Chapter 3
Urodynamics Evaluation of Underactive Bladder

Michael B. Chancellor

Introduction

The UAB syndrome is a chronic, complex, and debilitating disease which affects the urinary bladder with serious consequences including urinary incontinence and urinary tract infections (Chancellor and Kaufman 2008; Chancellor and Diokno 2014). The symptoms and severity of underactive bladder vary from one person to another and the course of the disease is often unpredictable. Some of the established causes of UAB include neurogenic, myogenic, aging, and medication side effects (van Koeveringe et al. 2011; Osman et al. 2014). Symptoms are variable and don't predict the underlying pathophysiology. The symptoms may include urgency, frequency, nocturia, hesitancy, and straining to void. The International Continence Society (Abrams et al. 2002) recommends using the term detrusor underactivity (DU), defined as a contraction of reduced strength and/or duration, resulting in prolonged bladder emptying and/or failure to achieve complete bladder emptying within a usual time span. UAB is associated with excessively large bladder capacity that does not adequately empty and DU is a medical diagnostic term based on urodynamics testing of impaired detrusor contractility (Fig. 3.1a–d).

Noninvasive measurement of post-void residual urine (PVR) volume via either catheter or ultrasound and uroflowmetry are two first-line urodynamics assessment techniques available to most clinicians (Blaivas and Chancellor 1996). PVR measurement and uroflow testing are simple to learn and of modest expense and may be used before consideration of catheter-based cystometrogram and multichannel urodynamics.

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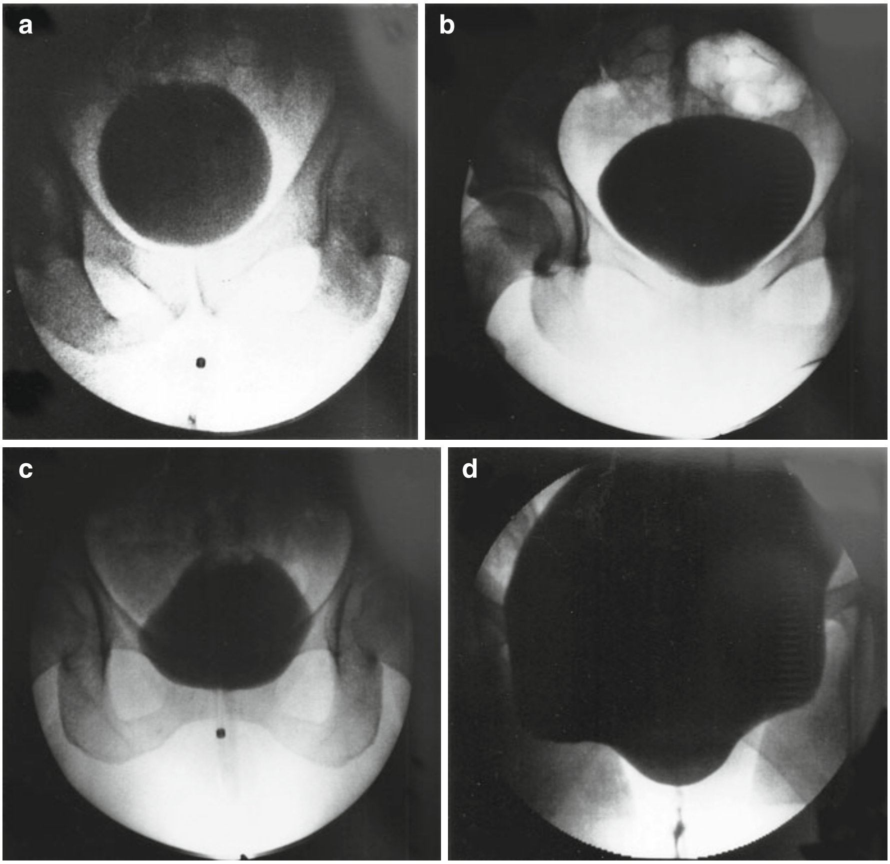


Fig. 3.1 (**a**–**c**) Normal-size bladder capacity in three patients on contrast-filled cystogram. (**d**) Cystogram of underactive bladder in a 54-year-old woman with bladder capacity over 1,200 ml and PVR of 750 ml

Post-void Residual Urine Volume

Post-void residual refers to the amount of urine left in the bladder after urination. Post-void residual testing is used to assess the degree of bladder dysfunction. There are two types of this test: in-and-out catheterization and transabdominal or pelvic ultrasound.

Acute urinary retention such as immediately after a surgical procedure with anesthesia and narcotics that resolves after a few hours and a single catheterization is not within the scope of UAB or DU. Chronic urinary retention has been defined by the International Continence Society as a PVR >300 mL or rather committing to an absolute volume, stating that it is "non-painful bladder, which remains palpable after the patient has passed urine" (Abrams et al. 2002).

European Urology's UAB working definition is "the underactive bladder is a symptom complex suggestive of detrusor underactivity and is usually characterized by prolonged urination time with or without a sensation of incomplete bladder emptying, usually with hesitancy, reduced sensation on filling, and a slow stream (Chapple et al. 2015)."

Other definitions of urinary retention and elevated residual urine volume one should be aware of include the National Library of Medicine's definition of urinary retention as "inability to empty the urinary bladder with voiding (urination)." In the United States the standard medical diagnosis code, ICD-10-CM, has the diagnosis code R33.9 *Retention of Urine* as:

- A disorder characterized by accumulation of urine within the bladder because of the inability to urinate
- Inability to empty the urinary bladder with voiding (urination)
- Incomplete emptying of the bladder

The Underactive Bladder Foundation (www.underactivebladder.org) working terminology of underactive bladder syndrome is "urinary symptoms including hesitancy, straining and incomplete bladder emptying in the absence of anatomic obstruction."

Ultrasound Measurement

This test is performed to measure the amount of urine that is left in a patient's bladder immediately after the patient made attempt to empty it completely. The test is done with ultrasound in the supine position. The clinician will place gel on the skin over the patient's bladder and then place an ultrasound probe over this area and make a recording (Figs. 3.2 and 3.3). There is no special preparation for this test and the patient may resume usual daily activities immediately following the ultrasound.

Catheterization Measurement

The test is done with a small thin, flexible tube (catheter). After going to the bathroom, the patient will lie flat on the exam table. The entrance to the urethra will be sterilely prepped and the clinician will insert the catheter into the bladder through the urethra. The volume of any urine remaining in the bladder will be drained and measured. There is no special preparation for this study.

Other than complete urinary retention and inability to void, there is no definite consensus between what is normal and abnormal nor a value above which clean intermittent catheterization must be implemented. In older people with less effective bladder emptying, most clinicians even tolerate a greater value for PVR if the

Fig. 3.2 Ultrasound post residual urine volume measurement machine

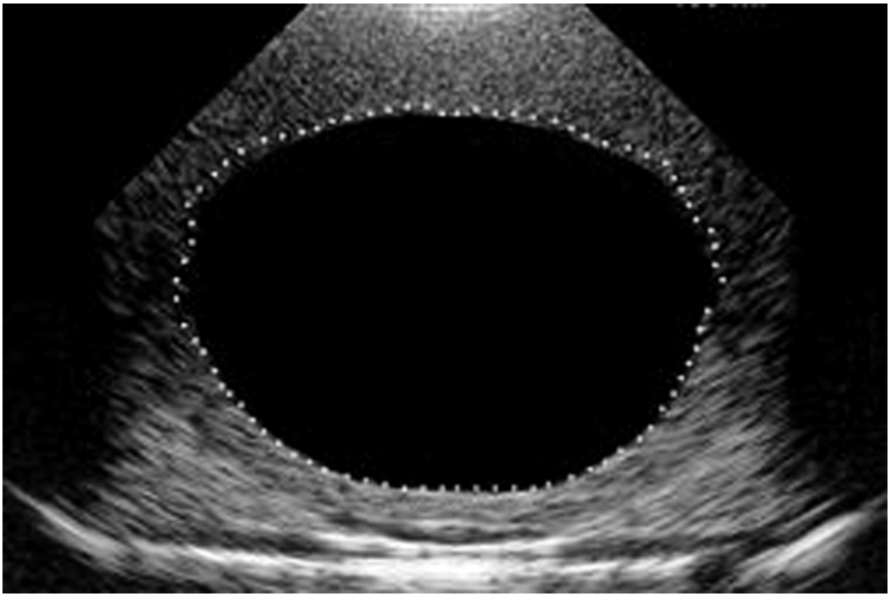


Fig. 3.3 Ultrasound image of bladder being measured for PVR with bladder outlined

patient does not have urinary tract infection and not significantly symptomatic. In general, 150–250 ml is considered by many experts as the threshold and cutoff for being abnormal. There is also a rational argument that PVR should not base not on a single number but rather as a percent of functional bladder capacity. Even for a value of >150–250 ml, further assessment and treatment may not necessarily be undertaken especially if someone would not be a surgical candidate or would not be able to handle catheter care.

Recent ICS guideline (Asimakopoulos et al. 2014) recommends that the interval between voiding and PVR measurement should be short and preferably via ultrasound instead of urethral catheterization. There is no universally accepted definition of a significant residual urine volume. Large PVR >200–300 ml may indicate marked bladder dysfunction and may predispose to unsatisfactory treatment results if, for example, invasive treatment for bladder-outlet obstruction is undertaken. The ICS guideline also concluded that PVR does not seem to be a strong predictor of acute urinary retention and does not specifically indicate the presence of BOO.

Practical Pearls of Post-void Residual Measurement

- The time interval between voiding and residual urine estimation should be recorded: this is particular important if the patient is in a diuretic phase.
- Poorly drained bladder diverticulum or vesicoureteral reflux offers a problem of interpretation and may indicate a need for surgical treatment if the patient is symptomatic.
- The absence of elevated residual urine is clinical valuable, but does not exclude obstruction or bladder dysfunction.
- An isolated finding of elevated residual urine volume requires confirmation before being considered significant.

Uroflow

Urinary flow rate represents the net interaction of detrusor contractility and outlet resistance (Fig. 3.4). The flow rate remains an extremely sensitive indicator of lower urinary tract dysfunction, but the Achilles heel of uroflow measurement is that a low flow may be due to UAB, bladder-outlet obstruction, or both (Chancellor et al. 1991). A slow downstream low flow in itself cannot distinguish the cause of upstream bladder dysfunction or outlet obstruction.

Consistently low flow rates despite adequate voided volumes generally indicate increased outlet resistance, decreased bladder contractility, or both. The minimum voided volume adequate for interpretation of an accurate uroflow is generally considered to be 125 ml (Blaivas and Chancellor 1996). Therefore, in an adult, flow events of less than 125 ml should be interpreted with caution. Nomenclature and some basic concepts bear defining prior to further discussion of different types of flow rates and patterns (Fig. 3.5):

- Voided volume: The total volume of urine expelled from the bladder.
- Flow time: The time over which measurable flow actually occurs.
- Maximum flow rate (Qmax): The maximum measured value of the flow rate.

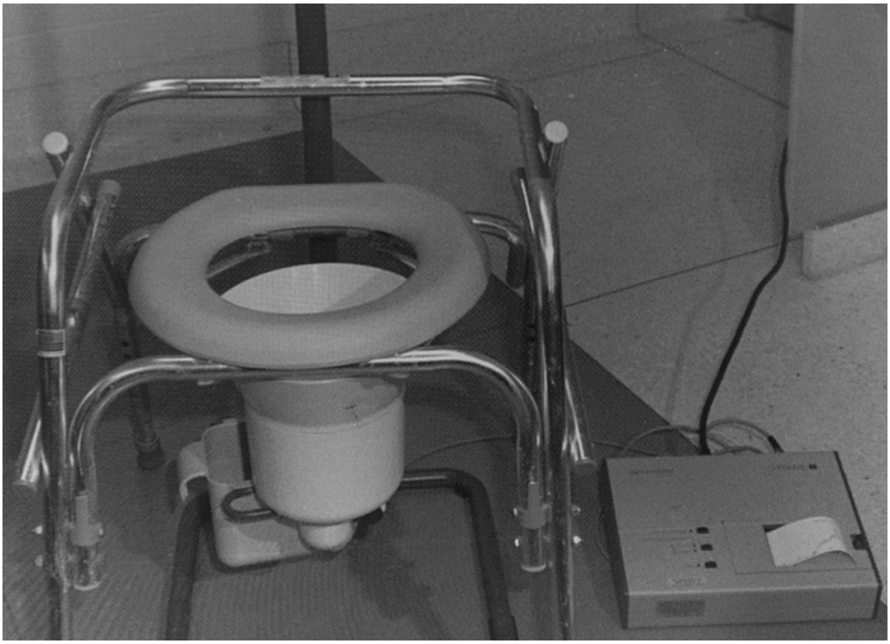


Fig. 3.4 Flowmeter

- Mean flow rate (Qmean): Volume voided divided by flow time. It is important to note that the average flow rate is only interpretable if flow is continuous and without aberrancy, either at the initiation or termination of voiding.
- Flow pattern: Subjective description of the regularity of voiding.
- Intermittent flow: Flow pattern where interruptions of varying duration occur between episodes of voiding. The same parameters used to characterize continuous flow may be used to describe intermittent flow only if caution is exercised. In order to quantify flow time, however, the time intervals between flow episodes should be disregarded. Conversely, the voiding time refers to the total duration of micturition, including the intervals between flow episodes.

Maximum Flow Rate

Among the many parameters provided by uroflowmetry, the maximum urinary flow rate (Qmax: ml/s) is regarded by most experts as most useful not only in assessing the degree of impairment but also in monitoring treatment effects. There have been multiple attempts to normalize uroflow parameters for age, sex, and voided or total bladder volume; however, none of the proposed methods have been universally accepted. It is currently assumed that correction or adjustment of the maximum flow rate value is unnecessary if voided volume exceeds 125 ml.

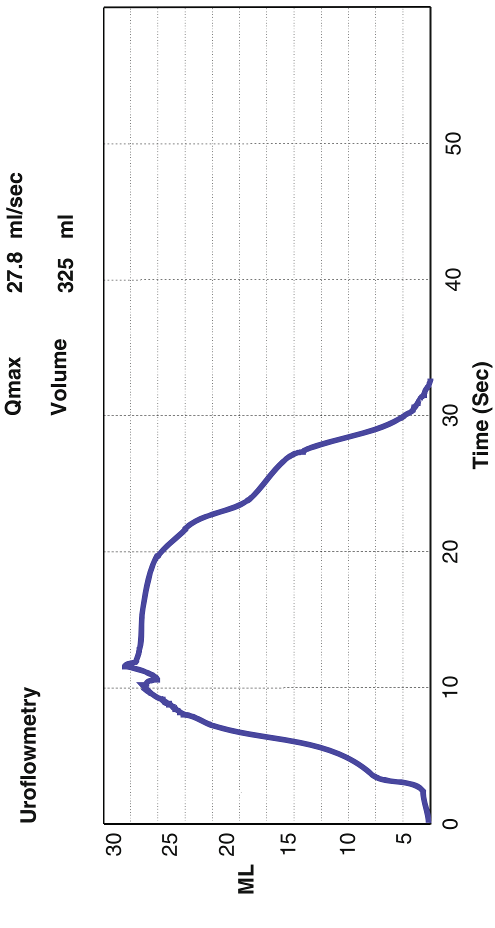


Fig. 3.5 Normal uroflow in a 63-year-old man without voiding symptoms. The patient voided 325 ml over 32 s duration and his maximum flow rate (Qmax) was 27.8 ml/s

Uroflow Patterns

A normal flow pattern is represented by a bell-shaped curve (Fig. 3.5). Upon comparison, women tend to have a higher mean and maximum flow rate than men. The urinary flow pattern of the patient with bladder-outlet obstruction is typically recognizable by a prolonged flow time accompanied by a sustained, substandard flow rate (Fig. 3.6).

Patients with outlet obstruction or impaired detrusor contractility (or both) may in fact eliminate urine by increasing intra-abdominal pressure until outlet resistance is overcome. This pattern of "Valsalva voiding" can often be identified by the urinary flow pattern (Fig. 3.7). In such instances, frequent sharp increases and decreases in the urinary flow rate are noted during the voiding period. Despite a Qmax which may approach normal values, this voiding method is not physiologic and can be detrimental. Valsalva voiding pattern exemplifies the importance of examining not only the flow parameters Qmax, Qmean, and voided volume but also the flow pattern. The parameters in such a case may not accurately reflect the severe nature of voiding dysfunction present in those utilizing Valsalva maneuvers to accomplish voiding (Blaivas and Chancellor 1996).

The pattern of bladder-outlet obstruction may indeed be more variable and not clearly indicative of obstruction. For example, refer to the equivocal flow rate seen in Fig. 3.8 of a 67-year-old man with moderate voiding symptoms and a PVR of 125 ml. He voided 250 ml with maximum flow rate of 12.5 ml/s. The uroflow in this

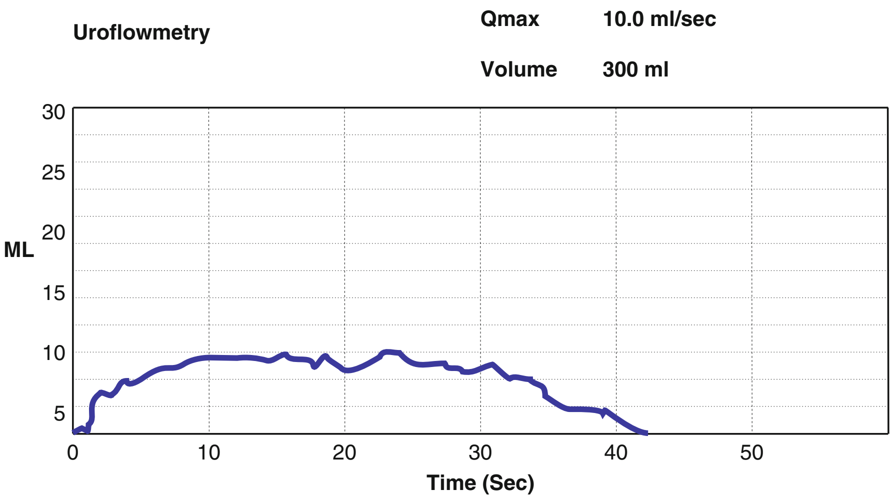


Fig. 3.6 Decreased flow rate in a 79-year-old diabetic woman with urgency, frequency, recurrent urinary tract infections, and a PVR of 150 ml. The flow pattern notes a low Qmax of 10.0 ml/s over 42 s and a voided volume of 300 ml. She has a grade 3 cystocele and a previous pelvic prolapse surgery 15 years ago. The impaired uroflow pattern is abnormal but it cannot differentiate among progressive impaired detrusor contractility with aging or diabetes, urethral obstruction from prolapse or previous surgery, or a combination of the conditions that can contribute to her UAB

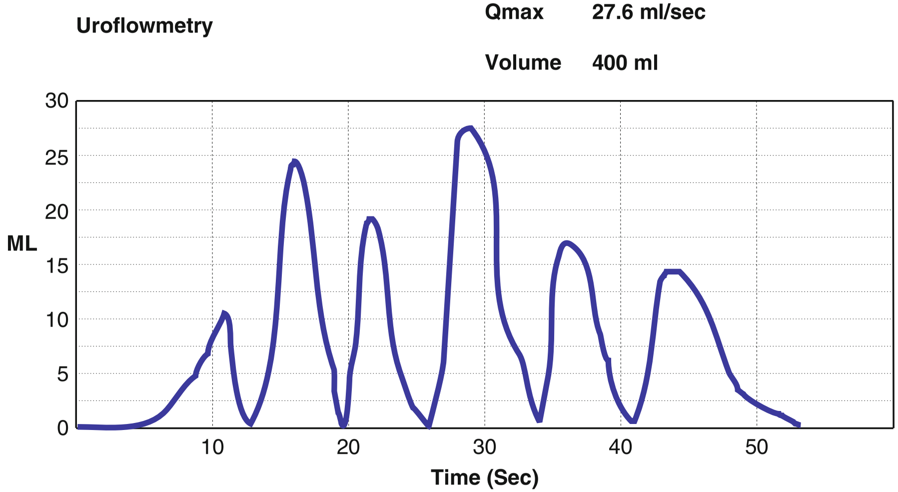


Fig. 3.7 Normal Qmax of 27.6 ml/s on this uroflow readout and the patient did not have any residual urine volume. But from the tracing, the voiding can be seen to be due to abdominal straining. The urinary stream occurs in spurts with complete interruption between the spurts. This pattern of "Valsalva voiding" points out the value of looking at the flow pattern in addition to just the numeric values of uroflowmetry

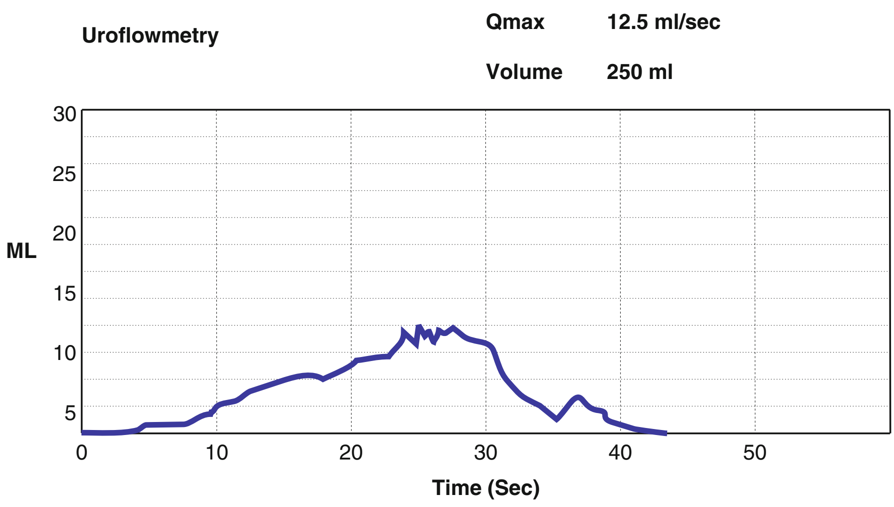


Fig. 3.8 Equivocal flow rate of Qmax at 12.5 ml/s in a 67-year-old man with moderate irritable and obstructive voiding symptoms. He voided 250 ml but had a PVR of 125 ml. The uroflow in this clinical situation is not diagnostic and multichannel pressure-flow urodynamics evaluation would be recommended

clinical situation is not diagnostic. Therefore, formal urodynamics evaluation would be necessary in order to determine whether either outlet obstruction or impaired contractility was responsible for the abnormal flow pattern in this patient.

It is most useful to ensure that the flow event depicted by the uroflow examination closely approximates the usual voiding event for that patient. Urodynamics evaluation, therefore, ideally should include at least two flow events. In individuals who can initiate voluntary micturition, one event should be at the initiation of the study prior to instrumentation, ideally when the patient arrives with a comfortably, but not excessively, full bladder.

Future Flow

The future of uroflowmetry is already here in Japan. Toto Corporation (Kokura, Japan) the world leader in smart toilet that Japan is famous for have embedded the sensors of flowmeter into top of the line smart toilet (i-Step Newsletter 2013) (Fig. 3.9). The toilet when commanded will sense the volume and flow rate and in a normal sitting or standing positions for women and men and provide readout. The build in flow toilets has been installed in some of the physician's offices in Japan and provides a more natural flow reading on a regular toilet rather than special urodynamics commode.

Fig. 3.9 Future flowmeter (Toto, Kokura, Japan). The next-generation uroflowmeter build into normal patient bathroom toilet in Doctor Tomohiro Ueda's specialty clinic in Kyoto, Japan

Practical Pearls of Uroflow

- Urinary flow rate varies significantly with the voided volumes. The minimum voided volume adequate for interpretation of an accurate uroflow is generally considered to be ≥125 ml.
- It may be helpful to have a urinary flow rate nomogram available in the laboratory for comparison of measured flow rate and voided volume (Siroky et al. 1979).
- Because urinary flow rates can vary in an individual from one voiding episode to another, more than one flow rate study should be done when first flow test is equivocal.
- In circumstances where doubt remains following an uroflow study, further urodynamics studies are essential to identify the etiology of voiding dysfunction.

Cystometrogram

Cystometry is the method by which the pressure/volume relationship of the bladder is measured. Cystometry (CMG) is used to assess detrusor activity, sensation, capacity, and compliance. Before starting to fill the bladder, the residual urine should be measured. Certain cystometric parameters may be significantly altered by the speed of bladder filling so filling should not be faster than 50 ml/min in most cases. The patient should be awake, unanesthetized, and neither sedated nor taking drugs that affect bladder function (Blaivas and Chancellor 1996; Schafer et al. 2002). Any variations should be specified and recorded (Fig. 3.10).

Definitions of Pressure Measurements

- Intravesical pressure (Pves) is the pressure within the bladder.
- Abdominal pressure (Pabd) is taken to be the pressure surrounding the bladder. In current practice it is estimated from rectal or, less commonly, extraperitoneal vaginal pressure measurement.
- Detrusor pressure (Pdet) is that component of intravesical pressure that is created by forces in the bladder wall (passive and active). It is estimated by subtracting abdominal pressure from intravesical pressure (Pdet = Pves–Pabd).
- The simultaneous measurement of abdominal pressure is essential for the interpretation of the intravesical pressure trace. However, artifacts on the detrusor pressure trace may be produced by intrinsic rectal contractions.

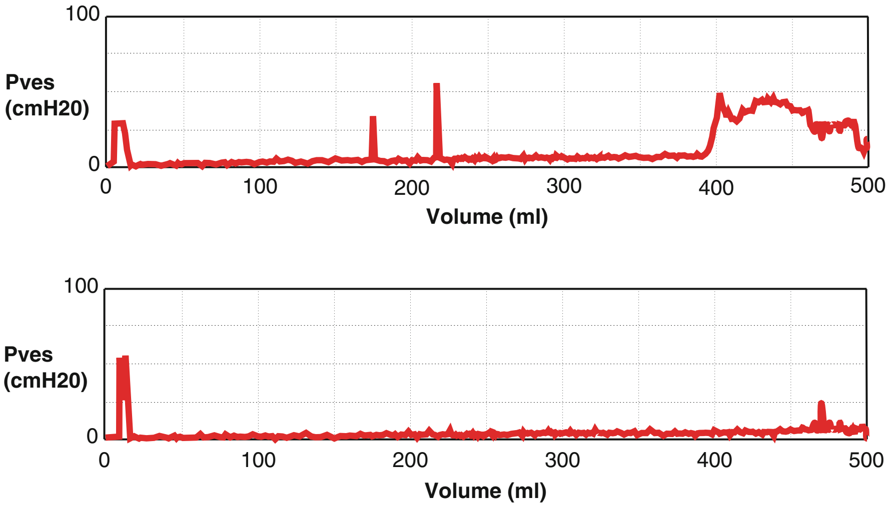
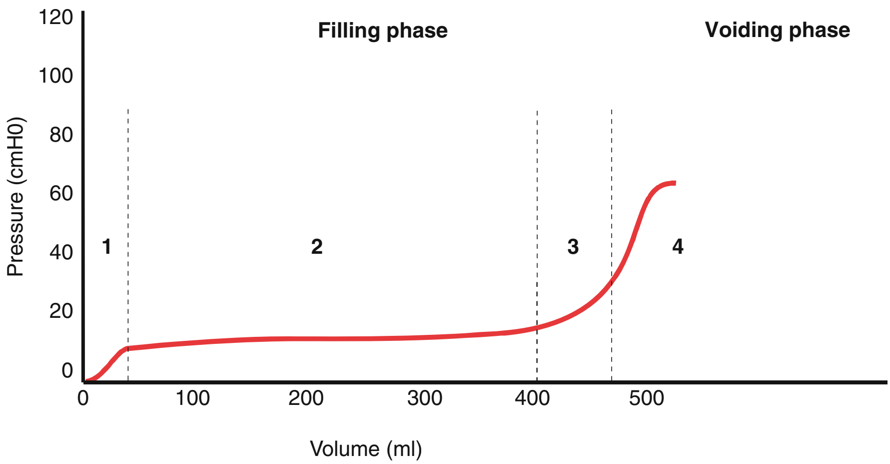


Fig. 3.10 Cystometrograms illustrating the filling and voiding phases of normal (*top*) versus UAB bladders (*bottom*). The normal patient had sensation of filling and fullness and at approximately 400 ml initiated a voluntary bladder contraction with maximum Pves of approximately 50 cmH20 and voiding to completion (*top*). The UAB patient did not have any sensation of filling and was not able to generation any intravesical pressure (*bottom*)

- Bladder sensation. Sensation is difficult to evaluate because of its subjective nature. It is usually assessed by questioning the patient in relation to the fullness of the bladder during cystometry.
- Maximum cystometric capacity, in patients with normal sensation, is the volume at which the patient feels he/she can no longer delay micturition.
- Compliance indicates the change in volume for a change in pressure. Compliance is calculated by dividing the volume change by the change in detrusor pressure during that change in bladder volume (Fig. 3.11). Compliance is expressed as ml/cmH2O.

Phases of the CMG: The normal adult cystometrogram is divided into four phases (Fig. 3.11).

- The initial pressure rise in phase 1 represents the initial response to filling, and the level at which the bladder trace stabilizes is known as the initial filling pressure. The designation "resting pressure," though often used, is incorrect. The first phase of the curve is contributed to by the initial myogenic response to filling and by the elastic and viscoelastic response of the bladder wall to stretch, factors previously discussed. With more rapid rates of filling, there may be an initially higher peak, which then levels off.
- Phase 2 is called the tonus limb, and compliance is normally high and uninterrupted by phasic rises. In practice, the compliance seen in the urodynamics laboratory is always lower than that existing during physiologic bladder filling. Normally, the rise is less than 10 cmH20.



$$\text{Compliance} = \frac{\triangle \text{ Volume}}{\triangle \text{ Pressure}} = \frac{400 \text{ ml}}{12 \text{ cmH20}} = 33.3 \text{ ml/cmH20}$$

Fig. 3.11 Idealized normal adult cystometrogram illustrating phases 1 through 4 and calculation of compliance

- Phase 3 is reached when the elastic and viscoelastic properties of the bladder wall have reached their limit. Any further increase in volume generates a substantial increase in pressure. This increase in pressure is not the same as a detrusor contraction. If a voluntary or involuntary contraction occurs, phase III may be obscured by the rise in pressure so generated.
- Phase 4 consists of the initiation of voluntary micturition. Many patients are unable to generate a voluntary detrusor contraction in the testing situation, especially in the supine position. This should not be called detrusor areflexia but, simply, absence of a detrusor contraction during cystometry, a finding that is not considered abnormal unless other clinical or urodynamics findings are present that substantiate the presence of neurologic or myogenic disease.

Bethanechol Supersensitivity Test

Bethanechol supersensitivity test was considered in the 1970s and 1980s as a helpful adjunct during urodynamics testing to determine if detrusor areflexia is neurogenic in etiology. The patient receives a subcutaneous injection of bethanechol 0.035 mg/kg, after which the cystometrogram is repeated 15 min later. A bladder afflicted by denervation will demonstrate a 15 cmH2O increase in intravesical pressure at 100 ml of filling, whereas a primary detrusor myopathy, such as from overdistention, will exhibit no such increase in pressure (Fig. 3.12). In patients with evidence of decentralization, a steady rise in intravesical pressure with filling will be noted, especially if the sphincteric mechanism is unimpaired, and high-pressure urinary storage will result.

Validity of the bethanechol supersensitivity test has mostly been abandoned. Wheeler et al. (1988) studied 7 women who strained to void and high residual urines and had detrusor areflexia, with a borderline or positive bethanechol supersensitivity test, ranging from 19 to 55 cmH2O change in intravesical pressure after 5 mg of subcutaneous bethanechol. However, all patients had a normal neurologic workup.

Blaivas et al. (1980) studied the bethanechol supersensitivity test in 33 patients who demonstrated detrusor areflexia during urodynamics. The presence or absence of a neurologic lesion was documented carefully by complete neurologic evaluation. Of the 21 patients with a neurogenic bladder, there was a falsely negative rate of 24 %. Of the 12 patients without a neurogenic bladder, the falsely positive rate was 50 %. The authors concluded that a positive bethanechol test is not by itself indicative of neurogenic bladder nor does a negative test exclude this diagnosis. The bethanechol test is not commonly used in urodynamics testing today because false-positive and false-negative results can frequently occur.

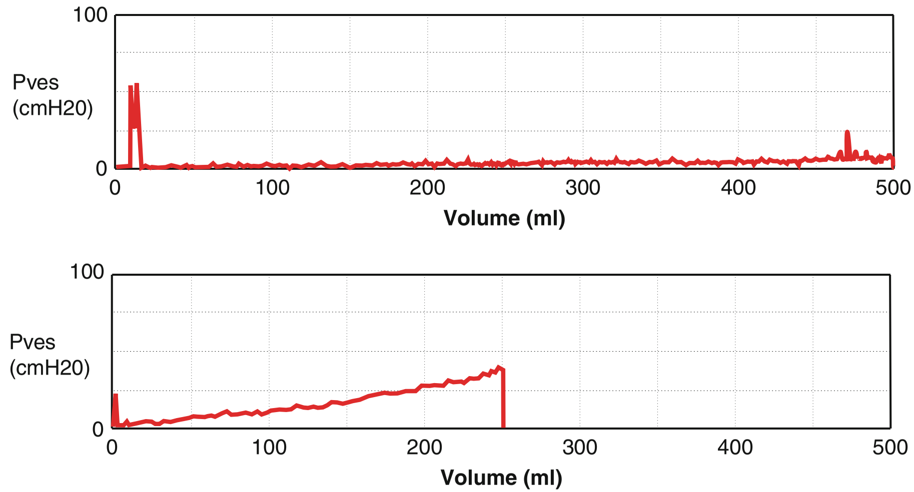


Fig. 3.12 Illustration of the bethanechol test in a 43-year-old man status post pelvic fracture with detrusor areflexia managed with intermittent catheterization. (*Top*) CMG demonstrated a compliant filling curve to capacity over 500 ml without voluntary or involuntary bladder contraction (*bottom*). CMG was repeated 15 min after subcutaneous injection of bethanechol 0.035 mg/kg. There was a 14 cmH2O increase in intravesical pressure at 100 ml of filling. The study was stopped at 250 ml due to patient discomfort

Pressure-Flow Multichannel and Video-Urodynamics

Intravesical pressure, intra-abdominal pressure (generally reflected by rectal pressure), and flow are often measured simultaneously. The purpose of pressure/flow studies is to be able to assess detrusor contractility more precisely and to better define whether obstruction is present (Ouslander et al. 1983; Chancellor and Kiilholma 1992). The normal adult male generally voids with a detrusor pressure of between 40 and 60 cmH20; the normal adult female voids at a lower pressure (Diokno et al. 1990) (Fig. 3.13). Indeed, many women void with almost no detectable rise in detrusor pressure. This does not indicate that contraction is not occurring but simply that outlet resistance, lower in the female to begin with, drops to very low levels during bladder contraction. Urodynamically, obstruction is defined by the relationship between detrusor pressure and flow-high pressure and low flow. Once obstruction is diagnosed, it is necessary to determine the site, and in order to do this, simultaneous fluoroscopy is often used (Figs. 3.14 and 3.15).

Multichannel detrusor pressure subtracted cystometry is performed by filling the bladder through a double- or triple-lumen, 8–10 Fr urodynamics catheters with normal saline at 30–50 ml/min. Rectal pressure is recorded with a fluid-filled catheter. Post-void residual urine volume will be recorded before the start of infusion. Infused volume and time are recorded automatically. The volume at first sensation of filling, first desire to void, urgency, and pain will be recorded in those patients with sensation. The volume at which involuntary bladder and urine leaks per meatus occur is equal to urodynamics bladder capacity.

Video-Urodynamics

Video-urodynamics is a technique utilizing synchronously recorded urodynamics studies and cystourethrography for the evaluation of complex lower urinary tract problems. The advantages of such a system are that by measuring and displaying all of the parameters simultaneously, one obtains a much clearer understanding of normal and abnormal physiology. The ability to obtain spot films from the recordings without interrupting the study permits the study to be performed in a much more physiologic manner. Video-urodynamics is considered the “gold standard” for the evaluation of voiding abnormalities. The whole event can be videotaped for later review and for documentation (Blaivas and Chancellor 1996).

Video-urodynamics adds an anatomic dimension to the urodynamics study that is complimentary to the pressure study. One of the key advantages of video-urodynamics study is that it can identify and localize the level of bladder-outlet obstruction (Figs. 3.16 and 3.17). While multichannel bladder and urethral pressure studies can identify the presence of obstruction, its anatomic level always remains

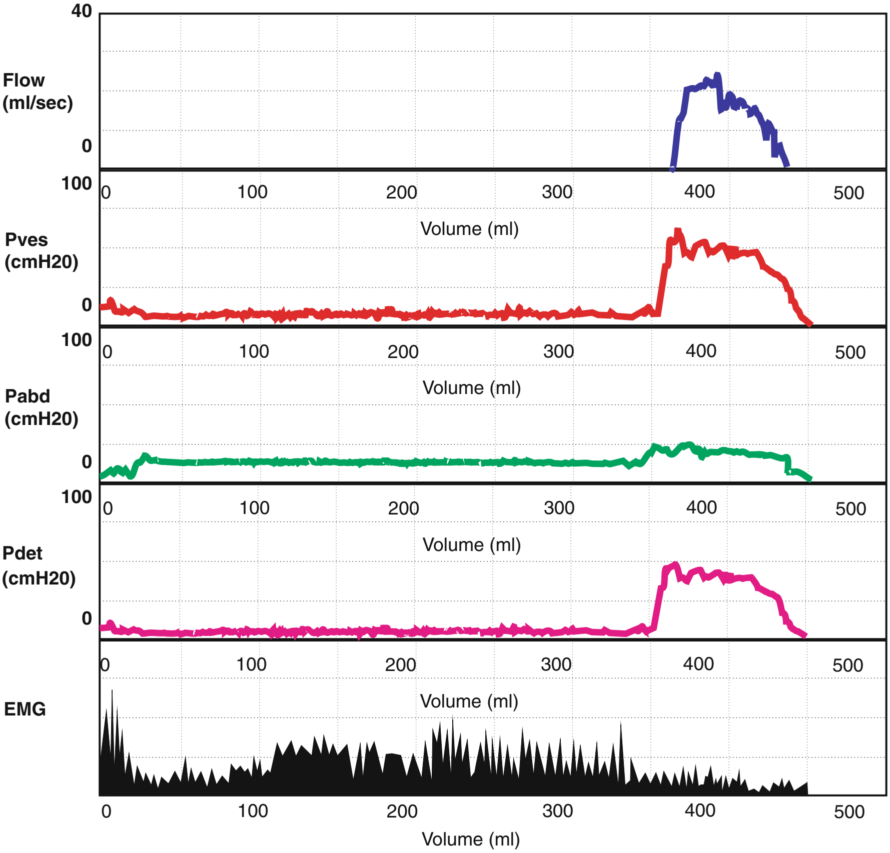


Fig. 3.13 Normal pressure-flow urodynamics in a 32-year-old. Urodynamics tracing demonstrates a voluntary detrusor contraction with detrusor voiding pressure of 46 cmH20 at 360 ml. Her maximum flow rate was 22 ml/s

in doubt. Cystogram or voiding cystourethrogram done in the absence of simultaneous bladder pressure measurement may be helpful, but cannot be certain the circumstance where the bladder neck or sphincter opening or closure is and if the high PVR with low voiding Pdet may be due to less common problems such as vesicoureteral reflux or bladder diverticulum (Fig. 3.18).

Another advantage of video-urodynamics is in the diagnosis of incontinence. Fluoroscopy is helpful to separate between urethral hypermobility and intrinsic sphincteric deficiency types of stress incontinence. Video-urodynamics helps identify bladder neck and urethral incompetence and confirm rotational descent of the bladder neck and urethra during stress maneuvers. The major disadvantage of video-urodynamics is that it requires a major investment in equipment.

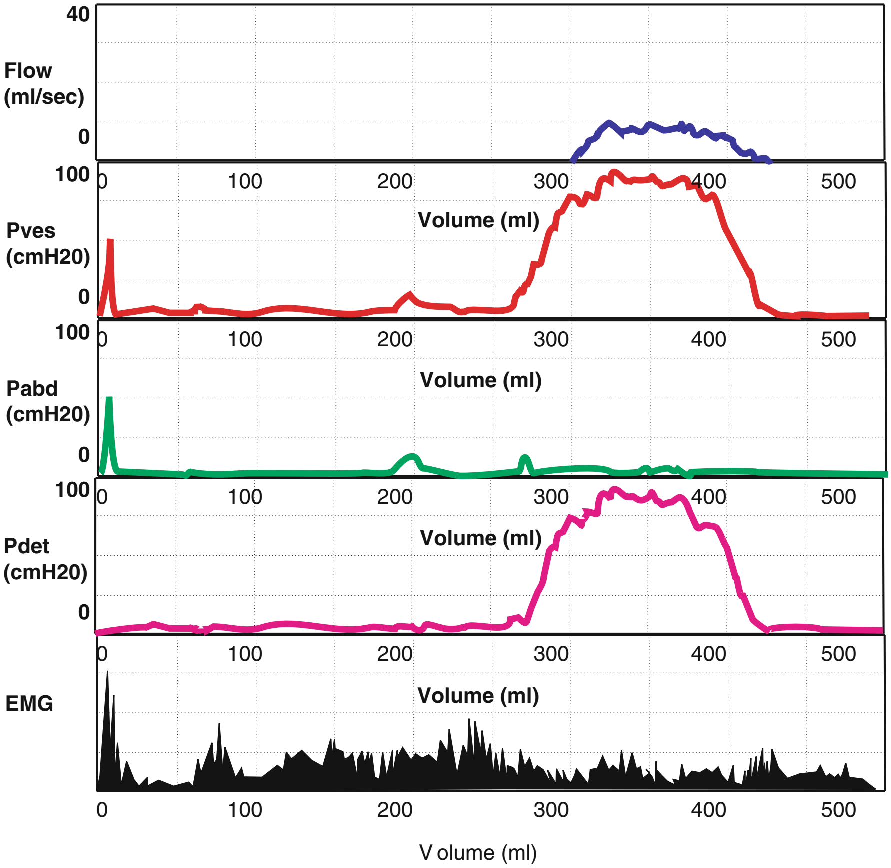


Fig. 3.14 Pressure-flow urodynamics in a 68-year-old man with obstructed voiding symptoms. Urodynamics tracing demonstrates an involuntary detrusor contraction starting at 275 ml that the patient could not inhibit, and he voided with a Pdet of 92 cm H20 and a Qmax of only 10 ml/s

Urodynamics Pitfalls in Assessment of UAB

- What are the precise criteria for outlet obstruction? Most authorities would agree that bladder-outlet obstruction is diagnostic as Qmax <10 ml/s with a sustained Pdet greater than 80 cmH20. Qmax between 10 and 15 ml/s and Pdet between 60 and 80 cmH20 are controversial for determining obstruction.
- Low pressure, low flow: There is a gray zone in which all the urodynamics parameters and computer assistant calculations presently available still cannot differentiate if low pressure, low flow (Qmax <10 ml/s in the presence of a detrusor contraction of <30 cmH2O) is due to outlet obstruction, impaired contractility, or a combination of both (Fig. 3.19). Impaired bladder emptying is often associated

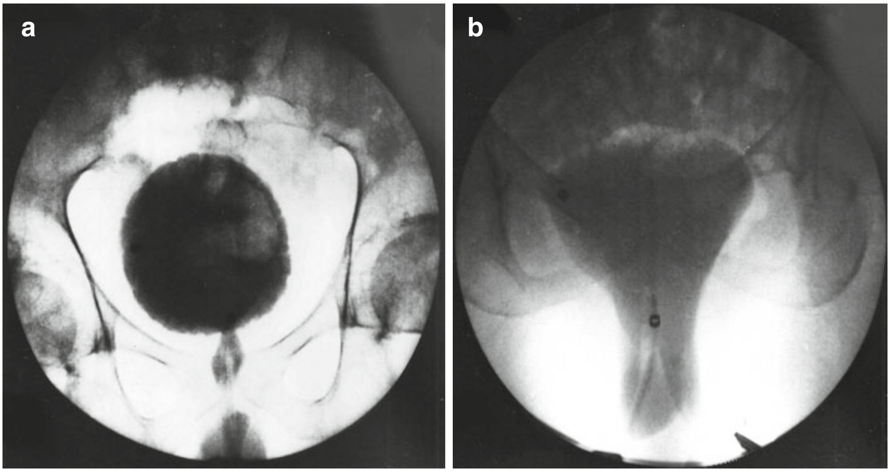


Fig. 3.15 Fluoroscopy imaging during the voiding phase demonstrating bladder-outlet obstruction at the (**a**) bladder neck and (**b**) grade 4 cystocele prolapse

with detrusor overactivity with or without bladder outflow obstruction (Blaivas and Chancellor 1996). Detrusor hyperreflexia impaired contractility (DHIC) is a common and important finding based on urodynamics studies in both healthy and symptomatic elderly (Ameda et al. 1999). Griffiths (2004) noted the coincidental occurrence and overlap of OAB and UAB with different etiological factors. Histological studies including electron microscopic analysis detected age-related change in the bladder in DHIC patients (Resnick and Yalla 1995) (Fig. 3.20).

- Concomitant neuropathy and obstruction: A difficult question in the urological management of an elderly man with Parkinson disease with detrusor hyperreflexia is whether this patient also has a bladder-outlet obstruction. Prostatectomy can be considered to relieve outlet obstruction but urgency and urge incontinence may persist or worsen after prostatectomy. Despite doing urodynamics on many of these men, we have no reliable method of predicting who will improve with prostatectomy. The patient must therefore have a clear understanding beforehand of the risks and benefits of surgery. He should be informed that he may remain incontinent and that, if anticholinergic medications fail, condom catheter drainage may be a possibility. If obstruction is ruled out, initial treatment with anticholinergic is recommended. Decreased bladder compliance is another important pathology that is associated with UAB and incontinence that requires urodynamics for diagnosis (Fig. 3.21).
- Testing anxiety: Anxiety during an urodynamics study is common. A person who cannot void during an urodynamics test does not imply obstruction or detrusor areflexia. Sometimes the study needs to be rescheduled after the patient is more familiar with the setup. At other times uroflow and residual urine is all the urodynamics testing we can ever get out of a particularly nervous patient who cannot tolerate a catheter.

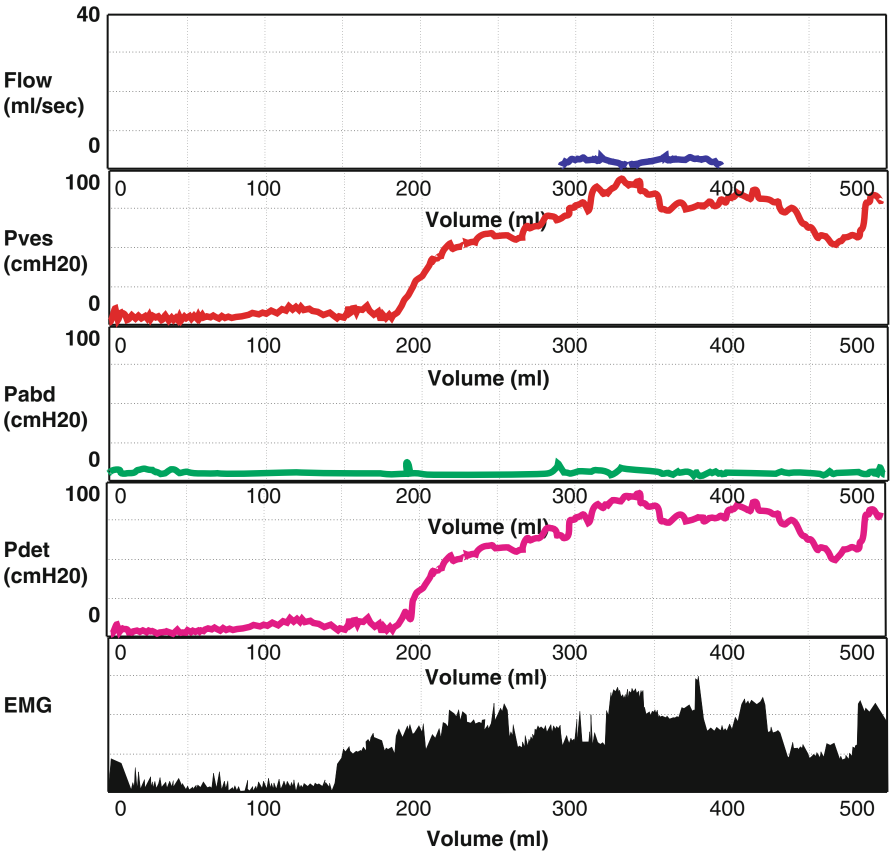


Fig. 3.16 Detrusor hyperreflexia with detrusor-external sphincter dyssynergia in a 33-year-old man with T1-level spinal cord injury. He performs intermittent self-catheterization and is taking antimuscarinic agents but still has refractory urge incontinence. Involuntary detrusor contraction occurred at low volume with elevated voiding pressure of 90 cmH20. Note the increased EMG activity during involuntary bladder contraction

Parameters of Detrusor Power and Work in UAB

There is a wide variation in the urodynamics criteria considered as diagnostic of DU in clinical studies (Osman et al. 2014). Measurement of detrusor contraction strength and sustainability of contraction have been proposed (Schafer 1991). For both contraction strength and sustainability of contraction, normal range is mostly derived from men undergoing surgery to relieve bladder-outlet obstruction (Schafer 1991). These ranges may not be applicable to women.

Multichannel Urodynamics Parameters: Pdet at Qmax (<40 cmH20); Qmax (<15 ml/s)

The urodynamics estimation of detrusor contractile function is based upon the detrusor pressure required to expel urine through the urethra. Measurement of

Fig. 3.17 Fluoroscopic imaging during voiding of the patient in Fig. 3.16 demonstrated a significantly trabeculated bladder with open bladder neck and prostatic urethra but closed membranous urethral sphincter

detrusor contractile function may underestimate true detrusor contractility, as the contraction generates both flow and pressure (Griffiths 2004). To compensate, methods attempting to estimate isovolumetric detrusor pressure during uninterrupted or interrupted voiding have been developed. Most methods are based on the inverse relation between pressure and flow. The bladder-outlet relationship (BOR) states that in any given bladder if outflow is stopped, the detrusor pressure reaches its highest possible value (isovolumetric pressure), and when increasing flow is allowed, pressure decreases reaching a minimum when flow reaches a maximum. On this basis, measuring detrusor pressure at the time of highest flow (i.e., Pdet at Qmax) does not correlate to the peak of contraction strength. Consequently, methods that assess isovolumetric detrusor pressure have been suggested and are either based on mathematical analysis of urodynamics data or real-time interruption of urine flow (Osman et al. 2014).

Occlusion Testing

Noninvasive techniques assessing contraction strength have been explored. One technique is to use condom catheters. The pressure is measured by a continuous column of fluid from the catheter via condom to the urethra and bladder.

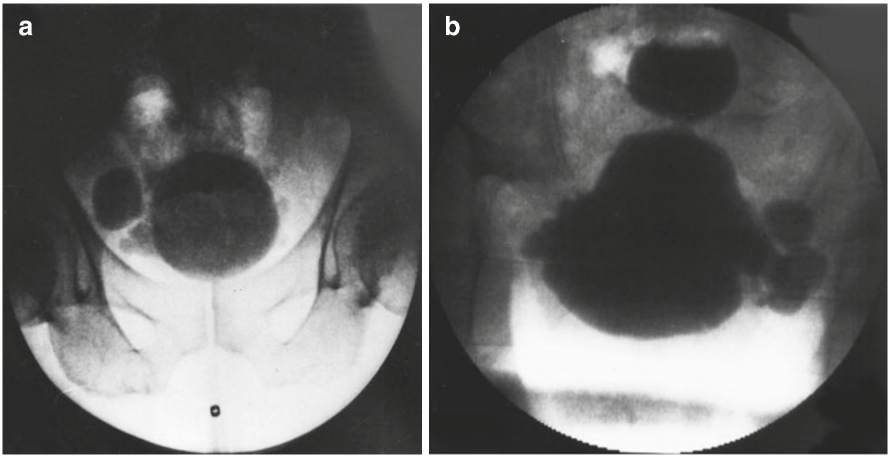


Fig. 3.18 Two examples where video-urodynamics were helpful in diagnosis of UAB symptoms. Two women with symptoms of urgency, frequency, sensation incomplete bladder emptying, recurrent urinary tract infections, and elevated PVR >200 ml. On pressure-flow studies, there were involuntary detrusor contraction but Pdet at maximum flow of less than 20 cmH20. Fluoroscopic imaging during voiding demonstrated a large right bladder side wall diverticulum with narrowed neck (**a**) and multiple diverticula in (**b**). Both women underwent surgical resection of their diverticula with resolution of symptoms and complete bladder emptying postoperatively

Measurements of Pdet-iso correlate with invasive pressure-flow urodynamics in nonobstructed patients but less so in bladder-outlet obstruction (Pel and van Mastright 1999). Several problems can lead to artifacts such as leakage around the condom, closure of the external sphincter in response to line occlusion, and increased compliance within the system (Blake and Abrams 2004). McIntosh et al. (2004) used an inflatable penile cuff to interrupt voiding but noted that this method overestimates Pdet-iso by approximately 16 cmH_2O. The occlusion test can only be applied to men and may be painful. Abdominal straining cannot be diagnosed by the occlusion urodynamics test.

Ambulatory Urodynamic

Ambulatory urodynamics may have a role in the diagnosis of UAB when a person cannot void or generate detrusor contraction on filling CMG in the urodynamics laboratory (Osman et al. 2014). van Koeveringe et al. (2010) found that in 71 % of patients whom no detrusor contraction during office filling CMG did have detrusor contractility in ambulatory urodynamics studies. Filling CMG is conducted at

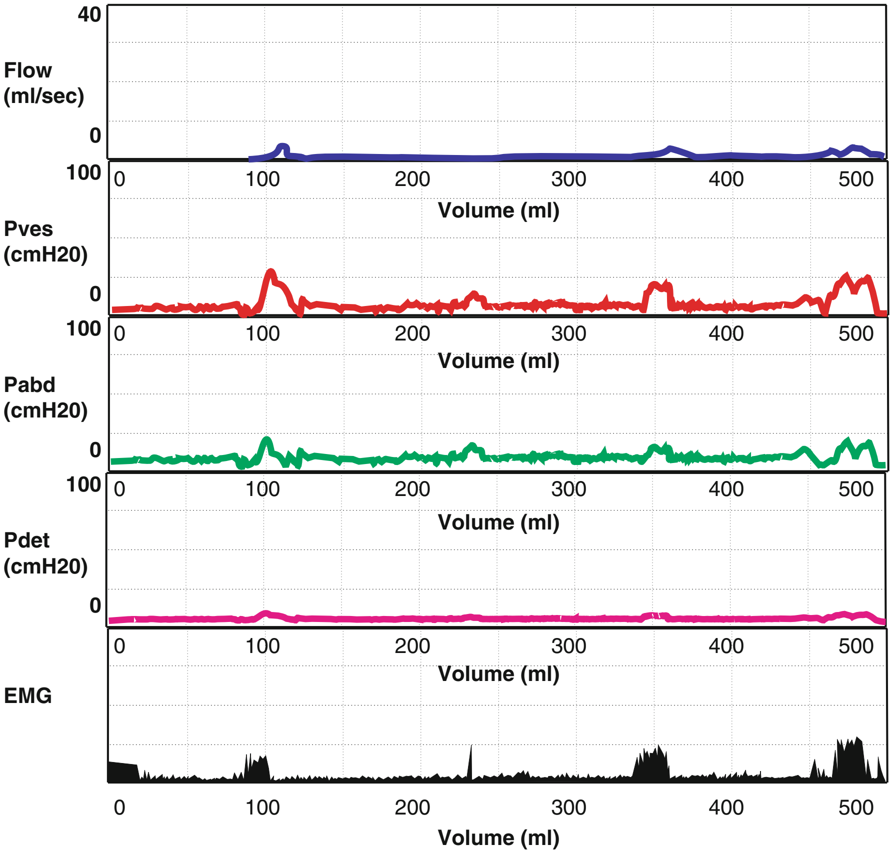


Fig. 3.19 UAB acontractile bladder on multichannel urodynamics. Detrusor areflexia in this case was secondary to acute bilateral herniated lumbar intervertebral disks in an otherwise healthy 54-year-old man without prior urological history. The bladder is areflexic to over 500 ml without voluntary or involuntary detrusor contractions

nonphysiological filling rates and so its validity as a modality for assessing detrusor contractility can be questioned. This is likely due to patient anxiety with catheter and observers that pelvic floor/sphincter contraction triggers the guarding reflex impairing detrusor contraction. Despite the potential advantages of ambulatory urodynamics, it remains a research tool as it is time consuming to setup, download, and interpret. The catheters can dislodge or fall out or are prone to artifacts of daily activity. Moreover, the frequent observation of involuntary detrusor contractions in normal patients without overactive bladder raises questions about value and interpretation of results. Advances in telemedicine and miniaturization may revolutionize ambulatory urodynamics in the future.

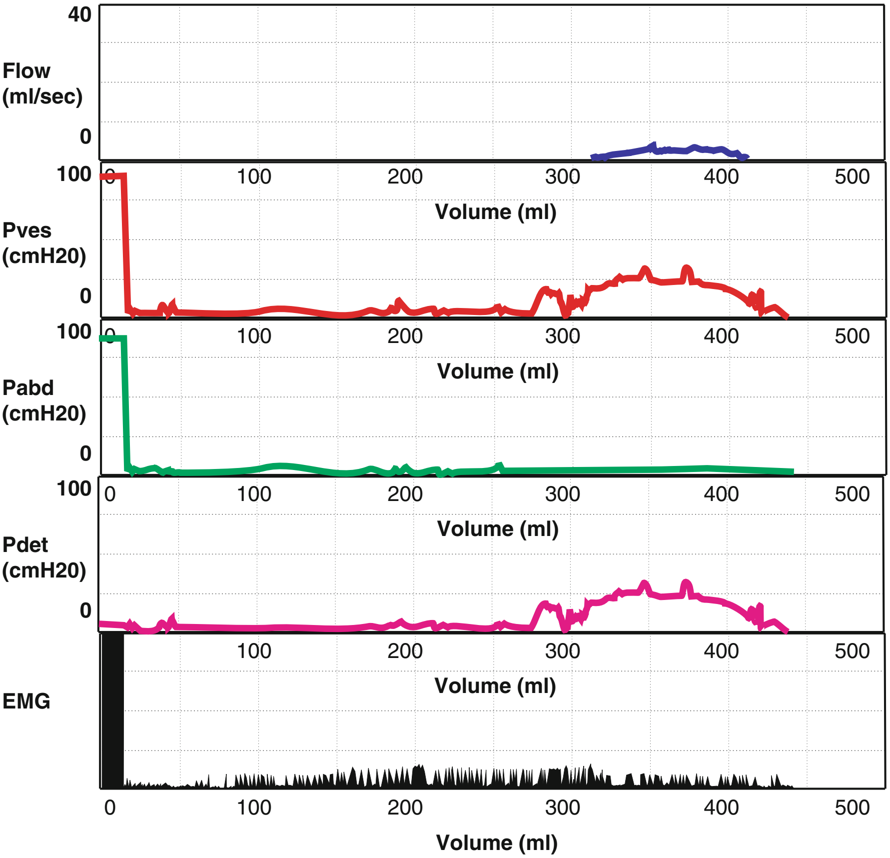


Fig. 3.20 Detrusor hyperreflexia with impaired contractility on pressure/flow urodynamics testing in a 75-year-old woman with urgency, frequency, and post-void residual urine volume of 225 ml. Urodynamics tracing demonstrates small-magnitude involuntary detrusor contraction with maximum Pdet of only 28 cmH20 and a Qmax of only 4 ml/s

Conclusions

Urodynamics testing for UAB starts with widely available office-based noninvasive urodynamics of post-void residual urine measurement and uroflowmetry. The fundamental rationale for multichannel pressure-flow urodynamics testing is that underactive bladder and detrusor underactivity is difficult to differentiate from bladder-outlet obstruction on the basis of symptoms, elevated residual urine volume, or impaired flow rate. However, diagnosis relies upon invasive pressure-flow studies that have methodological limitations and lack wide availability and clinical expertise. There is a need for biomarker and noninvasive methods of screening for

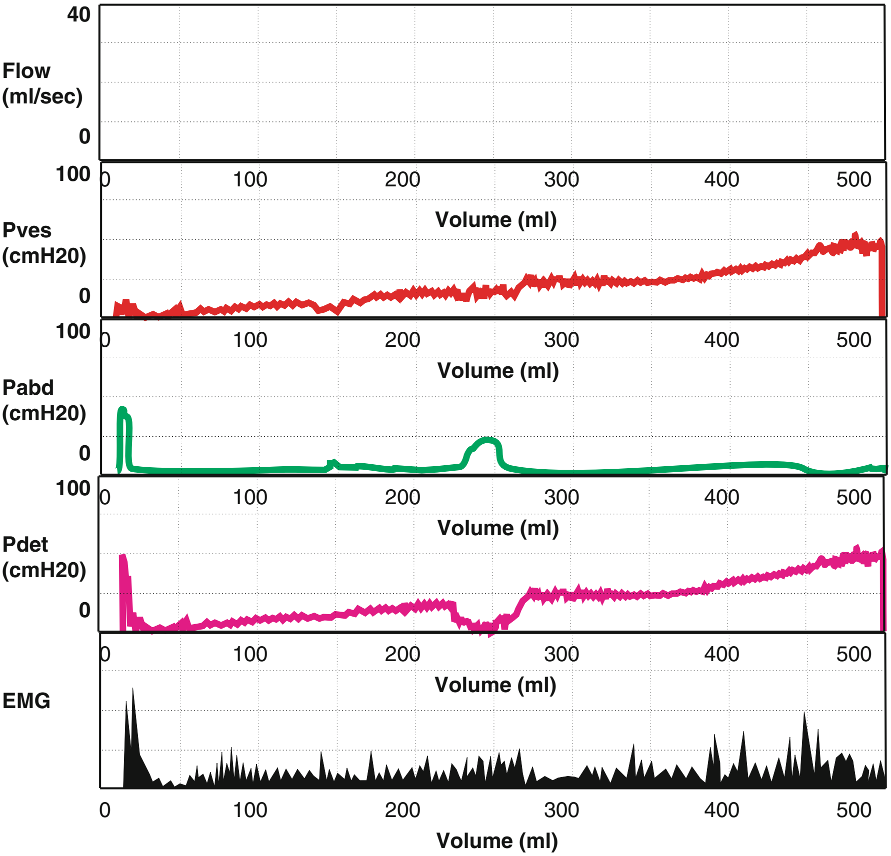


Fig. 3.21 Detrusor areflexia with poor compliance in a 31-year-old woman with pelvic fracture. She does careful intermittent self-catheterization and yet has incontinence and several bouts of febrile urinary tract infections. Urodynamics tracings demonstrated an areflexic bladder with detrusor leak point pressure of 50 cmH20

and diagnosing of underactivity bladder. Reliable and noninvasive method of determining detrusor contractility would be a priority for the large number of patients at risk for underactive bladder.

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