



Testing in Women with Lower Urinary Tract Dysfunction

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Introduction

The purpose of the lower urinary tract is to provide a low-pressure storage reservoir for urine, which empties only voluntarily, at a frequency that minimally disrupts daily living activities. When a patient presents with lower urinary tract symptoms that imply dysfunction of this purpose, additional diagnostic testing helps to modify the differential diagnosis, confirm or refute specific diagnoses, or provide valuable prognostic information to the health care provider or patient with regard to specific interventions. Lower urinary tract symptoms or dysfunction can be objectively evaluated with a combination of office or laboratory tests. Most lower urinary tract tests are designed to evaluate the storage and emptying ability of the bladder and urethra. Many office-based tests like a bladder diary, postvoid residual (PVR) measurement, and stress test

help in this regard, but when the diagnosis is still not evident or certain, more sophisticated tests are needed.

This chapter will focus on testing of lower urinary tract dysfunction in women. Tests that are primarily designed to evaluate anatomy, pelvic organ prolapse, or fistulas rather than function (eg, cystourethroscopy, cystogram, urethral magnetic resonance imaging (MRI), pelvic floor MRI, pelvic fluoroscopy, defecography) are not covered in this chapter. Investigations that are primarily designed to evaluate for infectious, inflammatory, or neoplastic processes (eg, urinalysis, potassium sensitivity testing, urine cytology) are outside the scope of this chapter. Lower urinary tract neurophysiologic testing, largely confined to research studies, will not be included. The term “urodynamics” will refer to functional tests of the bladder and urethra.

Urodynamic tests are similar to other diagnostic tests in medicine—a specific test should be requested for specific indications when the diagnosis cannot be made reliably after a careful history and physical examina-

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tion. Therefore, for the tests reviewed in this chapter, the limitations and indications based on available literature will be covered. Recommendations for the use of specific urodynamic tests will be made in the summary section.

The role of urodynamics in the evaluation of stress urinary incontinence remains controversial. Numerous studies have demonstrated the poor association between history alone and urodynamic diagnosis.¹⁻³ However, when a history of predominant stress incontinence is combined with a positive stress test, a normal PVR, and a normal bladder capacity, urodynamic stress incontinence is found 97% of the time.⁴ Information available today does not indicate that routine preoperative urodynamic tests improve surgical outcome. The summary section will make recommendations based on the literature as to when urodynamics are helpful before treatment, particularly stress incontinence surgery.

Tests That Measure Bladder Storage/Filling

There are simple and complex tests that evaluate bladder storage. These will be reviewed in order of increasing complexity.

BLADDER DIARY

A bladder diary is an inexpensive means of obtaining information about the daily function of a patient's bladder, including functional capacity. The recording of daily bladder events has been defined by the International Continence Society (ICS) Standardization Sub-Committee in three main forms:⁵

- Micturition time chart: this records only the times of micturitions, day and night, for at least 24 hours;
- Frequency Volume chart: this records the volumes voided as well as the time of each micturition, day and night, for at least 24 hours; and
- Bladder diary: this records the times of mic-

turitions and voided volumes, incontinence episodes, pad usage, and other information such as fluid intake, the degree of urgency, and the degree of incontinence.

Mean voided volume and frequency measurements over 24-hour periods have reasonable reproducibility with limits of agreement of 0.68 –1.47.⁶ Multiple-day diaries are used in clinical research studies to evaluate incontinence episodes. In a week-long diary, results from the first 3 days correlate well ($r = 0.887$) with the last 4 days, suggesting that a 3-day diary is an appropriate outcome measure for clinical trials evaluating treatments for incontinence.⁷

Limitations

The bladder diary requires considerable patient motivation and compliance. Providing patients with a "toilet hat" to assist them in recording voided volumes can help. Women with detrusor overactivity incontinence are less able to consistently report the number of leakage episodes compared with women with urodynamic stress incontinence.⁸

Indications

A bladder diary provides valuable information for evaluating frequency. Since many weight reduction programs emphasize aggressive fluid intake, it is not uncommon to find urinary frequency associated with normal bladder volumes and, therefore, polyuria secondary to excessive fluid intake. The ICS definition of polyuria is greater than 2800 mL of urine output in 24 hours for adults.⁵ By reviewing a patient's bladder diary with her, a clinician can demonstrate that her excessive frequency and nocturia is secondary to excessive intake, and this can be managed with fluid restriction. The major value of the one-day bladder diary is in the evaluation of urinary frequency and nocturia. The longer versions appear promising as outcome tools for incontinence treatment.

PAD TESTS

The pad test has been promoted as an objective measure of quantifiable urine loss that

can be used for incontinence interventions. The ICS standardized 1-hour (short-term) pad test involves a complex set of steps. The patient starts with an empty bladder and puts on a pre-weighed pad. After drinking 500 mL over 15 minutes, she engages in the following activities over the next 30 minutes: walking, climbing stairs, sitting then standing 10 times, coughing 10 times, running in place for 1 minute, bending over 5 times, and washing hands for 1 minute. Finally, the pad is weighed.⁹ Not surprisingly, in a systematic review, Soroka et al¹⁰ found that these guidelines were followed in only 25 of 75 papers. Long-term home tests have been performed to reflect urine loss with more realistic daily life activities. Pads are sealed in plastic bags and can be mailed in for weighing.

Limitations

Nearly all studies have shown that the amount of leakage is dependent on bladder volume, and therefore modified short-term pad tests attempt to standardize this variable. Test- retest variations of up to 24 g have been found in incontinent women with a standardized bladder volume of 50% cystometric bladder capacity.¹¹ Long-term tests demonstrate that extreme variations in activity significantly alter urinary leakage volume.¹²

Indications

Pad tests are a research tool to study incontinence interventions. These tests play a very limited role in diagnostic evaluations. Some investigators argue that these tests confirm incontinence in a patient who is not incontinent on more formal office or urodynamic evaluation. However, since this test does not help with the differential diagnosis of incontinence or even discriminate between urethral and extra-urethral incontinence, its diagnostic value is questionable.

SIMPLE OFFICE BLADDER FILLING

After voiding, the patient assumes supine or lithotomy position. A 14F straight red rub-

ber catheter is inserted, PVR is measured, and then the catheter is attached to a 50 mL to 60 mL catheter-tipped syringe with the piston removed. The bladder is filled by pouring sterile water or saline from a pre-measured bottle into the funnel-like syringe. By keeping the fluid column approximately 15 cm above the pubic symphysis, any upward movement of the fluid meniscus suggests a bladder pressure greater than 15 cm H₂O. If the patient is not straining, this very likely represents a detrusor contraction. The patient is also questioned about bladder sensation parameters (first desire to void, normal desire to void, and maximum cystometric capacity).

Limitations

The test gives qualitative, but not quantitative, information about bladder filling function. Because any increase in abdominal pressure is also transmitted to the bladder, the examiner must look for patient straining, which produces a falsely positive impression of bladder contractions. The examiner, by placing a hand on the abdomen, can palpate for intra-abdominal pressure increases and exclude that source as the cause of the meniscus rise. False negative results are obtained if the force of a bladder contraction does not reach 15 cm H₂O.

Indications

Simple office bladder filling is inexpensive and time efficient, requires few resources, and can be performed in any office. This qualitative test is indicated whenever screening information is needed for detrusor overactivity. The test assesses bladder sensation, capacity, and the presence of bladder contractions, but not their magnitude. When combined with a cough stress test, it has a sensitivity of 88% and a specificity of 77% for urodynamic stress incontinence compared with a “gold standard” multichannel cystometrogram.¹³

MULTICHANNEL CYSTOMETROGRAM (CMG)

The mainstay of urodynamic investigations is the multichannel CMG, also known as complex cystometry. With this examination, pressure is measured in the bladder during filling with an external transducer connected to a fine fluid-filled catheter or a microtransducer at the tip of a catheter within the bladder. Single channel studies (bladder pressure measurements only) are difficult to interpret because of the same limitations as simple office filling; increases in abdominal pressure are readily transmitted to the bladder. With multichannel studies, abdominal pressure is simultaneously measured indirectly with either an external transducer attached via tubing to a fluid-filled balloon catheter, or a microtip transducer, in the rectum or vagina. The detrusor pressure is calculated by electronically subtracting the measured abdominal pressure from the measured bladder pressure. Urodynamic stress incontinence is demonstrated by observed leakage on Valsalva or cough maneuvers without detrusor contractions. Normally, the bladder is extremely compliant and detrusor pressure does not increase markedly with filling. Patients with detrusor overactivity have involuntary detrusor contractions (with or without leakage) during normal filling volumes. Compliance is measured by calculating the change in volume over the change in pressure. Normal bladders should not have more than a 10 cm H₂O change in detrusor pressure from baseline to capacity.

Limitations

There is no standard methodology and technique used among centers performing this test. Variations exist for type and temperature of the filling medium; infusion rate; external or internal transducers; catheter diameter; patient position; zeroing to atmosphere or the patient; and maneuvers used to provoke stress loss or detrusor overactivity. Probably the most important limitation of CMG testing is that it records just a short window of the bladder's day that may not

reveal intermittent detrusor overactivity. Weber et al,¹⁴ using decision analysis methodology and estimates of prevalence and success rates based on the literature, found that a CMG did not improve (over office-based assessment) the effectiveness of primary surgical treatment of uncomplicated stress incontinent patients with urethral hypermobility. Both strategies resulted in a 96% cure rate after initial and secondary treatments. The cost-effectiveness analysis was highly influenced by the prevalence of urodynamic stress incontinence in the patient population. If the prevalence of urodynamic stress incontinence was less than 80% in the hypothetical patient, then urodynamic evaluation was cost effective. If the prevalence of urodynamic stress incontinence was more than 80%, office-based assessment was the most cost-effective. This study sets the groundwork for justifying a randomized trial of preoperative testing strategies for stress incontinence.

Indications

A multichannel CMG provides quantitative information (a pressure-volume signal) about bladder function during filling. This test is most commonly used to evaluate incontinence symptoms and to diagnose urodynamic stress incontinence, detrusor overactivity incontinence, or mixed incontinence. The study by Weber et al mentioned above gives helpful information to the practitioner who is trying to decide who needs urodynamics before surgical treatment of stress incontinence. After a thorough history, physical examination, simple cystometry, and a positive stress test, a differential diagnosis should be considered. If the practitioner is more than 80% sure that, for this patient, urodynamics will demonstrate only urodynamic stress incontinence (not mixed incontinence or detrusor overactivity), then that practitioner could proceed to surgery without further urodynamic evaluation. This means that uncomplicated patients less than 65 years old with predominant stress symptoms; without previous surgery, radiation,

neurologic conditions, or prolapse past the introitus, with a normal neurologic examination, normal PVR, normal bladder capacity, normal urinalysis, and positive stress testing do not need preoperative urodynamics. In tertiary care centers, this uncomplicated patient profile is very uncommon, as most patients presenting with incontinence also have urge incontinence symptoms.¹⁵ Whenever the stress incontinent patient becomes less than straightforward and her presenting features make her risk for having detrusor overactivity or mixed incontinence exceed 20%, then urodynamics should be performed. Urodynamics are cost-effective if the combined diagnosis of mixed incontinence or detrusor overactivity exceeds 20%.

AMBULATORY CYSTOMETRY

This investigation is a multichannel cystometrogram (CMG) performed while the patient is ambulatory using portable microtip transducer technology. It is performed over at least four hours during normal physiologic bladder filling and may record events that do not occur during a single “snapshot” laboratory CMG.

Limitations

Heslington and Hilton¹⁶ found detrusor overactivity in 68% of asymptomatic women with ambulatory monitoring, compared with 18% during conventional CMG testing. Unfortunately, symptomatic women (urgency, urge incontinence, and stress incontinence) had nearly the same rate of detrusor overactivity on ambulatory monitoring¹⁷!

Indications

Until normative data are more clearly established, this test remains only a research tool undergoing evaluation.

Tests That Measure Bladder Emptying

There are simple and complex tests that evaluate bladder emptying. These will be reviewed in order of increasing complexity.

POSTVOID RESIDUAL (PVR)

The PVR is a simple test that evaluates the bladder’s ability to empty. The measurement can be obtained either by catheterization or by ultrasound. PVR cannot be accurately estimated by bimanual examination.¹⁸ Abdominal ultrasound determinations are more than 96% specific in detecting PVRs greater than 100 mL.¹⁹ If a specific bladder scan machine is not available, any abdominal ultrasound equipment can be used. A transabdominal ultrasound is performed in the transverse and mid-sagittal planes. With measurements of the bladder’s diameter in three planes (anterior-posterior, transverse, and sagittal or longitudinal), the volume can be approximated by the following ellipsoid formula²⁰: Volume (ml) = [height (cm) x length (cm) x width (cm) x 0.52]. As can be seen with this equation, if no bladder dimension is greater than 5 centimeters, the PVR is less than 65 mL.

Limitations

The PVR increases with age and prolapse, and there are no clear-cut normal values, although the AHCPR concluded that less than 50 mL is normal. Repetitive values ranging from 100 to 200 mL or higher are considered inadequate emptying. Clinical judgment must be exercised and all other clinical information included in interpreting the significance of PVR volume, especially in the intermediate range of 50 mL to 199 mL.²¹ The PVR may show considerable variability on repeat testing, but normal values usually remain in the normal range with repeat testing.²²

Indications

This simple, inexpensive test can be performed by almost any health care provider and is indicated as part of the basic evaluation of any patient presenting with incontinence, urgency, frequency, or voiding difficulties. PVR should be considered the screening test of choice for overflow incontinence, neurologic abnormalities, or voiding dysfunction. It should also be considered

a prerequisite before surgery on the anterior vaginal compartment, since these procedures pose a risk of causing voiding dysfunction. Nearly all clinical practice guidelines, including those published by the Agency for Health Care Policy and Research (AHCPR)²³ and the Society of Obstetricians and Gynecologists of Canada,²⁴ have recommended PVR as an essential component of incontinence evaluation.

NONINVASIVE UROFLOWMETRY (NIF)

Urinary flow characteristics are a product of the bladder's ability to contract and the coordinated relaxation of the urethral sphincter in an unobstructed urethra. Thus, uroflowmetry is a measure of both urethral and bladder function. Without instrumentation, a woman voids into an electronic, sometimes computerized, device that measures the weight (volume) changes over time. The data are depicted graphically as a flow pattern plotting flow rate over time. Calculations can record maximum flow rate (Qmax), average flow rate (Qave), flow time, and volume voided. PVR should be obtained after uroflowmetry to assist in interpretation.

Normal female urinary flow should produce an uninterrupted bell-shaped curve with a left skew and a smooth arc. Normal flow parameters vary with age, sex, and bladder volume. Nomograms considering these factors have been developed. Most of this work has been done in men, where uroflowmetry is used to evaluate outlet obstruction due to benign prostatic hypertrophy (BPH).²⁵ Normative female parameters are referred to as the Liverpool nomograms.²⁶

Limitations

The most significant limitation of uroflowmetry in the evaluation of lower urinary tract dysfunction is that it does not provide information about the forces (detrusor or abdominal) of voiding. The test does not differentiate between poor detrusor contractility and an obstructive process in the urethra or bladder outlet. In addition, if the patient is asked

to void in an uncomfortable environment before she has a normal urge or with a bladder that is either not full enough or uncomfortably full, the studies may not be representative of her normal voiding pattern. Technical artifacts, such as spikes in the flow rate that are non-physiologic, require visual re-interpretation to prevent erroneously high values for Qmax.

Indications

Although the utility of uroflowmetry in women has not been fully delineated, researchers have explored multiple areas in which it may be of value. It is best used as a preliminary, non-invasive procedure to investigate patients with voiding dysfunction and to assess disease progression and treatment results.²⁷ Some have suggested using it as a tool to distinguish between patients who need more extensive studies and those who do not.²⁸ Farrar is more specific and suggests that further urodynamic work-up be obtained in patients with lower urinary tract symptoms and a peak flow rate below 15 mL/s.²⁹ Investigators have attempted to identify specific uroflow parameters that could serve as a prognostic tool before surgical treatment of stress incontinence. For instance, McLennan et al found that flow rates less than 20 mL/s were associated with prolonged return to voiding after sling procedures for stress incontinence.³⁰

PRESSURE-FLOW STUDIES (PFS)

The principle behind a pressure-flow study is to simultaneously measure urinary flow parameters and the forces associated with it. When uroflowmetry is combined with bladder and abdominal pressure measurements, the voiding mechanism can be further defined. This investigation is usually performed at the end of a filling CMG. The patient sits on a commode or urodynamics chair and is asked to void into an electronic flow meter while multichannel pressure recordings of the bladder and abdomen (and therefore subtracted detrusor pressures) are obtained. Some centers add perineal surface

electromyography (EMG) electrodes to record global myographic activity of the pelvic floor during voiding. The data should be compared with the patient's non-invasive flow study. Parameters measured include: volume voided, Qmax, Qave, voiding time, flow pattern, and detrusor pressures at baseline, at onset of void, at Qmax, and overall maximum. PVR should be obtained, directly or indirectly, at the end of the study. Theoretically, this study evaluates the most critical aspects of voiding, detrusor contractility, and urethral resistance, as well as their ability to function in a coordinated fashion. The pressure-flow relationship is at the core of our understanding of voiding dysfunction. Obstruction is defined as a low flow-high pressure state, while detrusor failure is a low flow-low pressure state.

Limitations

As with complex cystometry, these studies require expensive sophisticated equipment as well as the technical expertise to conduct the test and interpret the information. Historically, there has been poor standardization of testing procedures, urodynamic definitions, and interpretation guidelines such that reports in the literature are often not comparable. In an effort to rectify this, the ICS has standardized the terminology of PFS and developed the Guidelines for the Good Practice of Urodynamics.^{31,32}

Environmental, psychologic, and physical discomfort may prevent an accurate reproduction of the patient's normal voiding process. The tester and interpreter must remain vigilant for potential artifacts. As an example, Groutz and Blaivas demonstrated that the presence of a 7 French catheter in the urethra was associated with lower flow rates, longer flow times, and a higher incidence of intermittent flow patterns than a similar volume non-invasive uroflow in the same patient.³³ Baseman et al found similar effects on Qmax from a 6 French catheter when performing pressure-flow studies in asymptomatic women.³⁴ Nitti and colleagues found that 25% of patients could not

void during the pressure-flow study.³⁵ Consequently, pressure-flow studies must be interpreted in the context of the patient's subjective complaints and in conjunction with the non-invasive uroflow study.

As with uroflowmetry, most of the research with pressure-flow studies has been in men with obstruction secondary to BPH. Pressure-flow normative values in women have not been clearly established. The pressure-flow study, when it does demonstrate obstructive voiding, does not provide information as to the anatomic location of obstruction. There are no studies that conclusively demonstrate improved clinical outcomes using pressure-flow studies.

Indications

Two main indications for pressure-flow studies have been advocated: assessment of voiding symptoms or suspected obstruction; and urinary incontinence symptoms. Nomograms for pressure-flow relationships for men with lower urinary tract symptoms define three groups: obstructed, unobstructed, and equivocal.^{31,36} However, differences between male and female voiding mechanisms preclude the application of these pressure-flow nomograms to women. Anatomically, a shorter urethral length and the absence of a prostate in women produce lower urethral resistance. Functionally, women often void with pelvic floor relaxation, which also lowers urethral resistance. These differences result in higher flow rates and lower detrusor pressures in women. Alternatively, prolapse can produce obstruction if it is unreduced.

Traditionally, obstructive voiding in women has been reported as being very uncommon, especially in the absence of prolapse or previous bladder neck surgery. Consequently, most urodynamic studies in women focused on urinary incontinence and the storage function of the lower urinary tract. More recently, the rate of voiding dysfunction in women with lower urinary tract symptoms has been observed to range from 10% to 30%.^{35,37} Some investigators have

analyzed their urodynamic data to develop cut-off values that diagnose voiding obstruction in women. However, these studies include urodynamic values in the definition of the voiding dysfunction groups. The various values reported as evidence of voiding dysfunction include instrumented Qmax of less than 11 mL/s and Pdet at Qmax of greater than 21 cm/H₂O;³⁸ non-instrumented Qmax of less than 12 mL/s and Pdet at Qmax of greater than 50 cm H₂O;³⁹ instrumented Qmax of less than 15 mL/s and Pdet at Qmax of more than 20 cm H₂O;⁴⁰ or a nomogram based on a plot of Pdet at Qmax on the x-axis and non-instrumented Qmax on the y-axis.⁴¹ Nitti used high detrusor pressure and fluoroscopic evidence of obstruction to diagnose obstruction.⁴² In spite of this recent work, there are currently no universally accepted urodynamic parameters that diagnose obstruction in women.

Pressure-flow studies have limited use in the evaluation of stress incontinence in women under age 50.⁴³ However, it may prove to be important to identify and potentially treat underlying voiding dysfunction in patients presenting with storage symptoms, such as urgency and frequency, before surgery. Some have suggested using the pressure-flow study as a prognostic tool to predict which patients will have difficulty with voiding after stress incontinence surgery. There is some evidence that patients with poor detrusor contractility are at higher risk for voiding difficulties after incontinence surgery.⁴⁴ Lose et al noted that 42% of women with a detrusor contraction of less than 15 cm H₂O had impaired voiding, versus 18% of women with normal pressures.⁴⁵ Multiple reports suggest that patients who void with Valsalva will have delayed return to normal voiding⁴⁶⁻⁴⁸ or a higher surgical failure rate after autologous fascia sling.⁴⁹

In summary, pressure-flow studies offer promise in further defining lower urinary tract dysfunction in women, which may in turn allow new treatments to be designed or provide diagnostic tools to differentiate patients with more specificity than currently

available. Used in conjunction with symptom assessment and physical examination, they are reasonable studies to use in evaluating women with voiding complaints. The limitations are significant and must be understood before utilizing them routinely.

VIDEOURODYNAMICS (videocystography, fluoro-urodynamics)

By combining simultaneous fluoroscopic radio contrast imaging of the bladder and urethra on a video monitor display with multichannel CMG and pressure-flow studies, more information on bladder and urethral anatomy in relation to bladder filling and voiding can be obtained. These studies integrate the anatomic information obtained with fluoroscopic imaging with the functional information obtained from urodynamics. It is considered the most precise diagnostic evaluation of lower urinary tract function, by combining multiple technologies into one study. Videourodynamics provides all the advantages of the pressure-flow study as detailed above, along with anatomic information discussed under voiding cystourethrography (VCUG). Fluoroscopic imaging allows detection of an open bladder neck, bladder diverticula, vesico-ureteric reflux, and the precise moment incontinence occurs. It is the most comprehensive investigation of bladder storage and emptying.

Limitations

The test involves expensive equipment and personnel, radiation exposure, and the slight risk of a contrast reaction. The abnormal environment may not reproduce normal voiding. It is invasive, like CMG and pressure-flow studies, with the risk of a possible urinary tract infection.

Indications

Videourodynamic testing is helpful for patients who have symptoms of obstruction since it can define the anatomic location of the obstruction. It is typically indicated for failed anti-incontinence procedures, equivocal urodynamic results, or complicated

voiding dysfunction secondary to neurologic disease. It can identify simultaneous reflux in a non-compliant bladder. Whether the additional information added by fluoroscopy justifies the significantly higher costs and radiation exposure depends on the complexity of the case. It is possible that this test provides the most cost-effective assessment of patients with voiding dysfunction; however, this has not been demonstrated in a controlled trial.

Tests That Measure Urethral Function

URETHRAL PRESSURE MEASUREMENTS

This investigation's goal is to measure the function of the urethral sphincteric mechanism. When the measuring catheter (usually a microtip transducer catheter) is withdrawn through the urethra at a slow, constant rate, a pressure profile of the sphincteric mechanism is obtained. Various terms describe the parameters obtained including: maximum urethral pressure (MUP), maximum urethral closure pressure (MUCP), functional urethral length (FUL), and pressure transmission ratio (PTR). Although these parameters may be interesting from a research perspective, the only parameter that has been extensively advocated for clinical utility is the MUCP.

Limitations

Position, posture, orientation of the sensor, and size and rigidity of the catheter can influence the urethral pressure profile results.⁵⁰ In a thorough review of whether urethral pressure profile measurements are a useful diagnostic test for stress urinary incontinence, Weber⁵¹ reviewed criteria for useful diagnostic tests: 1) measurement methods must be standardized; 2) results must be reproducible; 3) calculated parameters should have clear cut-off values that differentiate health and disease without sig-

nificant overlap; 4) calculated parameters should contribute to the differential diagnosis and choice of therapy; and 5) calculated parameters must correlate with the outcome of therapy. Urethral pressure profile measurements fail the first three criteria.

The proponents of MUCP testing argue that this test is helpful for: 1) contributing to the differential diagnosis of stress incontinence subtypes (intrinsic sphincter deficiency or urethral hypermobility); 2) influencing the choice of therapy; and 3) providing prognostic information for outcome of therapy. When this continuous variable has been used to group patients into categories (MUCP < 20 cm H₂O and MUCP > 20 cm H₂O), most retrospective studies demonstrate that surgical success rates with a modified Burch procedure are decreased in the low MUCP group.⁵²⁻⁵⁴ Failure rates ranged from 12-18% when MUCP was greater than 20 cm H₂O, but increased to 33% to 54% when MUCP was less than 20 cm H₂O. The implication is that sling procedures should be done instead of Burch procedures when MUCP less than 20 cm H₂O is found.

Other data contradict the implication that MUCP provides significant prognostic information and should influence the choice of therapy. Richardson et al found comparable Burch failure rates of 15% in patients with low MUCP.⁵⁵ Sand et al, who earlier reported the 54% Burch failure rates with low MUCP patients, found later in a randomized trial with short-term follow-up that, by modifying the Burch technique to more aggressive correction, the failure rate was reduced to 5%.⁵⁶ This rate was not clinically or statistically different than the rate in the synthetic sling group. In a comparative study of patients with low MUCP, Maher et al⁵⁷ found failure rates of only 10% with the Burch procedure, compared with 29% with autologous fascia sling procedure.

Indications

The limited prognostic information that MUCP provides does not seem to merit its

use as a standard test for stress incontinence. In patients with stress incontinence and urethral hypermobility, it is not clear that this measure should influence choice of therapy.

LEAK POINT PRESSURE MEASUREMENTS

The amount of pressure required to produce urine leakage by Valsalva or coughing is termed the leak point pressure (LPP). Proponents argue that this is the preferred measure of urethral function for stress incontinence, because it is a measurement during “stress.” It was initially defined as an abdominal pressure measurement and McGuire et al⁵⁸ found correlation with the clinical grade of incontinence. Abdominal LPP less than 60 cm H₂O was highly correlated with the videourodynamically-defined Type III incontinence: “. . . a nonfunctional open “internal” sphincter and leakage not necessarily associated with rotational descent.” Management was based on these measurements:

“In female patients without genital prolapse, a low leak-point pressure of 65 or less indicates intrinsic sphincter dysfunction; a high leak-point pressure of 100 or more usually is associated with urethral hypermobility. Most patients in the low-pressure group have Grade III, Type III stress urinary incontinence. Most patients in the high-pressure group have some degree of urethral hypermobility and leakage is associated with that abnormality. In the middle-pressure group are patients with features of both intrinsic sphincter deficiency and hypermobility. Patients with pure hypermobility can be treated with a suspension procedure, whereas those with pure intrinsic sphincter deficiency are treated better by a sling, an injectable agent, or an artificial sphincter. Patients with features of both conditions do well with slings, but suspension procedures may be effective.”⁵⁹

With such strong management recommendations based on these measurements, it is not surprising that LPP became a cornerstone of stress incontinence evaluations in

the United States. Since then, many modifications in technique have developed. Many investigators use vesical pressure measurements since the bladder catheter is in a fluid medium and less susceptible to artifact, such as a blunted response. Although most investigators define LPP as the lowest intravesical pressure required for leakage with Valsalva or cough, others report LPP as the increase, or change from baseline vesical pressure, at the time of leakage. LPP determinations are typically performed during filling cystometry at various volumes, in various patient positions, and either directly visualized or indirectly imaged with fluoroscopy. MUCP and LPP correlate modestly with each other and both are limited, but comparable, in predicting incontinence severity.⁶⁰

Limitations

LPP measurements vary based on the baseline used for measurement, patient position, catheter size, bladder volume, the technique used to confirm loss, and whether a cough or Valsalva was used to produce leakage.⁶¹ This lack of standardization has been summarized,⁶² and makes study comparison impossible. Few reproducibility studies have been done with LPP, but it appears to be more reproducible than MUCP measurements.^{51,61} Unlike MUCP data, there is limited outcome data to support specific treatments based only on LPP measurements. Success rates with collagen injection do not correlate with preoperative LPP levels.⁶³

Indications

The limited prognostic information that LPP provides does not seem to merit its use as a standard test for stress incontinence. In patients with stress incontinence and urethral hypermobility, it is not clear that this measure should influence choice of therapy. Results from the Urinary Incontinence Treatment Network, which is performing a multicenter randomized surgical trial of Burch versus autologous fascia sling procedures,

should provide the answer as to whether this measure should influence choice of therapy.

Tests That Image Urethral Mobility

Most surgical interventions for stress incontinence are designed to decrease proximal urethral mobility and nearly all published surgical guidelines require a preoperative assessment of urethral mobility. Surgical failure rates are higher if the urethra is not mobile to begin with.⁶⁴ For years, lateral chain urethrocytography was used for this assessment, but it has been replaced by less invasive alternatives. There is probably no area of urogynecology and female urology with more worldwide patient evaluation disparity than the assessment of urethral mobility. In much of the world, the clinical assessment of urethral mobility is the subjective, non-quantifiable physical examination using inspection and palpation. In North America, the office cotton-swab (Q-tip) test is used to quantify the descent of the proximal urethra for clinical and sometimes research indications. Perineal ultrasound is a quantifiable modality used in some tertiary centers worldwide. Contrast x-ray studies like voiding cystograms or videourodynamics also image the position of the urethra. The simple and complex tests that evaluate urethral mobility will be reviewed in order of increasing complexity.

COTTON SWAB TEST

A simple, quantitative, office measurement of urethral mobility is obtained by placing a lubricated cotton swab within the urethra such that the tip of the swab is at the urethrovesical junction. After insertion of the cotton swab into the bladder, gentle withdrawal of the cotton swab is performed until resistance is met at the urethrovesical junction. The angle between the swab and the horizontal plane is measured with a goniometer while the patient is at rest and with maximal straining. Crystle et al discovered the test ac-

cidental when he was using a cotton-tipped applicator to anesthetize the urethra with lidocaine jelly before lateral chain cystograms and noted the correlation with straining angles.⁶⁵ Urethral hypermobility is defined as an angle of greater than 30 degrees, either at rest or with straining.⁶⁶ The measurement is not significantly affected by bladder volume.⁶⁷ Good intra-observer correlations of 0.77 to 0.92, and inter-observer correlations of 0.87 have been reported.^{68,68a} In a study of black and white subjects that used both cotton swab and perineal ultrasound as measures of bladder neck excursion during Valsalva, similar differences were observed in both groups with either test.⁶⁹

Limitations

This test should not be used to diagnose stress urinary incontinence; it is merely a test to determine if the stress incontinence is associated with urethral hypermobility. The test is uncomfortable for patients, but this discomfort can be reduced with intraurethral lidocaine jelly installation. Comparison studies of the cotton swab test and other measures of urethral mobility are often flawed by assumptions that the other method is the "gold standard."

Indications

The cotton swab test is the simplest, least expensive, quantifiable method for evaluating urethral mobility.

PERINEAL ULTRASOUND

A linear-array or curved-array transducer scanner is positioned in a sagittal direction on the perineum to image the urethrovesical junction and measurements are taken with an x,y coordinate system with the pubic bone as a reference. Perineal ultrasound is preferred over vaginal ultrasound, since the probe does not distort urethrovesical anatomy. Perineal ultrasound correlates well with lateral chain cystography.⁷⁰ There is good inter-observer agreement for deter-

mining bladder neck position, funneling, and bladder neck descent at rest and during Valsalva maneuver.⁷¹

Limitations

Comparisons with other methods of assessing urethral mobility are flawed by the absence of a “gold standard” measurement of urethral mobility.

Indications

As a research tool, perineal ultrasound can be performed painlessly, longitudinally, and without radiation exposure to evaluate bladder neck mobility. In the clinical setting, it is more time-consuming and expensive than the cotton swab test.

VOIDING CYSTOURETHROGRAPHY (VCUG)

Historically, stress incontinence was classified by assessing the position of the bladder neck and urethra using bead chain cystourethrography. The bead chain has been replaced with contrast material. The voiding cystourethrogram is performed by placing a catheter in the bladder, emptying the urine, and retrograde filling the bladder with contrast material. Fluoroscopy is performed in the standing position and an assessment of bladder and urethral anatomy at rest, during straining, and during voiding is obtained in relation to the bony landmarks of the pelvis. A cystocele is defined as descent of the bladder base or bladder neck below the inferior margin of the symphysis pubis. Urethral hypermobility is defined as movement of more than one centimeter. Bladder neck competency at rest and during strain is assessed. The images also detect bladder and urethral diverticuli, bladder trabeculation, fistulas, and vesicoureteral reflux.

Limitations

The test interpretation is often qualitative, rather than quantitative and introduces inter-observer variation. There is a risk of radiation exposure, contrast reaction, or urinary tract infection because it is invasive (re-

quires catheterization). Obesity can prevent adequate visualization of the bladder neck. Prolapse of the other compartments cannot be seen unless a more elaborate study is performed with contrast agents used in the rectum and vagina.

Indications

The voiding cystourethrogram is still a good test to evaluate bladder pathology such as vesicoureteral reflux and urinary fistulas; however, in the evaluation of lower urinary tract symptoms, its usefulness has significantly decreased with the advent of other imaging techniques and videourodynamics. The fluoroscopic findings of hypermobility and bladder neck competency have not been correlated with symptoms, urodynamic findings, or patient outcomes. The cotton swab test or perineal ultrasound tests are less complicated, less expensive, or less invasive methods to measure urethral hypermobility. Cystocele staging can be accomplished by the Pelvic Organ Prolapse Quantification (POP-Q) examination. Voiding cystourethrography has not been shown to be more accurate.

Voiding cystourethrography can assess bladder neck competency, but the clinical significance of an open bladder neck has not been clearly defined. This finding bears no relationship to the presence or type of incontinence^{72,73} especially if the bladder is filled to a comfortable volume. Assuming an open bladder neck is of clinical significance, ultrasound or MRI is a less invasive way to make the diagnosis. Without urodynamic catheters to measure simultaneous detrusor pressure, there is no way to differentiate an incompetent bladder neck from the normal bladder neck funneling that occurs with a detrusor contraction.

While voiding cystourethrography may be helpful in a patient with obstruction to identify the location of the obstruction (eg, dyssynergic sphincter, urethral stricture, or kinking due to prolapse), it cannot provide the functional information obtained by urodynamics that is essential in the diagnosis of

voiding dysfunction. Whenever possible, the combination of the two studies (videourodynamics) is preferable to assess voiding dysfunction.

SUMMARY

Table 1 reviews suggested lower urinary tract tests based on suspected diagnoses. All incontinent patients should receive the basic office evaluation and office tests. This initial evaluation then leads to suspected or tentative diagnoses and the remainder of testing is dependent on this initial assessment.

As can be seen from the table, the CMG is the mainstay of urodynamic investigations. In older patients with urge incontinence and

an elevated PVR, detrusor overactivity with impaired contractility should be considered.⁷⁴ Pressure-flow studies or videourodynamics are indicated with the suspicion of obstruction, detrusor hyperactivity with impaired contractility, or other voiding complaints. Intrinsic sphincter deficiency (ISD) should be diagnosed by a composite of historic, anatomic, urodynamic, and clinical criteria.⁷⁵ Either MUCP or LPP could be used as the urodynamic contribution to this composite diagnosis. Diagnostic corroboration of ISD is the only reason for performing the urethral function tests. Conclusive data do not exist at this time to support that these urethral function tests should influence

TABLE 1. Suggested Tests for Women with Lower Urinary Tract Dysfunction Based on Suspected Diagnoses

Suspected Diagnosis	Suggested Tests
Any incontinence	Bladder diary, stress test, PVR, urinalysis, cotton swab test,* simple bladder filling.
Stress incontinence (simple—no urge incontinence, no previous surgery, normal bladder capacity, positive stress test, normal PVR, urethral hypermobility)	No further testing necessary if the practitioner is more than 80% confident that only urodynamic stress incontinence would be found on CMG testing.
Stress incontinence (complex—not straightforward—any urge incontinence, low bladder capacity, previous surgery, prolapse)	Filling test (CMG preferred).
Mixed incontinence	Filling test (CMG preferred). May initiate therapy if PVR normal and then test nonresponders.
Detrusor overactivity	Filling test (CMG preferred). May initiate therapy if PVR normal and then test nonresponders.
Detrusor hyperactivity with impaired contractility	CMG and pressure-flow studies, or videourodynamics.
Overflow incontinence	PVR, CMG if abnormal.
Atonic bladder	PVR, CMG if abnormal.
Suspect ISD	LPP or MUCP to corroborate suspicion.
Frequency/urgency without infection	Bladder diary. Consider CMG if no polyuria; consider cystoscopy or testing for interstitial cystitis.
Nocturia	Bladder diary. Consider CMG if no polyuria or nocturnal diuresis.
Voiding difficulty/Bladder outlet obstruction	Uroflowmetry and PVR; pressure-flow study or videourodynamics if abnormal.
Detrusor sphincter dyssynergia	Pressure-flow study or videourodynamics.

PVR = postvoid residual

CMG = cystometrogram

LPP = leak point pressure

MUCP = maximum urethral closure pressure

ISD = intrinsic sphincter deficiency

* Could replace cotton swab test with other urethral imaging study like perineal ultrasound or voiding cystourethrography, but these are more complex and probably will not add to the clinical information.

therapy in patients with urethral hypermobility. In patients without hypermobility, management does not seem to be influenced by the absolute value of the LPP or MUCP.

In conclusion, it is important to remember that urodynamic tests are just like any other diagnostic investigation in medicine—a specific test should be requested for specific indications when the diagnosis cannot be made reliably after a careful history and physical examination. The most important urodynamic instrument is still the practitioner's brain.

References

1. Cantor TJ, Bates CP. A comparative study of symptoms and objective urodynamic findings in 214 incontinent women. *Br J Obstet Gynaecol.* 1980;87:889–892.
2. Cardozo LD, Stanton SL. Genuine stress incontinence and detrusor instability—a review of 200 patients. *Br J Obstet Gynaecol.* 1980;87:184–190.
3. Jensen JK, Nielsen FR Jr, Ostergard DR. The role of patient history in the diagnosis of urinary incontinence. *Obstet Gynecol.* 1994; 83:904–910.
4. Videla FL, Wall LL. Stress incontinence diagnosed without multichannel urodynamic studies. *Obstet Gynecol.* 1998;91:965–968.
5. Abrams P, Cardozo L, Fall M, et al. The standardisation of terminology of lower urinary tract function: report from the Standardisation Sub-committee of the International Continence Society. *Am J Obstet Gynecol.* 2002;187:116–126.
6. Siltberg H, Larsson G, Victor A. Frequency/volume chart: the basic tool for investigating urinary symptoms. *Acta Obstet Gynecol Scand Suppl.* 1997;166:24–27.
7. Nygaard I, Holcomb R. Reproducibility of the seven-day voiding diary in women with stress urinary incontinence. *Int Urogynecol J Pelvic Floor Dysfunct.* 2000;11:15–17.
8. Wyman JF, Choi SC, Harkins SW, et al. The urinary diary in evaluation of incontinent women: a test-retest analysis. *Obstet Gynecol.* 1988;71:812–817.
9. Abrams P, Blaivas JG, Stanton SL, et al. The standardisation of terminology of lower urinary tract function. The International Continence Society Committee on Standardisation of Terminology. *Scand J Urol Nephrol Suppl.* 1988;114:5–19.
10. Soroka D, Drutz HP, Glazener CM, et al. Perineal pad test in evaluating outcome of treatments for female incontinence: a systematic review. *Int Urogynecol J Pelvic Floor Dysfunct.* 2002;13:165–175.
11. Lose G, Rosenkilde P, Gammelgaard J, et al. Pad-weighing test performed with standardized bladder volume. *Urology.* 1988;32: 78–80.
12. Rasmussen A, Mouritsen L, Dalgaard A, et al. Twenty-four hour pad weighing test: reproducibility and dependency of activity level and fluid intake. *Neurourol Urodyn.* 1994;13:261–265.
13. Wall LL, Wiskind AK, Taylor PA. Simple bladder filling with a cough stress test compared with subtracted cystometry for the diagnosis of urinary incontinence. *Am J Obstet Gynecol.* 1994;171:1472–1477; discussion 1477–9.
14. Weber AM, Taylor RJ, Wei JT, et al. The cost-effectiveness of preoperative testing (basic office assessment vs. urodynamics) for stress urinary incontinence in women. *BJU Int.* 2002;89:356–363.
15. Cundiff GW, Harris RL, Coates KW, et al. Clinical predictors of urinary incontinence in women. *Am J Obstet Gynecol.* 1997;177: 262–266; discussion 266–7.
16. Heslington K, Hilton P. Ambulatory monitoring and conventional cystometry in asymptomatic female volunteers. *Br J Obstet Gynaecol.* 1996;103:434–441.
17. Heslington K. Ambulatory bladder monitoring: is it an advance? *Br J Urol.* 1997; 80(Suppl 1):49–53.
18. Nygaard IE. Postvoid residual volume cannot be accurately estimated by bimanual examination. *Int Urogynecol J Pelvic Floor Dysfunct.* 1996;7:74–76.
19. Goode PS, Locher JL, Bryant RL, et al. Measurement of postvoid residual urine with portable transabdominal bladder ultrasound scanner and urethral catheterization. *Int Urogynecol J Pelvic Floor Dysfunct.* 2000;11:296–300.
20. Griffiths CJ, Murray A, Ramsden PD. Accuracy and repeatability of bladder volume

- measurement using ultrasonic imaging. *J Urol*. 1986;136:808–812.
21. AHCPR. Managing acute and chronic urinary incontinence. Urinary Incontinence in Adults Guideline Update Panel. *Am Fam Physician*. 1996;54:1661–1672.
 22. Dunsmuir WD, Feneley M, Corry DA, et al. The day-to-day variation (test-retest reliability) of residual urine measurement. *Br J Urol*. 1996;77:192–193.
 23. Urinary incontinence in adults. Agency for Health Care Policy and Research. *Clin Pract Guide Quick Ref Guide Clin* 1992(2): QR1–27.
 24. Farrell SA, Epp A, Flood C, et al. The evaluation of stress incontinence prior to primary surgery. *J Obstet Gynaecol Can*. 2003;25: 313–324.
 25. Siroky MB, Olsson CA, Krane RJ. The flow rate nomogram: II. Clinical correlation. *J Urol*. 1980;123:208–210.
 26. Haylen BT, Ashby D, Sutherst JR, et al. Maximum and average urine flow rates in normal male and female populations—the Liverpool nomograms. *Br J Urol*. 1989;64: 30–38.
 27. Gajewsky JB. Uroflowmetry and Postvoid Residual. In Corcos J SE, ed. *The Urinary Sphincter*. New York: Marcel Dekker, 2001.
 28. Stephenson T. *Urodynamics: Principles, Practice and Application*. 2nd ed, 1994.
 29. Farrar. *Urodynamics: Principles, Practice and Application*. In Mundy AR, Wein AJ, ed., 1994. pp. 329.
 30. McLennan MT, Melick CF, Bent AE. Clinical and urodynamic predictors of delayed voiding after fascia lata suburethral sling. *Obstet Gynecol*. 1998;92:608–612.
 31. Griffiths D, Hofner K, van Mastrigt R, et al. Standardization of terminology of lower urinary tract function: pressure-flow studies of voiding, urethral resistance, and urethral obstruction. International Continence Society Subcommittee on Standardization of Terminology of Pressure-Flow Studies. *Neurourol Urodyn*. 1997;16:1–18.
 32. Schafer W, Abrams P, Liao L, et al. Good urodynamic practices: uroflowmetry, filling cystometry, and pressure-flow studies. *Neurourol Urodyn*. 2002;21:261–274.
 33. Groutz A, Blaivas JG, Sassone AM. Detrusor pressure uroflowmetry studies in women: effect of a 7Fr transurethral catheter. *J Urol*. 2000;164:109–114.
 34. Baseman AG, Baseman JG, Zimmern PE, et al. Effect of 6F urethral catheterization on urinary flow rates during repeated pressure-flow studies in healthy female volunteers. *Urology*. 2002;59:843–846.
 35. Carlson KV, Fiske J, Nitti VW. Value of routine evaluation of the voiding phase when performing urodynamic testing in women with lower urinary tract symptoms. *J Urol*. 2000;164:1614–1618.
 36. Abrams PH, Griffiths DJ. The assessment of prostatic obstruction from urodynamic measurements and from residual urine. *Br J Urol*. 1979;51:129–134.
 37. Webster JR. Combined video/pressure/flow cystourethrography in female patients with voiding disturbances. *Urology*. 1975;5: 209–215.
 38. Lemack GE, Zimmern PE. Pressure flow analysis may aid in identifying women with outflow obstruction. *J Urol*. 2000;163: 1823–1828.
 39. Massey JA, Abrams PH. Obstructed voiding in the female. *Br J Urol*. 1988;61:36–39.
 40. Chassagne S, Bernier PA, Haab F, et al. Proposed cutoff values to define bladder outlet obstruction in women. *Urology*. 1998;51: 408–411.
 41. Blaivas JG, Groutz A. Bladder outlet obstruction nomogram for women with lower urinary tract symptomatology. *Neurourol Urodyn*. 2000;19:553–564.
 42. Nitti VW, Tu LM, Gitlin J. Diagnosing bladder outlet obstruction in women. *J Urol*. 1999;161:1535–1540.
 43. Thompson PK, Duff DS, Thayer PS. Stress incontinence in women under 50: does urodynamics improve surgical outcome? *Int Urogynecol J Pelvic Floor Dysfunct*. 2000; 11:285–289.
 44. Bergman A, Bhatia NN. Uroflowmetry for predicting postoperative voiding difficulties in women with stress urinary incontinence. *Br J Obstet Gynaecol*. 1985;92:835–838.
 45. Lose G, Jorgensen L, Mortensen SO, et al. Voiding difficulties after colposuspension. *Obstet Gynecol*. 1987;69:33–38.
 46. Bhatia NN, Bergman A. Urodynamic predictability of voiding following incontinence surgery. *Obstet Gynecol*. 1984;63: 85–91.

47. Rud T, Ulmsten U, Andersson KE. Initiation of voiding in healthy women and those with stress incontinence. *Acta Obstet Gynecol Scand.* 1978;57:457–462.
48. Sze EH, Miklos JR, Karram MM. Voiding after Burch colposuspension and effects of concomitant pelvic surgery: correlation with preoperative voiding mechanism. *Obstet Gynecol.* 1996;88:564–567.
49. Iglesia CB, Shott S, Fenner DE, et al. Effect of preoperative voiding mechanism on success rate of autologous rectus fascia suburethral sling procedure. *Obstet Gynecol.* 1998;91:577–581.
50. Vereecken RL. A critical view on the value of urodynamics in non-neurogenic incontinence in women. *Int Urogynecol J Pelvic Floor Dysfunct.* 2000;11:188–195.
51. Weber AM. Is urethral pressure profilometry a useful diagnostic test for stress urinary incontinence? *Obstet Gynecol Surv.* 2001;56:720–735.
52. Sand PK, Bowen LW, Panganiban R, et al. The low pressure urethra as a factor in failed retropubic urethropexy. *Obstet Gynecol.* 1987;69:399–402.
53. Bergman A, Koonings PP, Ballard CA. Proposed management of low urethral pressure type of genuine stress urinary incontinence. *Gynecol Obstet Invest.* 1989;27:155–159.
54. Koonings PP, Bergman A, Ballard CA. Low urethral pressure and stress urinary incontinence in women: risk factor for failed retropubic surgical procedure. *Urology.* 1990;36:245–248.
55. Richardson DA, Ramahi A, Chalas E. Surgical management of stress incontinence in patients with low urethral pressure. *Gynecol Obstet Invest.* 1991;31:106–109.
56. Sand PK, Winkler H, Blackhurst DW, et al. A prospective randomized study comparing modified Burch retropubic urethropexy and suburethral sling for treatment of genuine stress incontinence with low-pressure urethra. *Am J Obstet Gynecol.* 2000;182:30–34.
57. Maher CF, Dwyer PL, Carey MP, et al. Colposuspension or sling for low urethral pressure stress incontinence? *Int Urogynecol J Pelvic Floor Dysfunct.* 1999;10:384–389.
58. McGuire EJ, Fitzpatrick CC, Wan J, et al. Clinical assessment of urethral sphincter function. *J Urol.* 1993;150:1452–1454.
59. McGuire EJ, Cespedes RD, O’Connell HE. Leak-point pressures. *Urol Clin North Am.* 1996;23:253–262.
60. Nager CW, Schulz JA, Stanton SL, et al. Correlation of urethral closure pressure, leak-point pressure and incontinence severity measures. *Int Urogynecol J Pelvic Floor Dysfunct.* 2001;12:395–400.
61. Weber AM. Leak point pressure measurement and stress urinary incontinence. *Curr Womens Health Rep.* 2001;1:45–52.
62. Swift SE, Utrie JW. The need for standardization of the valsalva leak-point pressure. *Int Urogynecol J Pelvic Floor Dysfunct.* 1996;7:227–230.
63. Kim YH, Kattan MW, Boone TB. Correlation of urodynamic results and urethral coaptation with success after transurethral collagen injection. *Urology.* 1997;50:941–948.
64. Bergman A, Koonings PP, Ballard CA. Negative Q-tip test as a risk factor for failed incontinence surgery in women. *J Reprod Med.* 1989;34:193–197.
65. Crystle CD, Charne LS, Copeland WE. Q-tip test in stress urinary incontinence. *Obstet Gynecol.* 1971;38:313–315.
66. Caputo RM, Benson JT. The Q-tip test and urethrovesical junction mobility. *Obstet Gynecol.* 1993;82:892–896.
67. Karram MM, Bhatia NN. The Q-tip test: standardization of the technique and its interpretation in women with urinary incontinence. *Obstet Gynecol.* 1988;71:807–811.
68. Thorp JM, Jones LH, Wells E, et al. Assessment of pelvic floor function: a series of simple tests in nulliparous women. *Int Urogynecol J Pelvic Floor Dysfunct.* 1996;7:94–97.
- 68a. LuKacz ES, Luber KM, Nager CW. The effects of the tension-free vaginal tape on proximal urethral position: a prospective longitudinal evaluation. *Int Urogynecol J Pelvic Floor Dysfunct.* 2003;14:179–184.
69. Howard D, Delancey JO, Tunn R, et al. Racial differences in the structure and function of the stress urinary continence mechanism. *Obstet Gynecol.* 2000;95:713–717.
70. Gordon D, Pearce M, Norton P, et al. Comparison of ultrasound and lateral chain urethrocytography in the determination of bladder neck descent. *Am J Obstet Gynecol.* 1989;160:182–185.

71. Schaer GN, Koechli OR, Schuessler B, et al. Perineal ultrasound for evaluating the bladder neck in urinary stress incontinence. *Obstet Gynecol.* 1995;85:220–224.
72. Turner-Warwick R, Whiteside CG, Milroy EJ, et al. The intravenous urodynamicogram. *Br J Urol.* 1979;51:15–18.
73. Versi E. The significance of an open bladder neck in women. *Br J Urol.* 1991;68:42–43.
74. Resnick NM, Yalla SV. Detrusor hyperactivity with impaired contractile function. An unrecognized but common cause of incontinence in elderly patients. *JAMA.* 1987;257:3076–3081.
75. Bump RC, Coates KW, Cundiff GW, et al. Diagnosing intrinsic sphincteric deficiency: comparing urethral closure pressure, urethral axis, and Valsalva leak point pressures. *Am J Obstet Gynecol.* 1997;177:303–310.