad tests up to 2 hours were developed to be performed in outpatient clinics or hospital wards under supervised conditions. Bladder volume is predefined 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 facilitate the occurrence of urine loss, if any, over a short period of time. Jakobseny et al. 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 [17]. The difference was attributed to significantly larger bladder volumes during performance of physical activity in a 40 minute pad test.

Kinn & Larsson reported no correlation between a short 10 minute test with fixed bladder volume and the degree of incontinence as judged from the symptoms [18].

Hahn & Fall 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 of incontinence severity and pad test results [15].

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

Table 4. Types of pad test

Author	Time	Bladder load	Exercise
Hahn & Fall [15]	20 min	50% of MCC*	stair climbing, 100 steps, coughing (10x), running (1 min), wash hands (1 min) jumping(1 min)
ICS [11]	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. [16]	24h		Everyday activities
Jakobseny et al. [17]	48h		Everyday activities

*Maximum Cystometric Capacity

tests was 0.94 (p<0.001) [15]. Kinn and Kinn & Larsson showed that the 10 minute test with a fixed pre-test bladder volume of 75% of maximal capacity was moderatey reproducible (r=0.74) [18]. 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 [19].

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

Jakobseny et al. reported that a one hour test detected less leakage at 3 g compared to a 40 minute (7 g) and a 48 hour pad test (37 g) [17]. 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 in-patient monitoring of urine leakage [20]. 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. noted that 90% completed the test and 69% had test results which correlated with daily leakage [16]. Lose et al. 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) [21]. Mouritsen et al. 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% [22]. Thind & Gerstenberg 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 [23].

b) Reproducibility

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

Lose and co-workers showed a significant variation between 1-hour ward test and retest in 18 patients (correlation coefficient 0.68) [12]. 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 found the reproducibility of the standard 1 hour pad test to be poor [25].

c) *Validity*

Walsh & Mills in the elderly and Holm-Bentzen et al. 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 [9, 26].

c) Bladder volume

Jorgensen et al 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 [16]. Fantl et al used 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 [27]. Lose et al. using 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 [28]. Jakobsen et al. 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 [29]. The amount of leakage in both groups was the same. Simons et al. found the volume in the bladder after a standard 1 hour pad test varies by –44 to +66g in a test-retest situation [25]. 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 compared a 1 hour pad test loss with the symptom impact index (SII) and the symptom severity index (SSI) [30]. 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 [31]. 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 [27, 32]. The reverse finding was reported by Matharu and co-workers [33]. 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 [34]. Ward et al. 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) [35]. The 1 hour pad test has also been tested for the reduction in loss after conservative and surgical therapy [36]. 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 [37]. Han et al showed, however, that a 1-hour pad test is more practical [38]. In children a 2-hour ward pad test yielded 70% positive results for incontinence [39]. Richmond et al. compared two exercise regimens with a 2-hour pad test and showed no significant differences in regard to which order the exercises were performed [40]. Walters et al. 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 [41]. 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.

III. 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

Quantification

Hellstrom et al. 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% [39].

2. 24-HOUR PAD TEST

a) Quantification

Lose et al. found a 90% correlation of a 24-hour pad test with history of stress incontinence in 31 women [21]. 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. showed that the 24-h home test is well tolerated and is as good at detecting incontinence as a 48-h test [22]. Griffiths et al. found only a 10% false negative rate of a 24-hour pad test in an elderly population [20]. Using non-parametric coefficient of correlation, they found a significant difference between the 1-hour test and the 24 hour test. Lose et al. 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 [21]. 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% [42]. Ryhammer et al. showed that 24-h test is superior to subjective self-reported assessment of urinary incontinence [43].

b) Reproducibility

Lose et showed poor correlation in a test-retest study with a variation of more than 100% [21] although Groutz et al. using Lin’s CCC, found 24-h test very reliable instrument [44]. 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 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 [45].

c) Diagnosis

Matharu et al found women with urodynamic stress incontinence leaked more than women with detrusor overactivity but the amounts were not diagnostic for the individual abnormalities [33]. 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 [46].

d) Validity

Karantanis et al found the 24-hour pad test was poorly correlated in women with USI with incontinence episodes on a 3 day urinary diary (Kendall’s corr coeff b = 0.4) and the ICIQ-SF (r = 0.4) [47]. Singh et al. reported that fewer (52%) women after surgery were willing to complete a 24 hour pad test at follow up [48].

3. 48-HOUR PAD TEST

a) Quantification

Jakobseny et al. showed that 48-hour pad test reflects everyday incontinence in 81% of patients [17]. No statistical analysis data were given. Ekelund et al., found patients own weighing correlate well to control weighing at the clinic in 48-h pad test (r=0.99) [49] **(Tables 5&6).**

Nygaard and Zmolek in 14 continent women showed a mean pad weight, attributed to sweat for all exercise sessions of 3.19 $\pm$ 3.16 g (the Kendall coefficient of concordance of the test-retest reliability was 0.96) but there was a lot of variation between patients [53]. Pyridium staining was not helpful in increasing specificity. Similar results with Pyridium were reported by Wall et al. in a 1-hour ward test [14]. In his study

Table 5. Test-retest correlation

Author	Test	Correlation coefficient	Symptoms
Klarskov & Hald 1984 [24]	1-h	0.96	SUI&UUI
Lose et al 1986 [12]	1-h	0.68	SUI & MIX
Fantl et al. 1987 [27]	1-h (vol)	0.97	SUI
Fantl et al. 1987 [27]	1-h (vol)	0.84	SUI & UUI
Lose et al. 1988 [28]	45-m (vol)	0.97	SUI & MIX
Victor et al. 1987 [50]	24-h	0.66	SUI
Lose et al. 1989 [21]	24-h	0.82	LUTS
Mouritsen et al. 1989 [22]	24-h	0.87	MIX
Versi et al. (1996) [51]	24-h	0.9	LUTS
Groutz et al. (2000) [44]	24-h	0.89	LUTS
Victor et al. 1987 [50]	48-h	0.9	SUI
Versi et al. (1996) [51]	48-h	0.94	LUTS
Groutz et al. (2000) [44]	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 [52]	20 min	10	0.0				
Nygaard & Zmolek, 1995 [53]	39.5 min	14	3.19	0.1-12.4	3.16		Exercise
Versi & Cardozo 1986 [54]	1h	90	0.39	0-1.15		0.04	
Sutherst et al. 1981 [55]	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 [21]	24h	46	4.0	0-10			
Jorgensen et al. 1987 [16]	24h	23	4.0	0-10			
Mouritsen et al. 1989 [22]	24h	25	2.6	0-7			
Karantanis et al. 2003 [45]	24h	120	0.3	0-1.3			
Versi et al. 1996 [51]	48h	15	7.13		4.32		

(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 (was calculated to be 1.003 g, and ranged from -6.5 to +3.85 g (SD 1.85 g) [9]. Lose et al. showed no evidence of evaporation over 7 days if the pad was stored in a plastic bag [21]. Versi et al. showed pads wetted with saline showed no difference in weight after 1 week and less than 10% weight loss after 8 weeks [51]. Twelve pads were weighed by the patient and a healthcare worker with a coefficient of variance =1.55% with a mean deviation of 49%.

b) Comments

Pad tests can either be used as a qualitative diagnostic tool to diagnose urinary incontinence and as a quantitative test to grade its severity. Pad test is unable to distinguish among different types of incontinence such as stress, urge or mixed urinary incontinence. The ICS definition of urinary incontinence (the complaint of any involuntary leakage of urine) does not describe how the diagnosis is made but clearly refers to a patient's complaint that exclude urodynamics and rather points at the patient perception of the condition. Following this line of thought, research in this area moved away from the evaluation of diagnostic accuracy of pad test versus a urodynamic diagnosis of UI and entered the more interesting field of the relation between the patient perception of UI and pad test.

Franco and co-workers from the St. George Hospital in London, UK tested the correlation between different questionnaires for UI and 1-hour pad test showing that only the ICIQ-SF reached statistical significance with a Kendall's tb of 0.177 and a P value of 0.037 while no significant correlation was found for a 0 to 10 VAS score, a patient-based 3-point symptom severity scale, Stamey grade, Urogenital Distress Inventory and the Incontinence Impact Questionnaire (IIQ-7) [56]. In another study from Wijma and co-workers, the diagnostic strength of pad test for self-reported symptoms of UI was evaluated during pregnancy and after childbirth and the authors conclude that the diagnostic value of pad testing has no clinical relevance in this setting [57]. A similar analysis, performed in a male population undergoing sling surgery for post-radical prostatectomy incontinence suggests a good correlation between ICIQ-SF and the Patient Global Perception of Improvement (PGPI) with a 24-hour pad test [58].

Studies from the Urinary Incontinence Treatment Network in US investigated the relation between different measures of incontinence severity and showed how pad weight from a 24-hour test had a good correlation with the incontinence episodes frequency derived from a 3-day bladder diary (Spearman correlation coefficient 0.61 but a much lower degree of correlation was found with questionnaires such as the Medical, Epidemiological, and Social Aspect of Aging (r=0.33), the Urogenital Distress Inventory (r=0.17) and the Incontinence Impact Questionnaire (r=0.34) [59].

In the same study, the use of pad testing as a prognostic parameter for treatment outcome was investigated but the 24-hours pad testing showed no prognostic value for treatment failure in a study of Burch colposuspension versus autologous rectus sling [60]. An interesting result was obtained in a predominantely female population of patients receiving neuromodulation for refractory urgency incontinence in which a 24-hour pad test performed after the initial test stimulation was able to predict long term satisfaction of this difficult patient population [61]. In this, as in other studies, the number of pads used per day proved to be an unreliable measure of urinary incontinence [62].

A couple of important methodological issues have been raised concerning the use of pad testing. Khan & Chien 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 [63]. Kromann-Andersen et al. 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 [64]. This trial has not been carried out.

A recent Health Technology Assessment of pad testing concluded that although high sensitivity and specificity for the diagnosis of UI was reported in some studies, it was difficult to draw any conclusion about the diagnostic accuracy for SUI because of the differences existing in pad test methodology. The number of studies comparing the same pad tests with adequate reporting is insufficient and no formal pooling of published data could be performed [65].

c) Role of the investigation

The test has been standardised by ICS in 1988 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.

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

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)**

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

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E. OTHER INVESTIGATIONS

I. URINALYSIS

“Urinalysis is a fundamental test that should be performed in all urological patients” [1]. In patients with urinary incontinence, urinalysis is not a diagnostic test for the condition, 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 [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 develop urge symptoms 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 [3, 7].

Urinalysis is also considered of importance in the evaluation of nursing home residents who are incontinent [8], in peri- and postmenopausal women [9], in older women reporting urinary incontinence [10]. Belmin et al, suggested than significant urine samples can even be obtained from disposable diapers in elderly incontinent women [11, 12].

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 [12]. 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 [13], others consider that the condition does not deserve any treatment [11].

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)**

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II. BLOOD TEST

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 measurement of anti diuretic hormone (ADH) and 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.

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III. TISSUE ANALYSIS

Since the last report of the International Consultation on Incontinence in 2005, several papers have been published based on the analysis of sample of tissues coming from patients with stress urinary incontinence (SUI) and/or pelvic organ prolapse aiming at evaluating the molecular bases of these conditions. The main targets of both preclinical and clinical research have been the pelvic floor-supporting tissues and the role of steroid hormones, with some intriguing linkages between the two lines of research.

Pelvic floor-supporting tissues are composed mainly of connective tissue in which fibrous elements such as collagen and elastic fibres and visco-elastic matrix based on proteoglycans are the predominant components of the so called extracellular matrix. Extracellular matrix is a complex network of numerous macromolecules that fulfill a large number of mechanical, chemical and biological functions [1]. While collagens and elastin fibres confer strength and elasticity to tissues, respectively, structural proteoglycans allow tissue cohesiveness. Specifically, collagen is the most prevalent component, with type I fibres usually well organized and associated with ligamentous tissue, while type III collagen is more common in the loose areolar tissue, which makes up the vaginal wall adventitia and surrounds the pelvic organs [2]. According to the molecular weight, indeed, proteoglycans are distinguished into large molecules (aggrecan, versican and perlecan) and small molecules, such as decorin, fibromodulin, biglycan, lumican and chondroadherin [3].

The organized structure of the matrix is due to a clear balance between the production of the different constituents and their breakdown. There are many proteolytic enzymes capable of degrading the elements of the extracellular matrix, falling into into three groups: the serine proteases, the cysteine proteases, and matrix metalloproteinases (MMPs) [4].

Several authors evaluated the expression of the different proteins as well as of their precursors and fragments of degradation. With regards to the metabolism of collagen, some studies seem to indicate that women with SUI have a reduced total collagen content in the skin and urogenital tissue [5-7], while other studies reported higher total collagen concentration and higher levels of mRNAs for type I and type III collagen in paraurethral connective tissue [8]. Chen et al., evaluating cultures of fibroblasts taken from endopelvic fascia and skin biopsies in 14 patients with stress urinary incontinence and 12 controls, showed that the overall collagen synthesis and the ratio of type III and type I fibres were not significantly different between fibroblasts obtained from women with or without SUI [4], indicating that alteration in the collagen synthesis might not be not involved in SUI. On the other hand, a few studies reported change in the relative percentages of the different fibres, with decreasing in type I and increasing in type III ones [9, 10]. Skorupski et al., evaluating in DNA obtained from peripheral blood leucocytes the transcription factor Sp1-binding site in the gene encoding a-1 chain of type I collagen, identified G-T polymorphism at the Sp1 binding site of the gene encoding a-1 chain of type I collagen as a possible risk factor for SUI [11], suggesting that alteration of the protein expression might be due to mutations in transcription factors. Again at molecular level, some studies evaluated the cycle regulatory proteins in patients with pelvic organ prolapsed, showing controversial results. Some papers reported reduced expression of proteins such as p53 and p21 which normally cause cycle G1 arrest suggesting an increase in proliferation capacities for fibroblasts derived from human cardinal ligaments of patients with prolapsed [2].

Other authors evaluated markers of collagen degradation. Specifically, Edwall et al. evaluated markers of collagen synthesis and breakdown such as the carboxy-terminal propeptide of type I procollagen (PICP), the carboxy-terminal telopeptide of type I collagen (ICTP), and the amino-terminal propeptide of procollagen III (PIIINP) in urogenital tissue homogenates and peripheral serum from 71 patients with SUI and 31 healthy control women [12].

After adjusting for age, BMI, parity, and hormonal status, the patients with SUI had significantly lower serum concentrations of PICP and significantly lower tissue concentrations of PIIINP and ICTP than the controls, suggesting reducing breakdown in the presence of unchanged synthesis of type I collagen and, regarding type III collagen, a potential reduction in either synthesis or breakdown, the second being considered more probable [12].

These data may lead to the hypothesis that SUI might be associated with impaired degradation of collagen, leading to reduced turnover and accumulation of aging collagen, negatively affecting the strength and elasticity of urogenital tissue. Further studies on transforming growth factor-ß (TGF-ß) identified the molecular basis of such mechanism, suggesting that overexpression of TGF-ß might trigger the accumulation of aging collagen, inhibiting the expression of collagenases and increasing the production of the tissue inhibitor metalloproteinase [13-15]. Moreover, some genes, such as those of the Homebox A (HOXA) family, encoding transcription factors that regulate mammalian embryonic growth and development of the urogenital tract, have been shown to be underexpressed in patients with pelvic organ prolapsed, suggesting a further molecular basis for the alterations in collagens [16].

Some other studies investigated the role of proteinases that may degrade elements of the extracellular matrix. Chen et al., evaluating full-thickness peri-urethral vaginal wall tissues from patients with SUI or prolapsed and matched control women, found significant decrease in mRNA and protein expressions of alpha-1 antitrypsin (ATT), a neutrophil elastase inhibitor in tissues from affected women, while no difference was found in neutrophil elastase and cathepsin K expressions [17]. Similarly, Gabriel et al. studied the expression of different MMPs in 17 women with prolapsed and 18 control, identifying higher expression of MMP2 in patients with prolapse [18]. These studies allowed to hypothesize that altered catabolism of some components of the extracellular matrix might contribute to the connective tissue alterations observed in pelvic floor dysfunction.

Other studies were focused on the expression of small proteoglycans. Wen et al. studied mRNA and protein levels of biglycan, decorin, and fibromodulin in vaginal wall tissue from women with SUI and menstrual-cycle matched continent women [1]. Specifically, the authors demonstrated that the mRNA expression of fibromodulin was significantly lower in patients in the proliferative phase compared to controls, while decorin mRNA expression was higher both in the proliferative and secretory phases in the patients with SUI, supporting the hypothesis that the expression of such small proteoglycans was hormonally modulated and may contribute to the altered pelvic floor connective tissues of the women with SUI [1].

Estrogens act interacting with specific receptors which, when activated by the ligand, have conformational change, dimerization and recruitment of co-factors, once translocated into the nucleus, these promote the expression of region of estrogen-responsive genes, called the estrogen response elements, leading to the synthesis of proteins [19]. More recently, selective modulators of estrogens receptors have been identified, that act modulating the activity of the receptors, working as agonists, partial agonists, or antagonists in a tissue-dependent manner [20]. Studies on these molecules supported a new role of estrogens in SUI and pelvic organ prolapsed. Specifically, in a randomized controlled trial testing one of these molecules (levormeloxifene) as osteoporosis treatment, a 3.4-fold increase in the reporting of pelvic organ prolapse and an almost 5-fold increase in the reporting of urinary incontinence have been observed [21]. To explain such effect, the expression of more than 500 proteins have been studied in the rat model, showing that estradiol induced the expression of metalloproteinase 7 and 14, reduced the expression of their inhibitors such as TIMP-3, while selective modulators of estrogens receptors such as raloxifene had minimal effects on metalloproteinase 7, and maintained or restored expression of the mRNA for tissue inhibitor of metalloproteinases-3 (TIMP-3) and other components of the extracellular matrix, such as glypican, and biglycan [19]. Although the role of selective estrogen-receptor modulators (SERMs) in the expression of the component of extracellular matrix has to be further clarified, these findings support the hypothesis that the increased occurrence of urinary incontinence and pelvic organ prolapse observed with estrogen therapy and SERMs such as levormeloxifene may be related to changes in expression of genes regulating collagen turnover that ultimately weaken the normal structural integrity and support for the genitourinary system [19].

To date, all these tissue analyses are not part of the everyday clinical practice but the data of these studies improved are improving our comprehension of the pathophysiology of urinary incontinence and pelvic organ prolapsed.

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G. CONCLUSIONS

Clinical research involving diagnostic accuracy and clinical benefit of imaging studies as other diagnostic tests is particularly difficult. Recommendation of a diagnostic test is based upon the evidence that the outcome of it provides valuable information for patient management and this often involves evaluating the outcome of surgery. Implementation of good clinical research in this area remains difficult and sometimes lack adequate founding.Research in this area is particularly daunting and often relies on academic founding only. We acknowledge that only a few of the imaging techniques and other investigations we reviewed in the current chapter have been properly evaluated with respect to reproducibility, specificity, sensitivity and predictive value in connection with the diagnosis and the management of urinary incontinence. Nevertheless, we acknowledge the great amount of work performed in the last four years and the continuous advancement in this field. The use of imaging and other investigations, described in this chapter, remains mostly based on expert opinion, common sense, availability and local expertise, rather than on evidence based clinical research. The diagnostic testes we considered can be subdivided into safety tests, tests with specific and selected indications, investigational tests.

Safety tests - Intended to protect patients' health, they are indicated in all patients complaining of urinary incontinence. They include urinalysis and measurement of post-voiding residual urine. While a consensus is easily achieved for urinalysis, the clinical benefit and cost-effectiveness 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 remains a reasonable option only in the preoperative evaluation of complicated and/or recurrent cases. Video urodynamics, is the gold standard in the evaluation of neurogenic incontinence, particularly in the paediatric population, although the clinical benefit of it remains unclear. In female urinary incontinence videourodynamics is not recommended except under specific complex circumstances. MRI remains the gold standard for the diagnosis of urethral diverticula although ultrasonography is a good alternative option. Lumbosacral spine X-rays have specific indications in children with suspect neurogenic incontinence without gluteo-sacral stigmata. Imaging of the CNS should be considered when a neurological 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 prolapse. 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 not there yet.

MRI of the pelvic floor is rapidly gaining popularity in the evaluation of enteroceles and in the morphological analysis of pelvic floor muscles although evidence of its clinical benefit is still lacking. Both ultrasonography and MRI are the most rapidly evolving techniques and hold promises for potential future clinical applications.

Research in this area is also performed to improve our understanding of the pathophysiology of continence disorders and pelvic organ prolapse. Functional neuroimaging continues to provide new insight on functional anatomy of CNS related to vesicourethral function and dysfunction. The content of the draft reflects the composition of the Committee which is made of clinicians with a particular interest in a specific area of imaging and neurophysiology. The chapter certainly reveals the enthusiasm the authors poured in clinical research in this area but we believe that the methodology implemented by the Consultation is the best guarantee of a balanced opinion and trustful recommendations. We hope that this chapter will stimulate clinical research in this field and will inspire those involved in the management of continence disorders and pelvic organ prolapse.

Neurophysiological testing should be part of the armamentarium available in the management of neurogenic incontinence and the establishment of good collaboration with neurophysiologists is recommended.