Multichannel Urodynamic Testing

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Introduction

The term urodynamics was introduced by David M. Davis [1]. The International Continence Society defines urodynamics as a set of tests used to measure urinary tract function and dysfunction [2]. Multichannel urodynamic testing refers to a set of tests that are typically performed together in order to provide a comprehensive evaluation of lower urinary tract function; the most commonly performed procedures are prestudy uroflowmetry, followed by filling cystometry with urethral pressure studies in selected cases, and voiding pressure flow study (Table 9.1) [3–6].

Uroflowmetry

Uroflowmetry may be performed immediately prior to multichannel urodynamic testing or as a stand-alone study. The patient is asked to arrive for testing with a moderate to strong desire to urinate and allowed to void promptly upon arrival. When combined with a multichannel urodynamic study or endoscopy, uroflowmetry should be completed prior to catheterization because urethral instrumentation has been shown to lower the maximum flow rate [7]. Urinary flow may be measured via one of several transducers; one measures weight changes as urine is collected in a beaker, and a second uses a spinning disc device that measures flow as it passes across the disc and alters the spin rate [3].

Urinary flow is determined by two factors: the velocity of urine flow as it exits the bladder vesicle and the cross sectional area of the urethra [8]. The velocity of urinary flow is primarily created by a detrusor contraction, although it may be augmented by abdominal straining [9]. Urethral caliber also influences urinary flow; a urethra with a larger diameter allows a higher flow rate, while a narrower urethral lumen restricts the maximum flow rate. The female urethra has a wider lumen than a male urethra and therefore, women tend to have a higher maximum urinary flow rate than men. In the normal urethra, flow is determined by its narrowest region (sometimes referred to as the flow determinant zone); this zone is found in the middle third of the female urethra and the membranous urethra in the male where the urethra traverses the rhabdosphincter. The flow determinant zone is shifted to the level of blockage in patients with bladder outlet obstruction. Because of the interaction between these factors, variability in either detrusor contraction strength or urethral diameter influences maximum and average urinary flow rate. In order to accurately identify the cause of an abnormal flow pattern simultaneous measurement of detrusor contraction pressure and urinary flow is needed.

A variety of potentially characteristic urinary flow patterns have been described, but we have found that a relatively simple classification schema based on three uroflow patterns is most useful for interpretation of the non-instrumented uroflowmetry [3, 10–12]. They are continuous (normal), prolonged, and interrupted/intermittent (Fig. 9.1) [3, 10–12]. The continuous flow pattern is characterized by a bell grade curve that tends to be slightly skewed to the left. The prolonged flow pattern is characterized by a lower maximum and average flow rate. The interrupted/intermittent flow pattern starts and stops at least once before voiding ends; the maximum flow rate may be comparable to values seen in the continuous flow pattern, but the average flow will be less than 50 % of the maximum flow rate.

Maximum and average flow rates vary among healthy women and men rendering it impossible to identify a single value describing a normal flow in an adult male or female. Limited evidence from studies in aging men undergoing prostatectomy for benign prostatic enlargement and adult women undergoing midurethral sling surgery suggests that a Qmax >15 ml/s is a reasonable cut point for distinguishing a

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Table 9.1 Typical components of a multichannel urodynamic study

Procedure	Brief description	Main parameters measured	Goals of study
Assessment of bladder filling/storage			
Filling cystometrogram (CMG)	Graphic representation of flow versus intravesical volume. Three pressures are routinely measured during the filling CMG: intravesical pressure (Pves), abdominal pressure (Pabd), and detrusor pressure (Pdet)	Cystometric capacity Bladder wall compliance Competence of the urethral sphincter mechanism Sensations of bladder filling Detrusor response to bladder filling	Evaluation of disorders related to bladder storage function including: small or large bladder capacity, low bladder wall compliance, stress incontinence with urethral incompetence of the sphincter mechanism, increased or reduced sensations of bladder filling, and detrusor response to bladder filling
Urethral pressure studies	Graphic representation of urethral pressure (Pura) Urethral pressure profile (UPP) measures maximum urethral closure pressure when the bladder is filled with 50–200 ml Cough-stress UPP measures competence of urethral closure in response to coughing	Urethral pressure measured in cm H_2O Maximum urethral closure pressure is a subtraction of the maximum urethral pressure from Pves	Evaluation of urethral sphincter competence
Assessment of bladder evacuation			
Prestudy uroflowmetry	Graphic representation of urinary flow (Q) as urine is collected in beaker placed over von Garrlet's flowmeter or when urine passes through spinning disc uroflowmeter	Maximum flow rate (Qmax): maximum flow sustained for 1 s or longer Average flow rate (Qave): mean flow rate calculated as voided volume divided by voiding time Voided volume: measured in ml Residual volume: measured by catheterization or bladder ultrasound	Characterized flow pattern, voided volume, and residual volumes Enables identification of abnormal flow patterns but does not indicate cause of voiding problems May be used for assessment of quality of voiding pressure flow study (voiding pressure flow study should reproduce flow pattern of non-instrumented prestudy uroflow study)
Voiding pressure flow study	Graphic representation of uroflowmetry, Pabd, Pves, and Pdet pressures with or without sphincter EMG	Uroflow with Qmax, Qave, voided volume Voiding pressures Pves, Pabd and Pdet Sphincter EMG may be recorded A second post void residual volume is measured immediately following the voiding pressure flow study	Evaluation of bladder evaluation including urinary flow, detrusor contraction strength, urethral resistance, and sphincter response to micturition when sphincter EMG is measured
Sphincter electromyography (EMG)	Graphic assessment of the electrical activity of pelvic floor muscles during bladder filling and storage; EMG is typically measured via transcutaneous patches that detect electrical signals from the pelvic floor muscles Alternatively, the electrical activity of motor units within the rhabdosphincter may be measured directly using EMG needle or the periurethral muscles may be directly measured via hooked wire electrodes	Summary activity measures gross motor movements of the pelvic floor muscles only Summary EMG may be displayed as a mirrored image; a wider tracing indicates greater EMG activity and a narrower image indicates lesser EMG activity Summary EMG activity may be measured via microvolts; normal resting tone is less than 5 microvolts; higher microvolts cause increased EMG activity Needle EMG allows assessment of individual motor units within the rhabdosphincter	During bladder filling/storage the EMG is assessed to determine pelvic floor muscle (PFM) response to voluntary pelvic floor muscle contraction (also called a Kegel contraction) Gently tapping the clitoris or squeezing the glans penis allows assessment of the bulbocavernosus reflex During bladder evacuation the EMG response to voiding is assessed, relaxation of the PFM causes quieting of the EMG tracing; paradoxical contraction of the pelvic floor EMG indicates dyssynergia (incoordination) of the striated sphincter and detrusor contraction or voluntary PFM contraction associated with voiding dysfunction

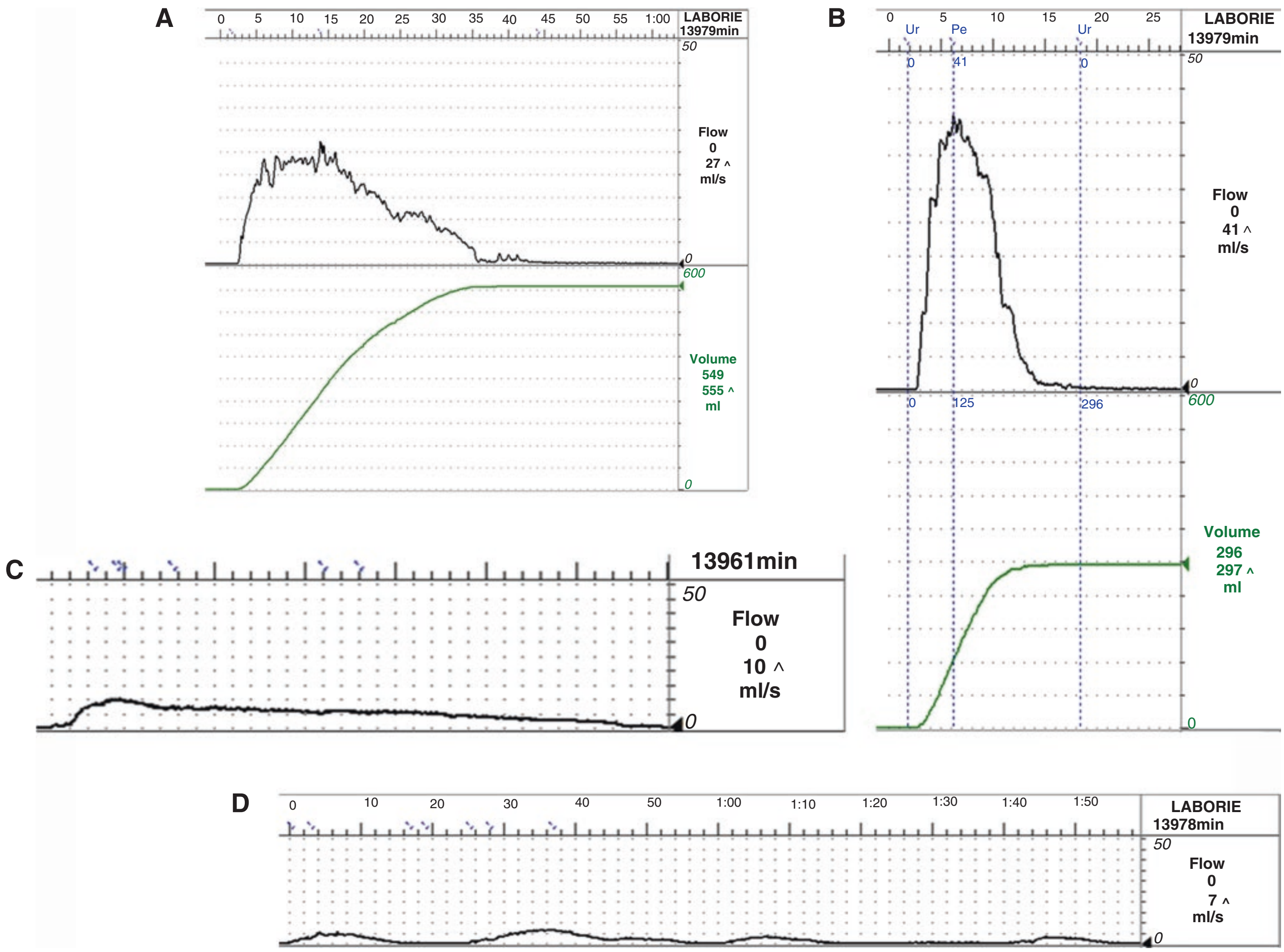

Fig. 9.1 Continuous flow pattern in an adult male (**a**), adult female (**b**), prolonged flow pattern in an adult male (**c**) and interrupted flow pattern in an adult female (**d**)

continuous from a prolonged flow pattern [12–14]. While it is tempting to associate a specific diagnosis to a particular flow pattern, such as bladder outlet obstruction with a prolonged flow pattern or underactive detrusor function augmented with abdominal straining with an interrupted/intermittent flow pattern, it is important to note that uroflowmetry alone cannot reliably distinguish the cause of an abnormal flow pattern. Instead, the uroflow results should be combined with a post void urine residual measurement and interpreted as indicating *either* underactive detrusor function or bladder outlet obstruction [15]. Differentiation of these conditions requires a voiding pressure flow study.

A post void residual measurement should be obtained immediately following the prestudy uroflow [3, 12]. When performed in the context of a multichannel urodynamic study, the residual is usually measured via catheterization. Nevertheless, estimation of the residual volume via ultrasound provides a less invasive alternative when uroflowmetry is performed as a stand-alone study [16, 17]. Similar to the maximum and mean flow rates, there is no absolute cut point for a residual volume indicating the need for additional evaluation. In addition, residual volumes vary significantly among older adults, requiring repeat assessment to determine a consistent pattern of elevated residual urine volumes [18]. Nevertheless, clinical experience suggests that patients with consistently higher residual volumes (>200 ml) may benefit from a voiding pressure flow analysis to determine the cause of incomplete bladder emptying.

Filling Cystometrogram

The filling cystometrogram is a graphic representation of multiple pressures plotted against intravesical volume with or without pelvic floor muscle electromyography (EMG); the main goal of this study is to evaluate bladder storage and filling [19]. Multichannel filling cystometry typically involves measurement of 3 pressures. Intravesical pressure (Pves) is measured by placing a transducer into the urinary bladder. Pves is a reflection of both detrusor generated force and abdominal forces acting on the bladder wall. Abdominal pressure (Pabd) is measured by a tube placed in the rectal vault or vaginal vault. Pabd is a measurement of the abdominal forces acting on the pelvis including the lower urinary tract. A third pressure, detrusor pressure (Pdet) is a calculated pressure by subtracting abdominal pressure from intravesical catheter pressure (Pdet = Pves – Pabd) [3, 20].

Most urodynamic systems use one of three transducer technologies to measure pressure [21]. Water-charged systems measure pressure transmitted along a column of water established between the patient and a flexible membrane; the water-charged transducer is placed outside the body. A small reservoir of water (3–5 ml) within a specially designed tube is used to measure Pabd. Air-charge transducers are small balloons that are filled (charged) with 0.8 ml of air, which are then incorporated into a specially designed catheter or tube to measure pressure. Microtransducers are mounted directly onto a reusable catheter; the transducer comes into contact with the wall of the rectum or vaginal vault to measure pressure. A disposable system incorporating microtransducer technology has been designed but is not yet commercially available in the USA.

Evidence guiding selection of the optimal transducer type for urodynamic testing is sparse [21]. The International Continence Society (ICS) recommends use of water-charged transducers based on multiple factors including its relatively rapid response to rapid changes in pressures such as those created by a cough [8, 21]. The ICS nevertheless acknowledges limitations of water-charged transducers including artifact when the fluid filled lines connecting the patient to the transducer are jostled during testing. Air-charged transducers are gaining more widespread use in North American in particular. Both air-charged and microtransducers have strengths when compared to water-charged transducers including rapid setup and reduced sensitivity to artifact when jostled during urodynamic testing. Nevertheless, both technologies require placement of the transducer inside the patient's body, which is contributory to greater variability with establishing the reference level. The water-charged system, where the transducer remains outside the patient's body, enables more consistent placement at the recommended reference level. Both air-charged and water-charged transducers exhibit similar responses when measuring pressures during a voiding pressure flow study [22]. The ICS also notes that air-charge transducers tend to exhibit a diminished or delayed response to rapidly changing pressures such as those observed during a cough [21]. However, the magnitude of this difference and its clinical relevance has not been established.

Regardless of the type of transducer used to measure pressures during multichannel urodynamic testing, all transducers must be zeroed with respect to atmosphere and a proper reference level established to ensure high quality, reproducible measurements [2, 8, 23]. Zeroing with respect to atmosphere provides a consistent standard for pressure measurement in urodynamic testing and it is strongly preferred over more variability introduced when transducers are zeroed with respect to each patient. The reference level established by the International Continence Society is the superior margin of the symphysis pubis [2]. This level is easily established with water-charged transducers that can be situated parallel to the superior margin by visual inspection. The reference level is more difficult to establish with air-charged or microtransducer catheters; it may be established by performing a simple urethral pressure profile and placing the transducer several centimeters above the maximum urethral pressure measured. Alternatively, standard placement may be used; the catheters used for both systems are graduated in centimeters to make this process easier. Clinical experience suggests that catheter should be inserted approximately 12 cm in adult females and 20 cm in adult males. Once transducers are in place within the bladder pressure measurement is technically straightforward, as the bladder is a fluid filled chamber. Measurement of Pabd is more technically challenging since neither the rectal vault nor posterior vaginal vault is normally filled with a liquid medium. Hence there is a need for a specially designed tube with a small reservoir to measure pressure or a microtransducer system.

Sphincter electromyography (EMG) also may be monitored during filling cystometry. EMG information can be gathered through several methods. Transcutaneous (patch) electrodes or percutaneous needles can be placed on the perianal area. Alternatively hooked wire electrodes can be percutaneously inserted into the periurethral striated muscle [4]. Measurement of pelvic floor muscle activity provides an opportunity to evaluate how the pelvic floor responds to bladder filling/storage, the bulbocavernosus reflex, and provocative maneuvers such as coughing. The EMG allows the clinician to determine the patient's ability to identify, contract, and relax the pelvic floor muscles.

Filling cystometry is completed by filling the urinary bladder with sterile water, saline, or a radiographic contrast material [21, 23]. Supraphysiologic fill rates from 30 ml/min to as high as 100 ml/min may be used. However, slower fill rates (30–50 ml/min) are preferred since the small catheter size used for most urodynamic testing (5–7 French) limits the ability to fill the bladder at higher rates. In addition, higher rates have been shown to exert negative effects on urodynamic findings when compared to physiologic filling during ambulatory monitoring.

Data from the filling cystometrogram is used to answer five essential questions: (1) what is the cystometric capacity, (2) is bladder wall compliance normal or low, (3) is the urethral sphincter mechanism competent, (4) are sensations of bladder filling normal, reduced, or increased, and (5) what is the detrusor response to bladder filling [5]. The immediacy of each of these questions varies based on the clinical history of the patient and the lower urinary tract symptoms or disorders prompting urodynamic testing. Nevertheless, answering each ensures a comprehensive filling cystometrogram (Table 9.2).

Cystometric Capacity

The International Continence Society defines three types of bladder capacity: functional, cystometric, and anesthetic (often referred to as anatomic) [20]. Functional capacity is defined as the intravesical volume when an individual voluntarily elects to urinate; it varies considerably based on multiple factors such as social context and proximity to a toilet. A study of 300 healthy women found a mean voided volume of 204 ml and an average maximum voided volume of 330 ml over a 1 day data collection. Nevertheless, the range of voided volume varied widely from 90–1020 ml [24]. A similarly designed study in 284 healthy men found a median voided volume of 237 ml and a median maximum voided volume of 382 ml [25]. In contrast to these values cystometric capacity tends to be higher in adults; it was 513 ml in a group of women without detrusor overactivity undergoing diagnostic urodynamic testing and 570–572 ml in a group of 30 healthy adult women undergoing sequential testing in a research setting [26, 27]. Cystometric capacity tends to be higher than functional bladder capacity because of the provocative nature of urodynamic testing. Patients are filled to a strong and persistent (imminent) desire to urinate, or until lower urinary tract symptoms such as urgency and urge incontinence are reproduced. This situation differs from the daily lives of patients with stress, urge or mixed urinary incontinence who tend to void at lower volumes in an attempt to prevent urinary leakage or involuntary voiding.

Whenever possible, cystometric capacity is calculated as voided volume plus residual volume. This technique is preferred over relying on the infused volume to determine capacity because of the renal contribution that occurs during provocative testing. A study of 186 adults undergoing

Table 9.2 Five questions for interpretation of the filling cystometrogram

Question	Normal range and cut point for clinically relevant abnormal finding	Effect of normal aging
(1) What is the cystometric capacity?	Normal range: 300–600 ml Cystometric capacity <300 ml often associated with detrusor overactivity, low bladder wall compliance, inflammation of the bladder wall Cystometric capacity >600 ml often associated with denervating disorders affecting lumbosacral spinal segments, metabolic disorders including diabetes mellitus and prolonged pattern of infrequent voiding	Functional bladder capacity does not decline with age [68]
(2) Is bladder wall compliance normal or low?	No absolute value for normal bladder wall compliance has been defined, whole bladder compliance values <10 ml/cm H_2O, sustained detrusor pressures ≥35 cm H_2O and detrusor leak point pressure ≥40 cm H_2O associate with urinary tract distress	No age related changes in bladder wall compliance have been observed [68]
(3) Is the urethral sphincter mechanism competent?	Any detectable abdominal leak point pressure (provoked by Valsalva maneuver or coughing) indicates urodynamic stress urinary incontinence; a negative pressure transmission ratio on cough-UPP indicates urodynamic stress UI A maximum urethral closure pressure <20 cm H_2O indicates intrinsic sphincter deficiency, an abdominal leak point pressure <60 cm H_2O assessed at 200 ml indicates intrinsic sphincter deficiency	Urethral sphincter incompetence (urodynamic stress UI) is not a component of normal aging Maximum urethral closure pressure declines with aging in healthy adult women [68]
(4) Are sensations of bladder filling normal reduced or increased?	First sensation of bladder filling, first desire to urinate and strong desire to urinate are found in healthy adult women subjected to urodynamic evaluation; they occur in a predictable order	Sensations of bladder filling diminish with age; the volume at which characteristic sensory thresholds increased 100 ml in a group of healthy women (mean age 55 years; range 22–90 years)
(5) What is the detrusor response to bladder filling?	No detrusor contractions during the filling cystometrogram is considered normal; some adults experience lower amplitude, phasic detrusor contractions that do not cause urgency or urge incontinence	Detrusor overactivity with urgency or incontinence is not a normal response of the aging bladder [68]

urodynamic testing found that all participants had higher voided plus residual volume than infused volumes; the mean renal contribution was 14% above infused volume [28]. Nevertheless, infused volume must be used when voided volume cannot be measured in the neurologically impaired or older adult unable to sit safely on a toilet for a voiding pressure flow study.

Large cystometric capacity is often accompanied by reduced sensations of bladder filling with or without incomplete bladder emptying. A large cystometric capacity is seen in multiple conditions affecting older adults such as diabetes mellitus and denervating disorders affecting lumbosacral spinal segments such as cauda equina syndrome or spinal stenosis [29, 30]. While supporting evidence is sparse, clinical experience strongly suggests that a lifelong pattern of infrequent voiding also increases bladder size. Voluntary restriction of voiding, often related to working in an environment when voiding is restricted such as a factory floor, long haul trucking industry, or health care profession may lead to a chronic pattern of less frequent voiding and increased bladder capacity [31]. Smaller cystometric capacity has been linked to inflammation of the bladder wall, detrusor overactivity, and low bladder wall compliance [32–35].

Bladder Wall Compliance

Compliance of the bladder wall is a measure of the relationship between detrusor pressure (Pdet) and intravesical volume during bladder filling and before the occurrence of a voluntary or overactive detrusor contraction [36, 37]. In the healthy person, Pdet remains at a comparatively stable and low value because of its ability to accommodate increasing intravesical volumes via its viscoelastic properties and low detrusor muscle resting tone. Low bladder wall compliance is characterized by a steady rise in Pdet during the filling cystometrogram. Bladder wall compliance can be assessed in several ways: pattern recognition, identification of pressure specific bladder volumes, and calculation of whole bladder compliance. Pattern recognition is used to "screen" for low bladder compliance. If visual inspection of the Pdet tracing during filling cystometry reveals a nearly flat slope, compliance is deemed normal. In contrast, if a steeper slope is visualized, low bladder compliance is suspected and further analysis is performed (Fig. 9.2). Low bladder wall compliance must be distinguished from overactive detrusor contractions [6]. Detrusor overactivity is characterized by a rapid rise in pressure caused by contraction of smooth muscle in the bladder wall, followed by a peak pressure (amplitude) and comparatively rapid decline to baseline (Fig. 9.3).

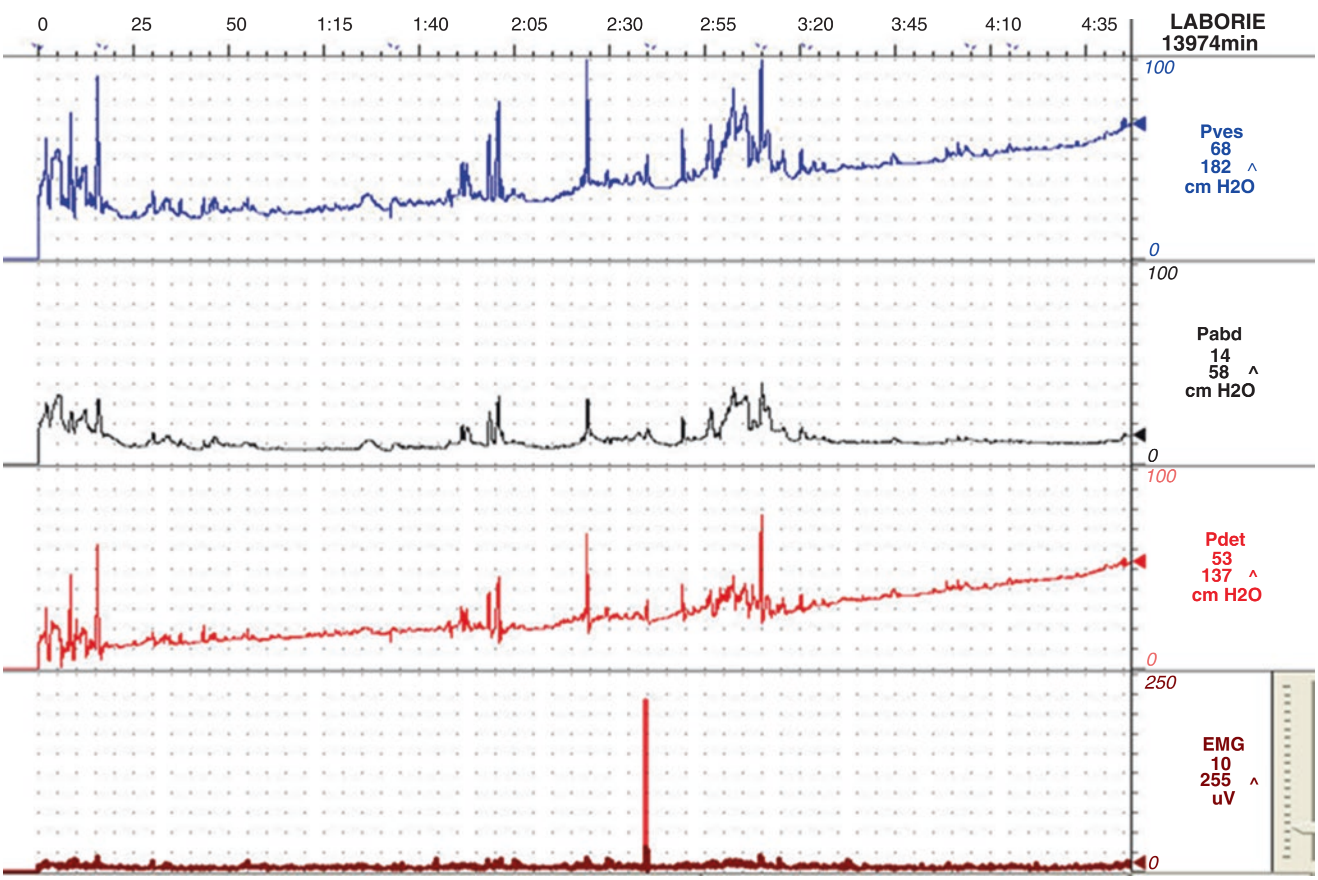

Fig. 9.2 Low bladder wall compliance with sustained pressure rises in Pdet tracing

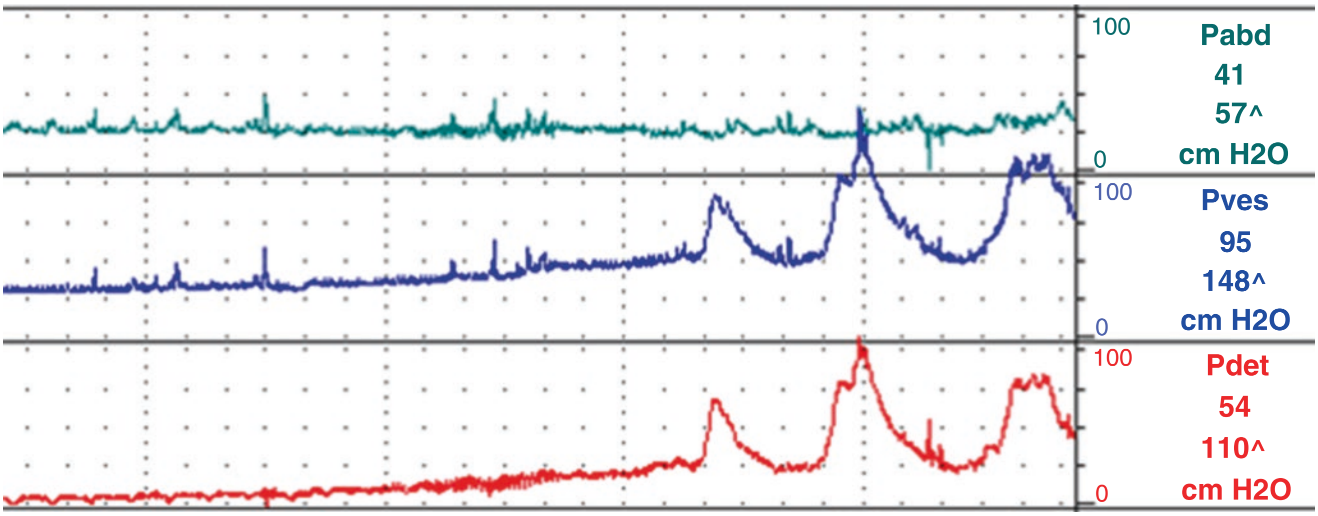

Fig. 9.3 Filling cystometrogram with low bladder wall compliance superimposed on phasic detrusor overactivity; note the rapid pressure rise of the overactive detrusor contractions as compared to the steady rise of Pdet characteristic of low bladder wall compliance

Identification of volume specific pressures is particularly relevant when determining the volume at which an individual can safely store urine; such knowledge is essential when determining the frequency of intermittent catheterization. One landmark study of bladder wall compliance evaluated 923 children with neurogenic bladders and 69 children with lower urinary tract complaints and normal urodynamic findings [38]. Children with normal urodynamic findings stored 95 % of intravesical volume at a Pdet <20 cm H_2O and 99 % at a Pdet <30 cm H_2O. Based on these findings, and observations of participants with lower bladder wall compliance, researchers concluded that a sustained Pdet ≤20 cm H_2O indicates normal bladder wall compliance. In contrast, a sustained Pdet of 21–30 cm H_2O indicates a low risk of urinary tract distress, and a sustained Pdet ≥35 cm H_2O indicates a high imminent risk of urinary tract distress (recurrent febrile urinary tract infections, vesicoureteral reflux, hydronephrosis, and/or compromised renal function). These findings are consistent with another landmark study of low bladder wall compliance in children with myelodysplasia. In this study a urodynamic outcome measure, the detrusor leak point pressure, was evaluated for its ability to predict urinary tract distress. The detrusor leak point pressure is the Pdet required for a low compliant bladder to overcome urethral closure and produce overflow urinary incontinence; study findings revealed that all subjects with a detrusor leak point pressures ≥40 cm H_2O had urinary tract distress [39].

Calculation of whole bladder compliance is a third alternative for measuring bladder wall compliance. It provides a single number designed to summarize the compliance curve during the entire filling storage phase of bladder function [6, 20, 37]. It is calculated using the formula: Compliance = infused volume/ΔPdet. Compliance is expressed as ml per cm H_2O; infused volume is the volume of fluid instilled at cystometric capacity, and ΔPdet is the difference in detrusor pressure at cystometric capacity immediately prior to the onset of a voluntary or overactive detrusor contraction minus Pdet at the beginning of filling. A cut point of ≤10 cm H_2O is used to identify clinically relevant low bladder wall compliance [6, 37]. Values indicating normal bladder wall compliance are less well defined; 40 ml/cm H_2O was identified as normal compliance in a group of adult women [6, 39, 40]. However, clinical experience overwhelmingly suggests that many patients have much higher values.

Low bladder wall compliance is clinically relevant because of its deleterious effects on urinary tract function [6, 38–41]. Low bladder wall compliance has been associated with diminished blood flow and histologic changes in the bladder wall [42]. It has also been associated with urinary tract distress, manifested as recurring febrile urinary tract infections, vesicoureteral reflux, hydronephrosis, and impaired renal function [6, 38, 39, 41, 43]. In the older adult, low bladder wall compliance is associated with neurological disorders such as spinal cord injury, multiple sclerosis, cauda equina syndrome, tethered spinal cord, and non-neurologic conditions including tuberculous cystitis, pelvic radiation, long-term interstitial cystitis, and chronic bladder outlet obstruction due to prostatic enlargement [35, 43–47].

Urethral Sphincter Competence

Stress urinary incontinence (UI) can be defined as a symptom, physical sign noted during physical assessment, or a medical diagnosis. The International Continence Society defines urodynamic stress UI as a urodynamic observation; it occurs when abdominal forces exceed urethral closure forces resulting in urinary leakage [20]. Urodynamic evaluation of urethral sphincter competence addresses two questions: (1) does this patient have urodynamic stress UI, and (2) does this patient have intrinsic sphincter deficiency (sometimes referred to as urethral sphincter incompetence or deficiency) [48]. Two urodynamic techniques are used to determine urethral sphincter competence: abdominal leak point pressure measurement and urethral pressure profilometry. The clinical relevance of the first question (does the patient have any stress UI) is apparent. The accurate identification of the type of incontinence is necessary since the surgical management of intrinsic sphincter deficiency differs from other forms of incontinence, and therefore may influence surgical outcomes [49].

The abdominal leak point pressure is defined as the magnitude of intravesical pressure required to overcome urethral closure and provoke urinary leakage in the absence of a detrusor contraction [20]. It should be measured in the upright (sitting or standing) position. The patient's bladder is filled to 200 ml, the fill is temporarily discontinued, and the patient is asked to perform Valsalva's maneuver with sufficient vigor to raise Pves at least 100 cm H_2O. The intravesical pressure at which leakage is observed is recorded and subtracted from the baseline intravesical pressure (Fig. 9.4) [45]. Any measureable value indicates urodynamic stress UI; in addition, an abdominal leak point pressure <60 cm H_2O indicates intrinsic sphincter deficiency [49]. While this strategy will provoke urodynamic stress UI in many women and men, additional maneuvers are often required to detect urodynamic stress UI without intrinsic sphincter deficiency. Therefore, when straining does not produce urine loss, the patient is asked to cough while observing for urine loss. Because of the very rapid pressure changes provoked by a cough, it is not possible to determine the precise abdominal leak point pressure using this technique. Instead, the maximum pressure produced with the cough when leakage is observed is recorded and the event is labelled "cough leak point pressure." If urodynamic stress UI is not produced using either maneuver, cystometric filling is continued and these maneuvers are repeated every 150–200 ml until cystometric capacity is reached. If none of these maneuvers produces stress UI, the intravesical catheter may be removed and Pabd is used as a proxy for Pves; this technique has also been recommended for routine investigation of men with stress UI following radical prostatectomy [50]. Removal of the intravesical catheter is recommend because it has been found to "unmask" subtle cases of urodynamic stress UI when the intravesical tube is removed from the urethra.

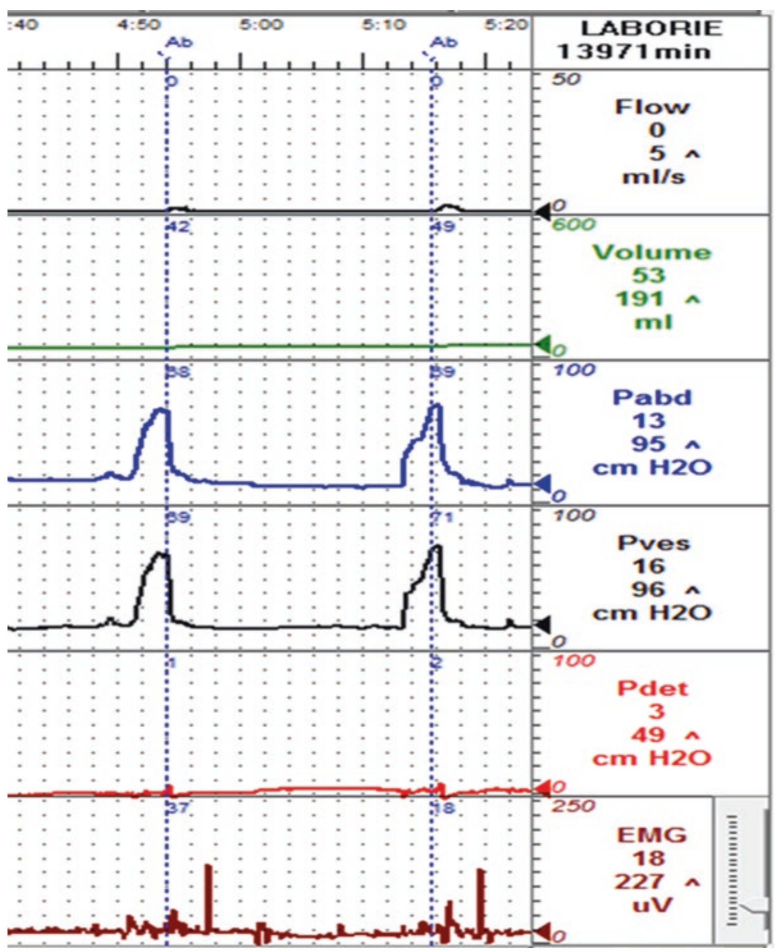

Fig. 9.4 Abdominal leak point pressure measurement demonstrating urodynamic stress urinary incontinence

The presence of severe pelvic organ prolapse (Pelvic Organ Prolapse Quantification System Stages 3 and 4) may obscure urodynamic stress UI [51]. In this case, reduction of severe prolapse using a gauze vaginal pack, ring pessary, or other maneuver is recommended to detect urodynamic stress UI that may be revealed when pelvic organ prolapse is repaired surgically.

Urethral pressure profilometry may also be used to assess urethral sphincter competence [48]. Unlike the abdominal leak point pressure, urethral pressure profilometry relies on direct assessment of urethral pressure (Pura), ideally combined with simultaneous measurement of intravesical pressure (Pves) and urethral closure pressure (Pclo), a computer generated tracing calculated by subtracting Pves from Pura. The technique for measuring urethral pressure presents unique challenges to the urodynamic clinician because of the narrow lumen of the urethra during bladder filling/storage and absence of a fluid medium in the urethra required for accurate pressure measurement. When measuring urethral pressures with water-charged transducers the clinician must create a small pocket of water by slowly perfusing water through the pressure monitoring line as it is pulled through the urethra. Measurement of Pura by a microtransducer does not require infusion of water; instead the catheter may be pulled through the urethra and pressures are recorded as the transducer interacts with the urethral wall. However, this technique is prone to artifact when the comparatively stiff catheter interacts with the urethral wall resulting in variable pressure readings depending on the orientation of the catheter [52]. The air-charged catheter creates a fluid environment via the small air filled balloon incorporated into the catheter. This design enables the catheter to be pulled through the urethra without significant discomfort. Since pressure is measured in a small fluid filled chamber, the artifact created by the microtransducer is eliminated.

A urethral pressure profile (UPP) is obtained by filling the bladder with 50–200 ml and slowly pulling the catheter through the urethra [48, 53]. Multiple parameters may be measured with the UPP including maximum urethral pressure, maximum urethral closure pressure, total profile length, and functional profile length. However, only one of these parameters, maximum urethral closure pressure, has proved useful for diagnosis of intrinsic sphincter deficiency [54]. A maximum urethral closure pressure <20 cm H_2O indicates intrinsic sphincter deficiency. While the UPP is useful for evaluation of urethral closure pressures, it is not a dynamic study and does not directly diagnose stress UI. In addition no cutoff point has been determined for the maximum urethral closure pressure (or any other parameter measured during the UPP) that reliably differentiates women with stress UI from those with a competent urethral sphincter mechanism [55]. These limitations can be overcome by combining a traditional UPP with a cough-stress UPP. The Cough-stress UPP is completed by asking the patient to cough individually as the catheter is slowly pulled through the urethra while measuring Pura, Pves, and Pclo. Individuals with competent urethral sphincter mechanisms (no stress UI) will have a positive pressure transmission ratio (upward spike seen on the Pclo tracing) while those with stress UI will have a negative pressure transmission ratio (downward spike seen on the Pclo tracing) (Fig. 9.5).

The predictive power of these tests for detection of any stress UI was measured in 108 women undergoing multichannel urodynamic evaluation [56]. Abdominal leak point pressure testing was determined to be most likely to reproduce any stress UI. Nevertheless, the evidence supporting use of a UPP for diagnosing intrinsic sphincter deficiency is stronger than that supporting use of the abdominal leak point pressure [54]. We therefore recommend completing both investigations when completing urodynamic testing in contemplation of surgical management of stress UI in the older adult.

Sensations of Bladder Filling

Assessment of sensations of bladder filling is particularly difficult in the context of multichannel urodynamic testing [57]. The presence of pressure monitoring lines in the bladder and rectal or posterior vaginal vault almost certainly alter sensations of bladder filling. This effect is further intensified by the clinical setting (the urodynamic suite) which bears little resemblance to the relative privacy of most toilets. Three sensations are commonly identified during the filling cystometrogram, the first sensation of bladder filling, first desire to void, and strong desire to void [58, 59]. The first sensation of the bladder is described as initial awareness of bladder filling, the first desire to void is characterized by a desire to urinate at the next convenient moment, and a strong desire is defined as a strong and persistent desire to urinate at the earliest possible time. These characteristic sensations have been shown to occur in a predictable sequence when filling cystometry is performed in healthy volunteers [59].

In addition to identifying these characteristic sensations of bladder filling, the urodynamic clinician should assess the patient for urgency and pain. Urgency is defined as a sudden and strong desire to urinate that cannot be deferred [20]. It is the main lower urinary tract symptom associated with overactive bladder syndrome. Urgency differs from physiologic "strong desire to void" in several important ways: (1) it is sudden and difficult to defer, (2) it may occur at any bladder volume and tends to occur at lower volumes ultimately reducing cystometric and functional bladder capacity, (3) it is associated with detrusor overactivity on urodynamic testing, (4) it is often associated with urge incontinence [60, 61].

Evaluation of lower urinary tract pain is also challenging; painful bladder syndrome is often misdiagnosed as chronic pelvic pain, vulvodynia, endometriosis, or overactive bladder [62]. While urodynamic testing plays a limited role in the

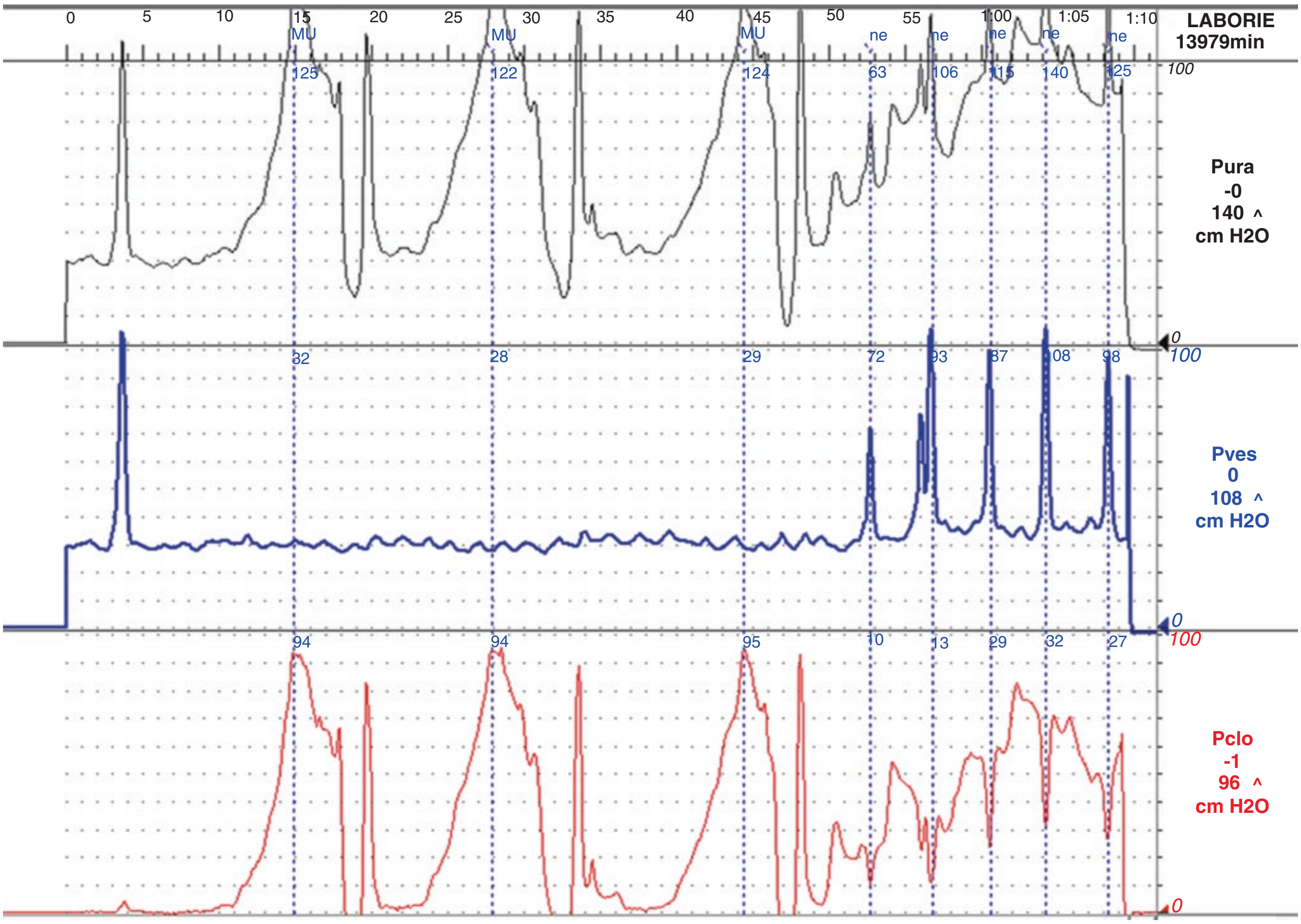

Fig. 9.5 Urethral pressure profile (UPP) demonstrating three maximum urethral closure pressure measurements varying from 94 to 95 cm H_2O and cough-stress UPP with negative pressure transmission ratios indicating urodynamic stress urinary incontinence

diagnosis of painful bladder syndrome, we have found that differentiation of urgency associated with fear of urinary leakage or incontinence from urgency associated with pain induced by bladder filling clinically relevant. A study of 214 patients found that that women with painful bladder syndrome/interstitial cystitis reported first sensation, first desire, and strong desire occurred at low volumes and were strongly associated with increased pain [32]. Nevertheless, this study did not associate pain with the symptom of urgency or with occurrences of detrusor overactivity. Further research is needed to establish the optimal approach for assessing the relationship between lower urinary tract pain to urinary urgency and detrusor overactivity in patients with chronic pelvic pain.

The ICS nomenclature committee has established multiple categories for summarizing sensations of bladder filling based on multichannel urodynamic testing [20]. Normal sensations of bladder filling are defined as awareness of the three characteristic sensory threshold events, first sensation to urinate, first desire to urinate, and strong desire to urinate. The term increased sensations of bladder filling is defined as an early and persistent desire to void (presumably sensations occurring at lower volumes). The description does not account for the patient who described a first sensation and first desire to void at a higher intravesical volume with urgency with or without urge incontinence. The term reduced sensations of bladder filling is defined as awareness of bladder filling but absence of a specific desire to urinate. The term absent sensations is described as no reported sensations of bladder filling. A newer term, non-specific sensations of bladder filling, is defined as absence of specific bladder sensations; this person instead reports "abdominal fullness, vegetative symptoms or spasticity." The vagueness of these categories of sensory reports reflects our limited understanding of the sensory function of the urinary bladder and lower urinary tract.

Detrusor Response to Bladder Filling

In the healthy adult, the detrusor remains in a relaxed state resulting in the characteristic flat line Pdet tracing seen on urodynamic testing. Detrusor overactivity is a urodynamic observation characterized by an involuntary detrusor contraction that occurs during the filling cystometrogram [20]. Detrusor overactivity causes urgency and/or urge incontinence characteristic of overactive bladder syndrome. The ICS nomenclature committee defines two types of detrusor overactivity, phasic and terminal. Phasic detrusor overactivity occurs as the bladder is filled and before permission to void is granted; it may cause urgency and urinary leakage but it occurs and subsides allowing additional filling until cystometric capacity is reached. In contrast, terminal detrusor overactivity is characterized by a single detrusor contraction that occurs before permission to void is granted; it terminates bladder filling and causes involuntary voiding.

Detrusor overactivity may also be categorized based on its underlying cause [20]. Urodynamic testing alone cannot differentiate neurogenic from idiopathic detrusor overactivity. Neurogenic detrusor overactivity occurs in a patient with an established diagnosis of a neurologic disorder or lesion affecting the central nervous system. Prevalent disorders of the brain associated with neurogenic detrusor overactivity in the older adult include Alzheimer's dementia, stroke, or Parkinson's disease. Persons with neurogenic detrusor overactivity on urodynamic testing usually experience associated symptoms of urgency and urge incontinence [63, 64]. Spinal cord disorders associated with neurogenic detrusor overactivity include spinal cord injury, disc problems, spinal cord tethering, and stenosis. Persons with spinal cord lesions or disorders may also experience reduced or absent sensations of bladder filling and detrusor-striated sphincter dyssynergia. These bladder conditions may lead to incomplete bladder emptying and related complications such as recurring urinary tract infections. Multiple sclerosis is a special case because the denervating lesions occur in multiple levels of the central nervous system resulting in a variety of urodynamic findings, including neurogenic detrusor overactivity; some persons will experience urgency and urge incontinence, while others may experience reduced or absent sensations of bladder filling, detrusor-striated sphincter dyssynergia, and incontinence without sensory awareness [64].

Voiding Pressure Flow Study

The voiding pressure flow study (VPFS) combines uroflowmetry with the pressures measured during the filling cystometrogram. It is considered the gold standard for evaluation of normal versus abnormal voiding caused by underactive detrusor function, bladder outlet obstruction, or a combination of these conditions [65, 66]. The VPFS is typically completed following the filling CMG. Patients with a normal detrusor response to bladder filling are asked to urinate when they perceive an imminent desire to void. Terminal detrusor overactivity causing bladder evaluation may be analyzed as a voiding pressure flow study only when the patient is given permission to void at the onset of the detrusor contraction; this maneuver is essential because it enables the patients and clinician to separate bladder storage from the voiding phase of a multichannel urodynamic evaluation [66]. An alternative to this approach when terminal detrusor overactivity occurs is to fill the bladder again to a lower volume and ask the patient to void voluntarily. Analysis of the VPFS focuses on three components: the urinary flow pattern, detrusor contraction strength, and urethral resistance. A synthesis of these components enables the clinician to differentiate a normal study from incomplete bladder evacuation caused by bladder outlet obstruction, underactive detrusor function, or a combination of these factors (Table 9.3).

Table 9.3 Elements of the voiding pressure flow study (VPFS)

Component of the VPFS	Normal range and cut point for clinically relevant abnormal findings	Effects of normal aging
Urinary flow pattern	Continuous flow pattern with Qmax >15 ml/s and Qave 50 % of Qmax is considered normal Lower residual volumes is considered normal; there is no absolute cut point for clinically relevant residual volume (consistent residual volumes >200 ml may indicate need for further evaluation) Qmax ≤15 ml/s is a cut point for distinguishing normal from prolonged or interrupted flow pattern	Q max declines significantly with aging in healthy adult women and men [66, 68] Residual volumes remained low in a group of 85 healthy women with and without detrusor overactivity, median residual volume 12 ml (IQR 0–14 ml) [68]
Detrusor contractility	Normal values have not been well defined; they vary according to age and gender Women tend to void with lower Pdet@Qmax than men	Detrusor contraction strength declines with aging [68]
Urethral Resistance	Values <20 on the ICS obstruction nomogram indicate no obstruction on women and men Values >40 on the ICS obstruction nomogram indicate higher magnitude obstruction in men Values >30 on the ICS obstruction nomogram indicated higher magnitude obstruction in women	Precise effect not well studied, urethral resistance tends to decline with aging in women and increase with aging in men
Pelvic floor muscle EMG response to voiding	Reflexive relaxation of the pelvic floor muscles and striated sphincter leads to reduction in EMG activity	No known effects of aging on EMG response

Pelvic floor muscle EMG is often measured during the VPFS. In the healthy adult, the striated sphincter and pelvic floor muscles reflexively relax during micturition, which is reflected in a reduction in EMG activity seen on the VPFS tracing [67]. In contrast, patients with detrusor-striated sphincter dyssynergia (discoordination between detrusor muscle and striated sphincter contractions seen in neurological lesions or disorders affecting spinal segments below the pontine micturition center and above the sacral micturition center) have increased EMG activity, usually accompanied by an interrupted flow pattern.

The events that characterize a normal voiding pressure flow study include relaxation of the pelvic floor muscles seen on EMG that occurs several seconds before onset of a detrusor contraction. Urinary flow begins when Pdet overcomes urethral resistance; this event is labelled urethral opening pressure. Flow continues until the detrusor contraction begins to fade; at some point during this process urinary flow stops and Pdet gradually declines until it returns to baseline [65, 66]. Some patients will experience a detrusor contraction after the bladder has emptied; the detrusor after-contraction presents as a strong and rapid rise in detrusor pressure occurring after bladder evacuation. The clinical relevance of the detrusor after-contraction is unknown (Fig. 9.6) [68, 69].

Visual Inspection of the Voiding Pressure Flow Study

Identification of the urinary flow pattern is based on the same categorization schema used to interpret a prestudy or standalone uroflow study. A continuous flow pattern in the healthy adult resembles a bell shaped curve that tends to be skewed slightly to the left; Qmax should be ≥15 ml/s in men and often

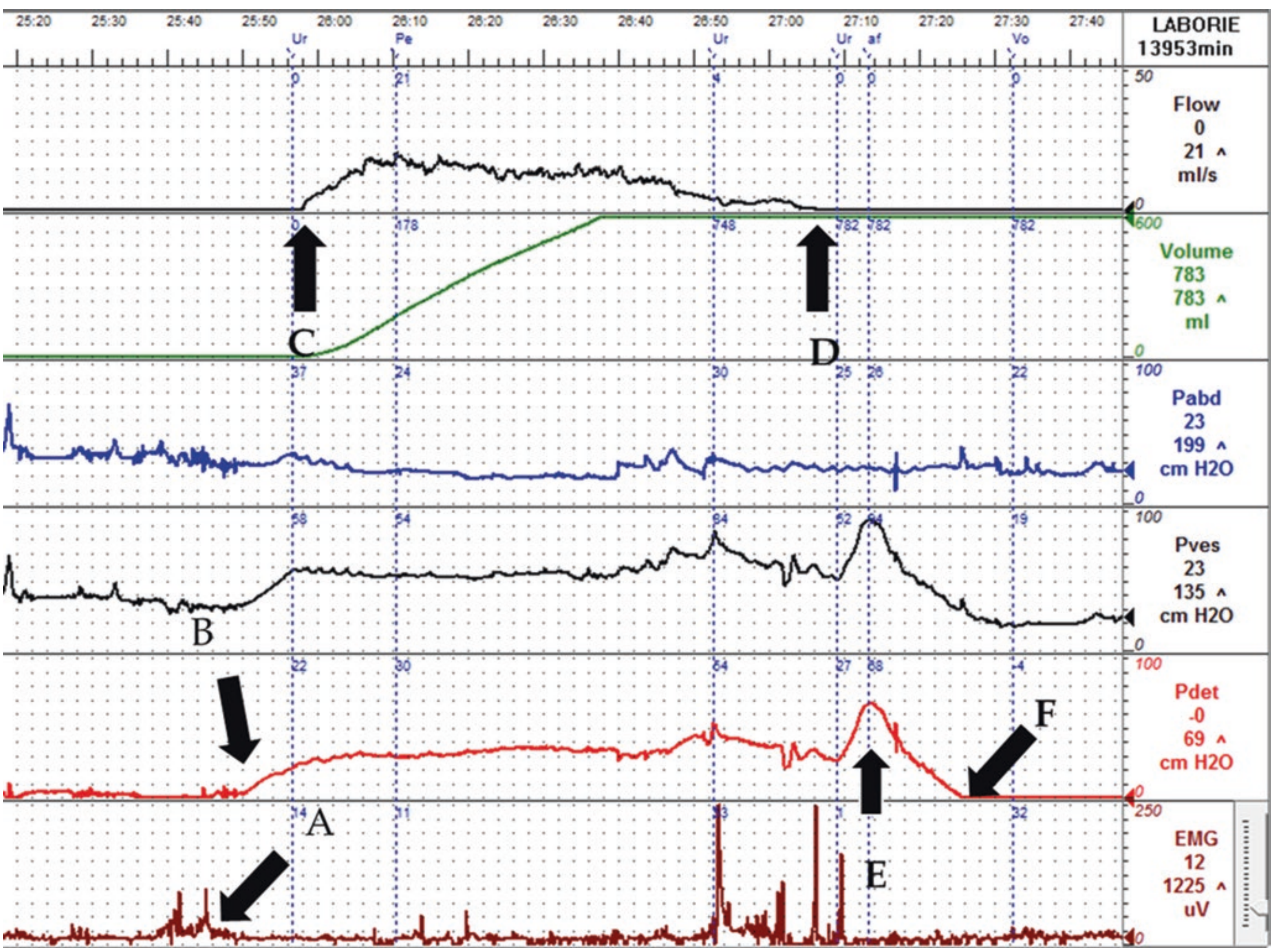

Fig. 9.6 Characteristic events of a normal voiding pressure flow study. (*A*) Relaxation of striated sphincter with reduction in pelvic floor EMG activity. (*B*) Onset of detrusor contraction, (*C*) Urethral opening pressure is reached with onset of flow. (*D*) Termination of Flow. (*E*) Detrusor after-detrusor contraction occurs after bladder evacuation. (*F*) Detrusor pressure returns to baseline

higher in women and Qave should be 50 % of Qmax. A prolonged flow pattern remains continuous (without interruption) but its Qmax is <15 ml/s. An interrupted (intermittent) urinary flow pattern starts and stops more than once during micturition; Qmax may be >15 ml/s but Qave will be <50 % of the maximum flow rate. However, unlike this screening study, analysis of the flow pattern during the VPFS is combined with evaluation of the detrusor contractility and urethral resistance in order to determine the cause of an abnormal flow pattern.

Urodynamic evaluation of detrusor contractility begins with assessment of the amplitude and duration of the Pdet tracing during voiding. Ultimately, this assessment is combined with analysis of the flow pattern and urethral resistance. Because of the invasive nature of the VPFS, few studies have been completed in otherwise healthy adult women and men. A study of 24 healthy women revealed an average maximum detrusor voiding pressures (Pdet@Qmax) of 29 cm H_2O in women aged 22–39 years, a mean Pdet@Qmax of 26 cm H_2O in women aged 45–53 years of age and a mean Pdet@Qmax of 24 cm H_2O in women aged 55–80 years [70]. A study of 33 healthy adult men aged 18–44 years of age revealed a mean Pdet@Qmax of 53 cm H_2O [71]. Because of variability in urethral resistance in adult women and men of varying ages, no single cut point for a Pdet@Qmax indicating bladder outlet obstruction or underactive detrusor function has been determined; instead, detrusor contractility must be evaluated in the context of flow pattern and urethral resistance.

Urodynamic evaluation of urethral resistance is based on a comparison of urinary flow and detrusor pressure. These relationships can be assessed qualitatively by inspection of the urinary flow and Pdet at maximum or minimum flow, or it can be quantitatively evaluated via a voiding pressure nomogram. Adult women have a shorter and straighter urethral course than do adult men. As a result, they tend to urinate with a higher Qmax and lower Pdet@Qmax than do men [70]. Adult men have a more torturous urethral course that passes through the prostate, as a result they tend to void with a lower Qmax and higher Pdet@Qmax [71]. This difference is more apparent in aging men who experience benign prostatic enlargement and increased urethral resistance versus aging women who experience a reduction in urethral resistance measured on a UPP [72, 73].

Bladder outlet obstruction is diagnosed on the VPFS when urethral resistance is increased due to an anatomic or functional increase in urethral resistance; this event causes a rise in detrusor contraction pressures as the lower urinary tract attempts to maintain urinary flow and ensure complete bladder evacuation (Fig. 9.7). Functional bladder outlet obstruction

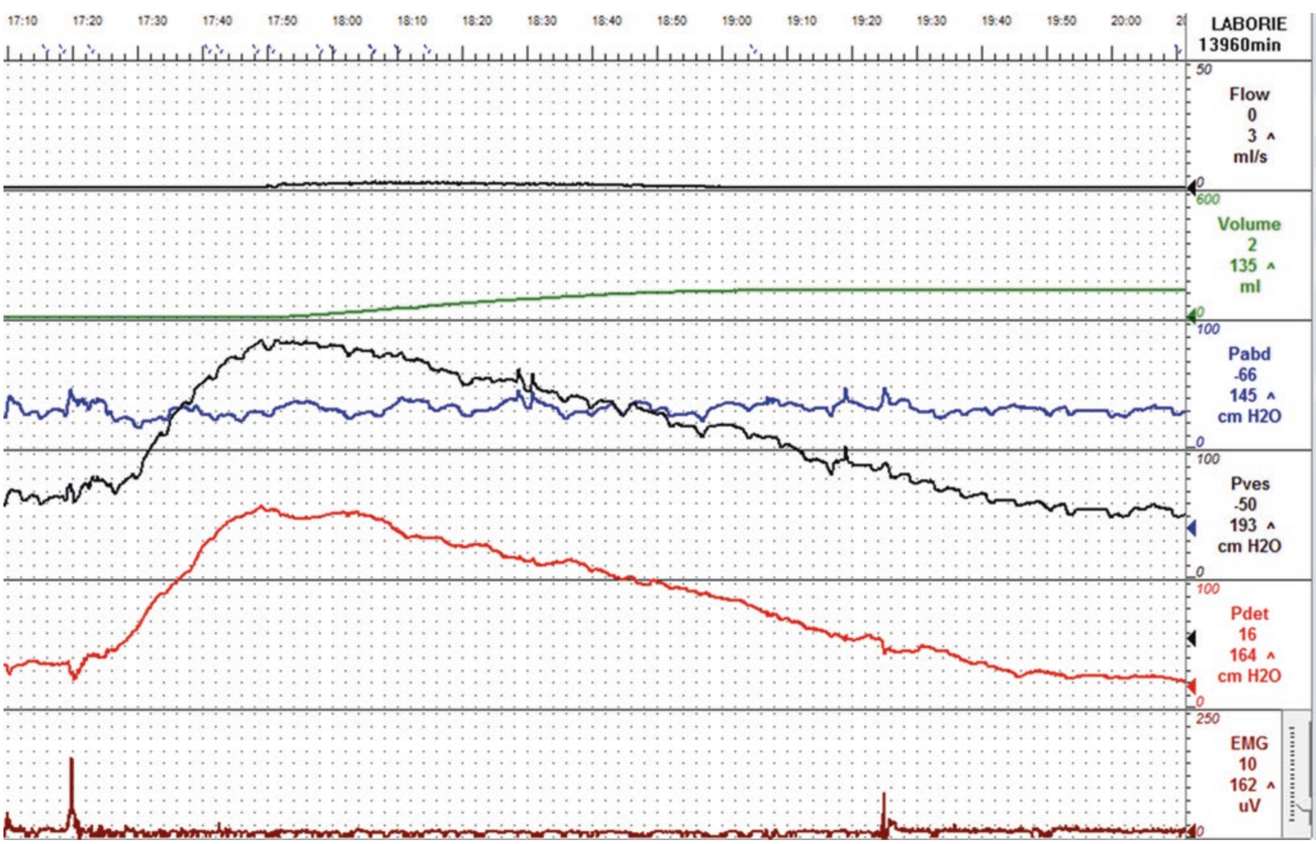

Fig. 9.7 Voiding pressure flow study demonstrating prolonged flow pattern and high detrusor contraction pressure characteristic of bladder outlet obstruction. Sphincter EMG response to voiding is normal; obstruction in this 78-year-old male was caused by benign prostatic enlargement

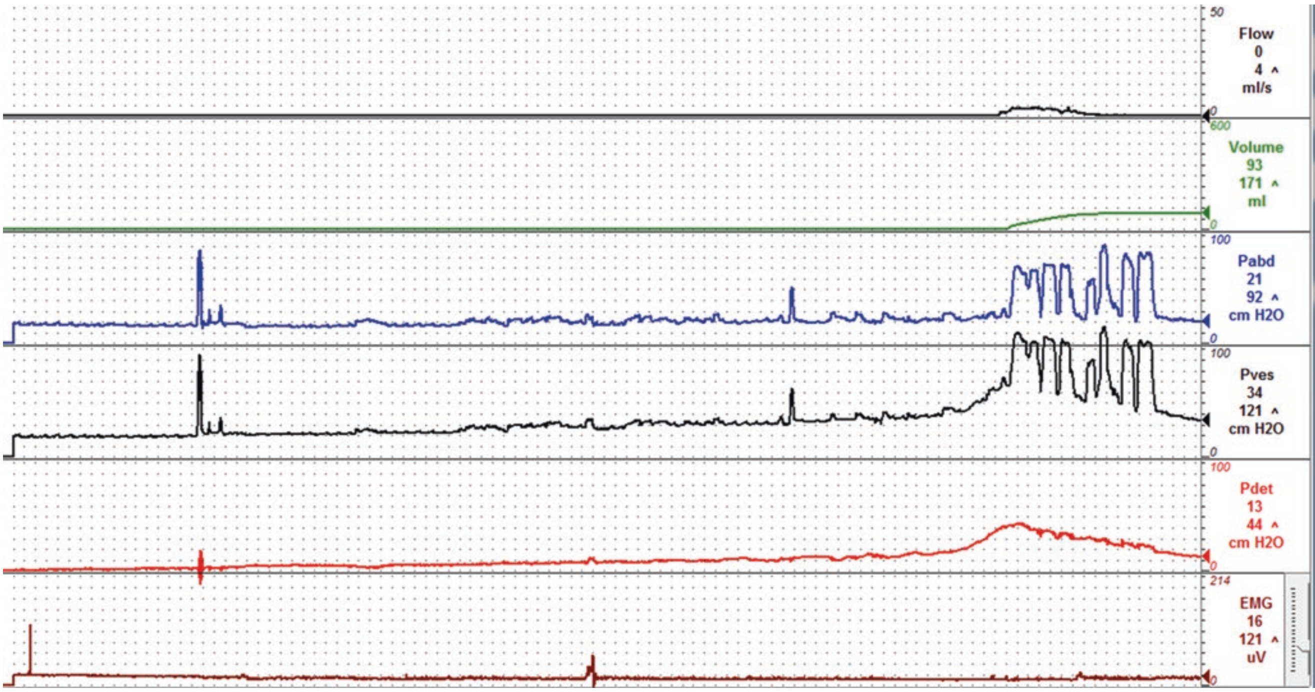

Fig. 9.8 Voiding pressure flow study demonstrating prolonged flow pattern and low detrusor contraction pressure characteristic of underactive detrusor function in a 67-year-old male with spinal stenosis. He attempts to augment bladder emptying with abdominal straining noted in intravesical and abdominal pressure tracings

associated with detrusor-striated sphincter dyssynergia may be diagnosed when pelvic floor EMG is monitored during the VPFS; it is more likely to produce an interrupted/intermittent urinary stream as the striated sphincter and periurethral muscles contract and relax in an uncoordinated manner during micturition. Underactive detrusor function is characterized by a prolonged flow pattern combined with a lower detrusor contraction pressures (Fig. 9.8).

A number of pressure flow nomograms have been developed that provide a more quantitative analysis of urethral resistance and detrusor contractility. The most widely used in urodynamic testing are the ICS nomogram and the linear passive urethral resistance relationship (linPURR) nomogram [74]. The ICS nomogram measures urethral resistance by comparing Qmax and Pdet@Qmax; the resulting ICS obstruction number (also referred to as the urethral resistance algorithm, URA) is used to describe the magnitude of obstruction; values <20 indicate no clinically relevant obstruction, values from 20 to 40 indicate equivocal (lower magnitude) obstruction and values >40 indicate higher magnitude obstruction [75]. Values from this nomogram have been extrapolated for clinical use in women; a single cut point of 20 was used to differentiate clinically relevant bladder outlet obstruction from normal urethral resistance in women [76]. The linPURR nomogram compares Pdet at minimum flow to evaluate urethral resistance; it divides obstruction into seven grades (0–VI) [75]. This nomogram also allows assessment of detrusor contractility, which is divided into six categories ranging from very weak to strong. Similar to the ICS nomogram, it was developed and validated in a group of older men with obstruction related to benign prostatic enlargement. It has not been adapted for use in adult or aging women. An ICS composite nomogram has been developed that merges the ICS obstruction nomogram (describe above) and the ICS bladder contractility nomogram; this composite nomogram allows categorization of patients into nine zones reflecting the complex relationship of bladder outlet obstruction and detrusor contractility [77, 78].

Multichannel Urodynamic Testing in the Aged Adult: Case Examples

The American Urological Association (AUA) and Society for Urodynamics and Female Urology (SUFU) have generated a clinical practice guideline for urodynamic testing in adults [79]. Several principles are particularly useful when considering indications for multichannel urodynamic testing in adults. The following cases review scenarios where multichannel urodynamic testing provided clinically useful information in the evaluation of an elderly patient with complex lower urinary tract dysfunction.

Case 1: Multichannel Urodynamic Testing in a 75-Year-Old Female with Mixed Urinary Incontinence Symptoms

Mrs. A is a 75-year-old woman who complains of mixed urinary incontinence, along with weak urinary steam and feeling of incomplete bladder emptying. She also complains of constipation and a bulging sensation of the vaginal area. Recent pelvic examination reveals severe vaginal wall prolapse (Pelvic Organ Prolapse Quantification System Stage 4), defined as eversion of the vaginal wall ≥2 cm. Multichannel urodynamic testing was performed in contemplation of surgical repair of pelvic organ prolapse and stress urinary incontinence. Filling cystometry revealed a cystometric capacity of 428 ml, and normal bladder wall compliance (whole bladder compliance: 75 ml/cm H_2O). No stress UI was observed when provoked at 200 ml; a vaginal pack was inserted to reduce her cystocele; she then experienced stress UI with an abdominal leak point pressure of 64–68 cm H_2O (Fig. 9.9). Urethral pressure profilometry shows maximum urethral closure pressures of 22–24 cm H_2O; cough-stress UPP showed negative pressure transmission ratio indicating stress UI. Sensations of bladder filling were normal and no detrusor overactivity was observed on urodynamic testing. Voiding pressure flow study was completed after vaginal pack had been removed; it revealed prolonged flow pattern with Qmax of 12 ml/s and Qave of 5 ml/s and her Pdet@Qmax was high at 84 cm H_2O. In this case, urodynamic testing revealed urodynamic stress UI that was apparent only after her vaginal wall prolapse had been reduced. No evidence of urge incontinence (increased sensations of bladder filling with or without detrusor overactivity). Voiding pressure flow study was consistent with bladder outlet obstruction probably attributable to her cystocele.

The AUA/SUFU guideline task force noted that urodynamic testing is not indicated for routine evaluation of all adults with stress or urge incontinence [79]. However, testing is recommended for selected patents with mixed urinary incontinence when considering invasive, potentially morbid, or irreversible treatments. Testing was ordered for Mrs. A because she desired surgical repair of her vaginal prolapse. Guideline statements recommend filling cystometry to identify detrusor overactivity or low bladder wall compliance, along with assessment of urethral function. Filling cystometry revealed normal bladder wall compliance, normal sensations

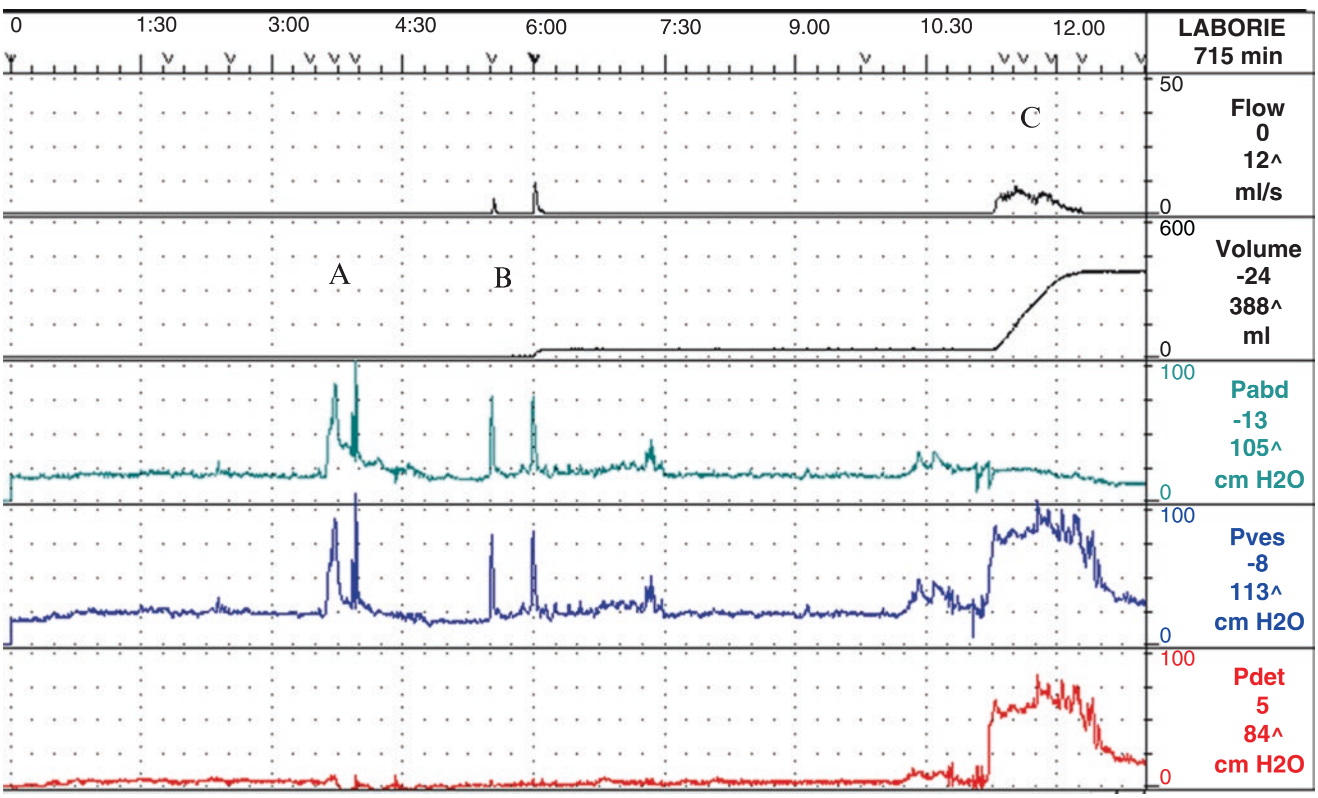

Fig. 9.9 Filling cystometrogram and voiding pressure flow study in a 75-year-old female with mixed urinary incontinence symptoms and pelvic organ prolapse. (*A*) No leakage when abdominal leak point pressure measured without reduction of vaginal wall prolapse. (*B*) Urodynamic stress urinary incontinence when abdominal leak point pressure testing repeated with vaginal wall prolapse reduced. (*C*) Voiding pressure flow study showing prolonged flow pattern and elevated detrusor contraction pressure indicating bladder outlet obstruction associated with severe vaginal wall prolapse

of bladder filling and no detrusor overactivity. Urethral function was evaluated via urethral pressure profilometry and abdominal leak point testing; both demonstrated urodynamic stress UI but neither found evidence of intrinsic sphincter deficiency. Mrs. A underwent anterior repair and sacrocolpopexy for pelvic organ prolapse and placement of a suburethral sling for her stress UI. She reported resolution of stress UI and improvement in the force of her urinary stream.

Case 2: Urodynamic Testing in a 90-Year-Old Male with Urinary Retention Requiring Twice Daily Intermittent Catheterization Despite Transurethral Prostate Photovaporization 7 Years Ago

Mr. B is a 90-year-old gentleman with urinary retention requiring intermittent catheterization twice daily. He underwent transurethral resection of prostate using photovaporization 7 years prior to referral for urodynamic testing. Mr. B initially noted marked improvement in the force of his urinary stream and reduction of nocturia from 5 to 3 episodes per night. He reports increasing difficulty urinating over the past year and was found to have a 560 ml residual 1 month ago prompting initiation of intermittent catheterization twice daily (morning and before sleep) and urodynamic evaluation for possible repeat transurethral prostate resection. In addition to his difficulty emptying his bladder, Mr. B reports urgency and urge incontinence requiring absorptive briefs when away from his home. Multichannel urodynamic testing demonstrated a cystometric capacity of 407 ml and normal bladder compliance (whole bladder compliance was 129 ml/cm H_2O) (Fig. 9.10). Terminal detrusor overactivity occurred at a volume of 388 ml. He was given permission to urinate which revealed prolonged flow pattern with Qmax 6 ml/s and a Qave of 2 ml/s. His voided volume was 88 ml and his residual volume was 319 ml. Detrusor pressure at maximum flow was 15 cm H_2O and the

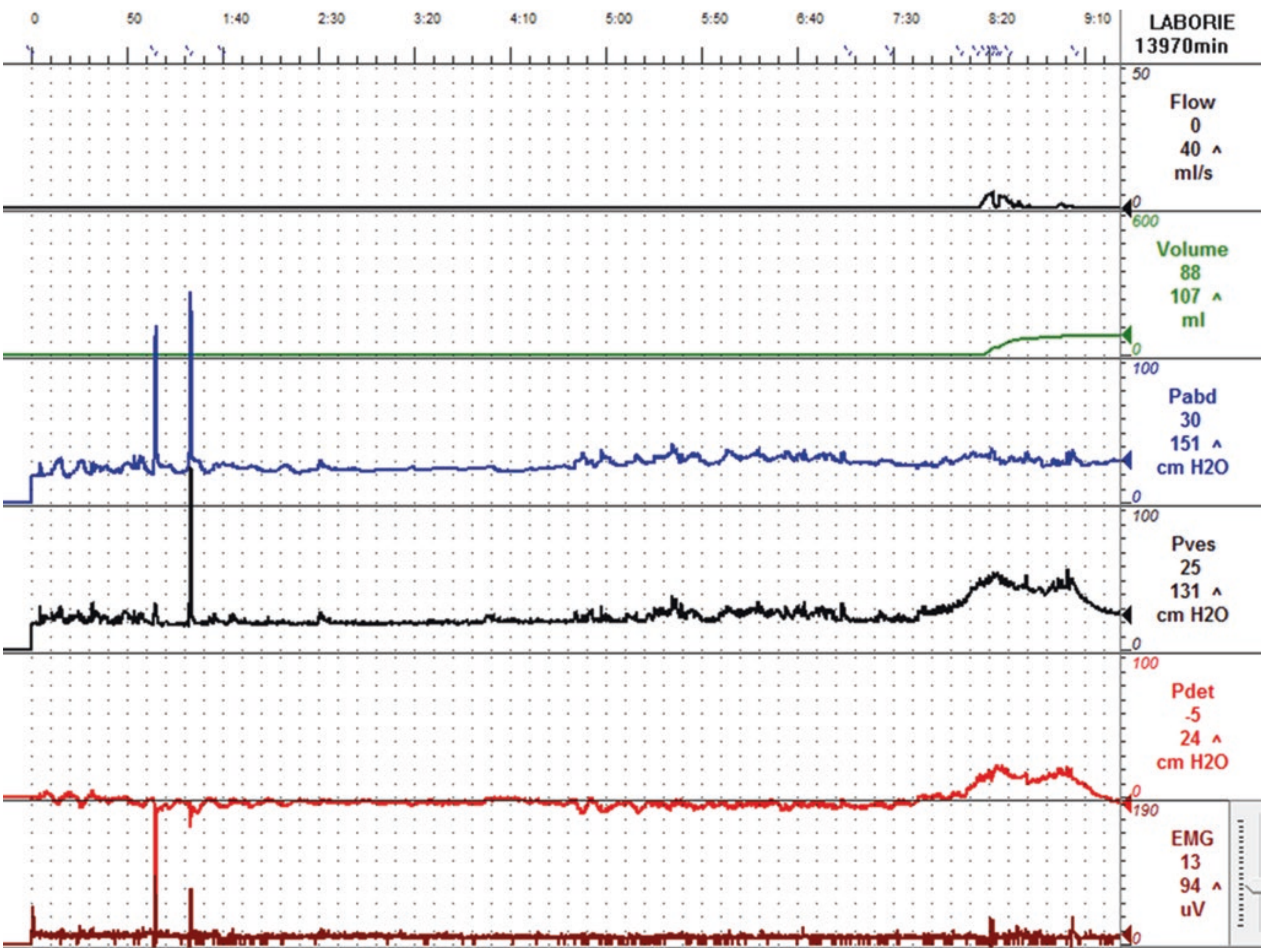

Fig. 9.10 Filling cystometrogram and voiding pressure flow study in a 90-year-old male with urinary retention managed by intermittent catheterization twice daily and urge incontinence. Voiding pressure flow study shows underactive detrusor contraction without bladder outlet obstruction

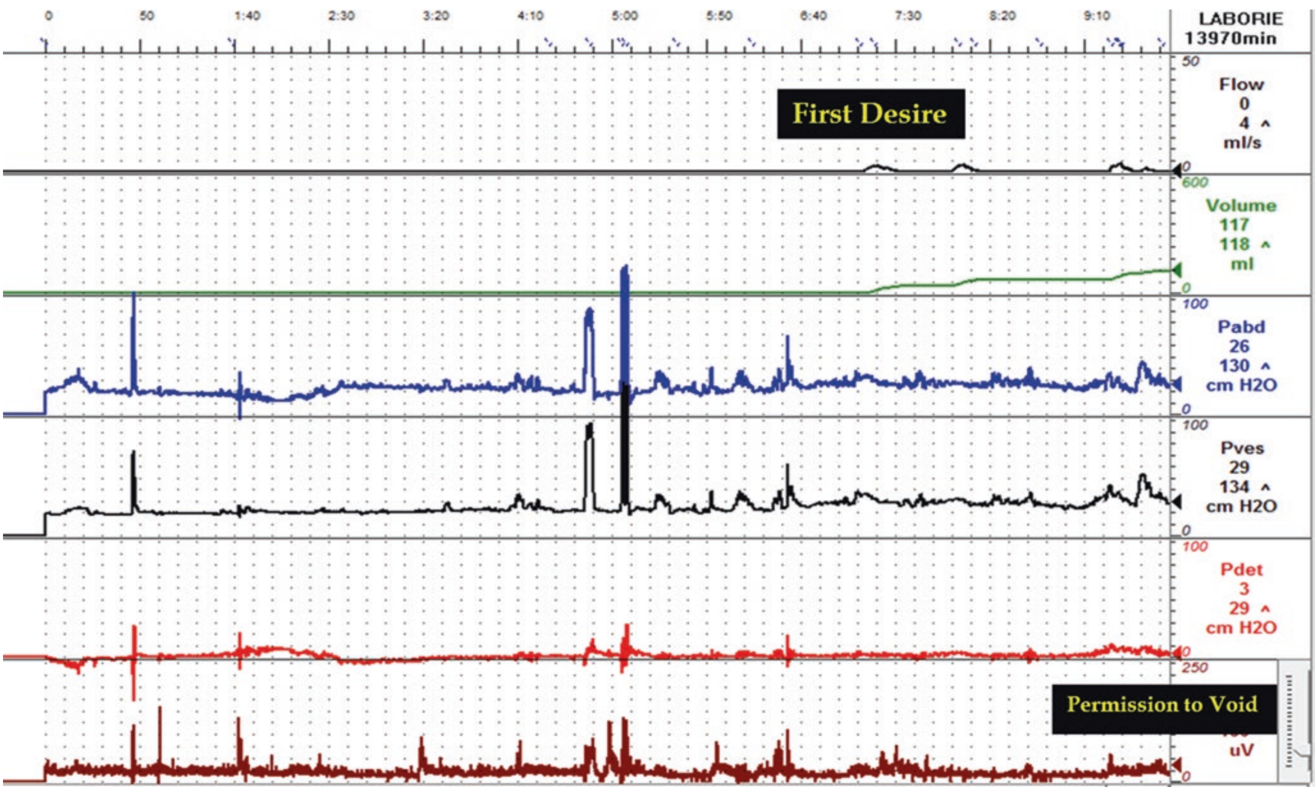

Fig. 9.11 Filling cystometrogram in an 89-year-old female with detrusor hyperreflexia with impaired contractile function

ICS obstruction nomogram revealed a URA of 12, indicating no clinically relevant bladder outlet obstruction.

The AUA/SUFU guidelines recommend VPFS to determine bladder outlet obstruction in men with lower urinary tract symptoms when invasive, potentially morbid, or irreversible treatment is considered. In this case, Mr. B was found to have no evidence of obstruction; instead, his incomplete bladder emptying was related to underactive detrusor function and repeat transurethral prostate resection was deemed inappropriate in the absence of obstruction. Catheterization frequency was increased to 4 times daily which reduced the frequency of daytime voiding and urge incontinence episodes.

Case 3: Detrusor Overactivity Combined with Underactive Detrusor Function (Impaired Contractility) in an 89-Year-Old Female

Mrs. D is an 89-year-old female with mild Alzheimer's disease who is brought in by her husband and daughter, who are her caretakers. They are for concerned for worsening urinary incontinence requiring use of adult briefs and recurring urinary tract infections. The patient has been hospitalized several times due to episodes of worsening confusion during UTIs. The patient is ambulatory with minimal assistance. Her medication list is only significant for donepezil. Multichannel urodynamic testing was performed to distinguish the cause of her incontinence and how this may relate to her recurrent infections. As seen in Fig. 9.11, cystometric capacity was 118 ml with a normal compliance. She has reduced sensation of bladder filling. During filling phase she had two low amplitude detrusor contractions with associated urgency and small volume urge incontinence. With permission to void her Pdet was 10 cm H_2O at a Qmax of 4 ml/s, indicating poor contractility. Her post void residual was 150 ml. This patient shows a common finding in elderly patients, detrusor hyperreflexia with impaired contractile function (DHIC). This condition is hypothesized to represent an advanced form of overactive bladder in which the detrusor has deteriorated over time resulting in an underactive bladder [80, 81]. Patients with DHIC in prospective observational study have been shown to have higher rates of urinary retention and recurrent cystitis than those with detrusor overactivity and preserved contractility [82].

Key Points

- Urodynamics is a set of tests used to measure lower urinary tract function and dysfunction; the most commonly employed tests are uroflowmetry, filling cystometrogram, voiding pressure flow study, and post void residual measurement.
- The prestudy uroflowmetry is a screening test; it is used to differentiate a normal (continuous) from abnormal (prolonged or interrupted) flow pattern but it cannot be used to determine the underlying cause of abnormal results.
- The filling cystometrogram is used to evaluate bladder filling/storage; however, normal cystometric capacity is usually higher than functional bladder capacity because it is intended to reproduce bothersome lower urinary tract symptoms.
- Urethral sphincter competence can be assessed by abdominal leak point pressure measurements; any detectable abdominal leak point indicates urodynamic stress urinary incontinence and if >60 cm H_2O, also indicates intrinsic sphincter deficiency.
- Detrusor overactivity is the occurrence of any detrusor contractions during the filling cystometrogram; this urodynamic finding is strongly associated with urgency and urge incontinence characteristic of overactive bladder dysfunction.
- Analysis of the voiding pressure flow study enables differentiation of normal micturition from abnormal flow with or without incomplete bladder emptying associated with underactive detrusor function or bladder outlet obstruction.
- Age related changes measured in healthy women include reduced sensations of bladder filling, reduced detrusor contraction strength, and reduced urethral closure pressures in women.
- Reduced bladder capacity is not seen in healthy older adults; it does occur in adults who also have detrusor overactivity.
- Multichannel urodynamics is useful for measurement of lower urinary tract dysfunction when considering invasive or potentially irreversible interventions.

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