Evaluation of Voiding Dysfunction and Measurement of Bladder Volume

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When evaluating patients with voiding dysfunction, noninvasive tests such as uroflowmetry and measurement of postvoid residual urine volume (PVR) can help to determine whether additional testing is warranted. PVR can be measured by 2 methods: catheterization or bedside bladder ultrasonography. Although both methods have advantages, the convenience, efficiency, and safety of bladder ultrasound makes its use beneficial in a wide variety of populations, including hospitalized patients, children, and the elderly. More recently, bladder ultrasound has been used for other procedures, such as suprapubic aspiration, evaluation of intravesical masses, and to determine bladder wall thickness and bladder wall mass, both of which have been associated with outflow obstruction.

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When evaluating patients with lower urinary tract symptoms (LUTS), it is often helpful for clinicians to characterize the potential urinary problem as a storage disorder, voiding disorder, or a combination of both. It is not uncommon for abnormalities of the voiding phase to cause problems in the storage phase, for example, the occurrence of bladder overactivity with bladder outlet obstruction (BOO).

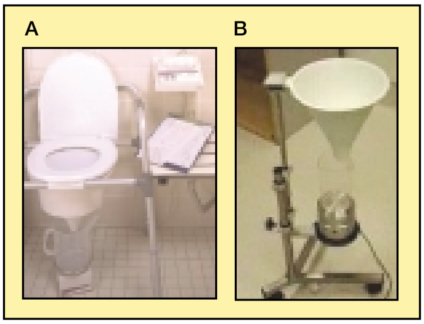

Figure 1. *Example of a load cell uroflowmetry device. Flowmeters can be* (A) *conveniently positioned beneath a commode or* (B) *free-standing to accommodate a patient's typical voiding position.*

The evaluation of a patient with LUTS consists of a detailed medical history taking; administration of a patient-driven questionnaire, such as the American Urological Association Symptom Index; and a genitourinary examination, including a pelvic examination in women or a digital rectal examination in men. Laboratory tests considered standard by most guidelines are urinalysis and serum creatinine measurement, which can be used to assess for urinary tract infections (UTIs) and renal function, respectively. Additional tests include urinary cytology to screen for carcinoma in situ of the urothelium. When considering a prostate-specific antigen measurement, the clinician should take into account the patient's age, life expectancy, and intent to treat.

Uroflowmetry

Uroflowmetry can serve as a noninvasive screening test for selecting patients who should undergo more sophisticated urodynamic studies. The market offers an array of uroflowmeters, each with its own advantages and disadvantages: weight transducers (load cells) (Figure 1), displaced air transducers, and spinning disc flowmeters. The load cell is the most widely used system, mainly because it is accurate, durable, and relatively inexpensive.

Uroflowmetry measures urine voided per unit time, which is usually expressed as milliliters per second. The International Continence Society has standardized certain objective measurements to be recorded during uroflow measurement.[1] These include flow pattern, voided volume, maximum flow rate (Q_{max}), voiding time, and time to maximum flow (Figure 2). However, flow pattern, Q_{max}, and volume voided generally are regarded to be the most clinically useful for both screening and following patients.

Several flow patterns have been described that typify normal flow, obstructive flow, detrusor impairment, "Valsalva voiding," and urine flow soon after a de-obstructive bladder outlet procedure (superflow) (Figure 3). The Q_{max} is helpful in distinguishing those who have BOO from those who do not. The following cutoff values for Q_{max} are widely accepted: rates greater than 20 mL/s indicate a low probability of BOO; rates between 15 mL/s and 20 mL/s indicate a low probability of BOO (but symptomatic patients should be considered for urodynamic studies); rates between 10 mL/s and 15 mL/s are equivocal; and rates less than 10 mL/s are often the result of BOO or detrusor impairment.[2]

Because uroflow is partly dependent on volume voided, uroflowmetry nomograms, such as the Siroky, the Bristol, the Liverpool, and the Balslev-Jorgensen nomograms, are useful in distinguishing normal from abnormal flow rates. The Siroky nomogram is the most widely used in the United States today, but its specificity and sensitivity in diagnosing BOO are mixed (30% and 91%, respectively).[3] In fact, uroflowmetry alone is insufficient to diagnose BOO, because it cannot distinguish true obstruction from poor bladder contractility. The strength of uroflow is in helping to identify patients who need further urodynamic studies to diagnose an underlying problem.

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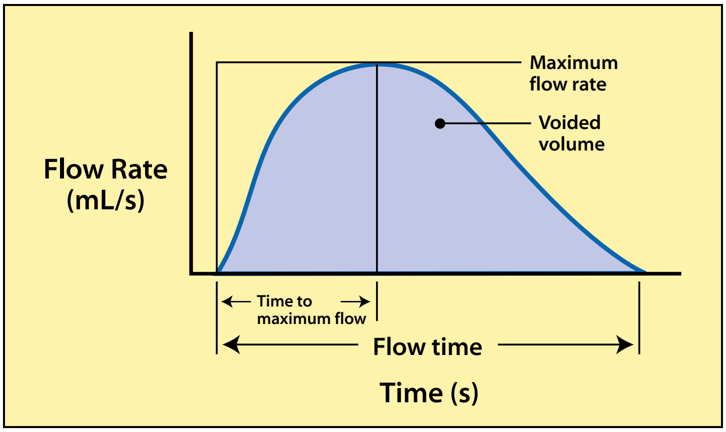
Postvoid Residual Urine Volume

Measurement of postvoid residual urine volume (PVR), the amount of residual urine in the bladder after a voluntary void, is another noninvasive screening test for evaluating voiding

Figure 2. *Schematic of a normal uroflow curve with International Continence Society–recommended terminology.*



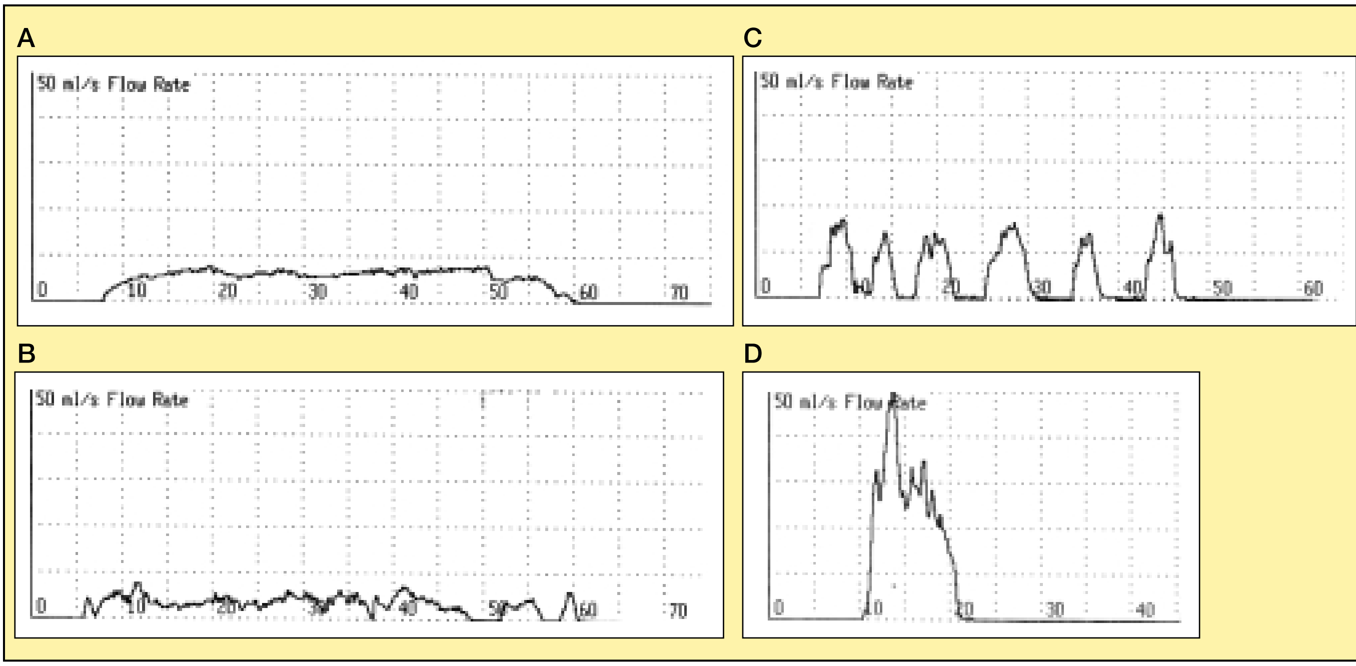


Figure 3. *Typical uroflow patterns of common voiding disorders:* (A) *obstructive, or "breadloaf," pattern;* (B) *detrusor impairment pattern;* (C) *Valsalva voiding pattern; and* (D) *superflow pattern. Voided volumes should be greater than 150 mL; volumes less than 150 mL can result in misinterpretation. Differentiating between patterns A and B can be challenging. A more precise diagnosis can be achieved with a pressure-flow study, a component of urodynamics.*

dysfunction. Like uroflowmetry, PVR measurement helps to identify patients in need of further evaluation and to evaluate treatment effect during follow-up. Threshold values delineating what constitutes an abnormal PVR are poorly defined. However, most urologists agree that volumes of 50 mL to 100 mL constitute the lower threshold defining abnormal residual urine volume. Large PVRs are associated with UTIs, especially in persons at risk, such as children or patients with spinal cord injury or diabetes. Very large PVRs (>300 mL) may be associated with an increased risk of upper urinary tract dilation and renal insufficiency.

High PVRs can be caused by BOO, bladder hypocontractility or acontractility or, in rare cases, a large bladder diverticulum (Figure 4). BOO can stem from prostatic enlargement, poor sphincter relaxation (dyssynergia), urethral or meatal blockage, or less common causes, such as a bladder stone. Poor bladder contractility can result from neurogenic, myogenic, psychogenic, or pharmacologic causes.

PVR Measurement

There are 2 methods of measuring PVR: sterile catheterization and bladder ultrasound. Although sterile catheterization provides a urine sample, there are many disadvantages associated with the procedure: it causes patient discomfort, carries a risk of urethral trauma and UTI, is time-consuming, and may not be necessary. In contrast, bladder ultrasound can be performed with a portable device, is noninvasive and time-efficient, minimizes medical waste and supplies, and determines when catheterization is medically appropriate; however, no urine specimen is obtained during this procedure.

Portable 3-dimensional ultrasound

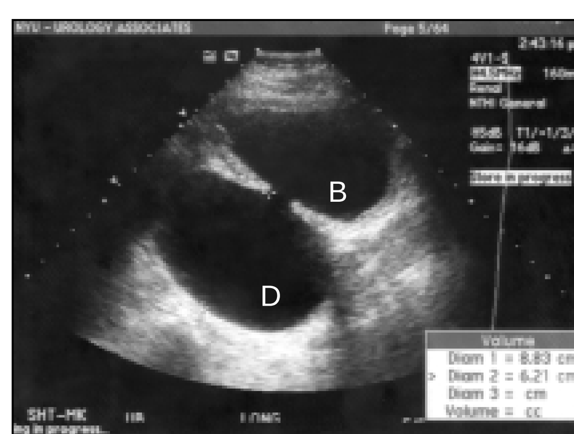


Figure 4. *Large bladder diverticulum (D) can be diagnosed as an elevated postvoid residual urine volume (PVR) on ultrasound. Bladder diverticula are a less common cause of elevated PVRs; they may be congenital but more commonly result from bladder outlet obstruction. B, bladder.*

devices have been shown to provide highly accurate measurement of bladder volume. Coombes and Millard[4] compared the BladderScan™ BVI 2500 series (Diagnostic Ultrasound, Bothell, Wash) with catheterization for the measurement of bladder volume. Study results demonstrated no significant difference between estimates made with the BladderScan BVI 2500+ and catheter estimates of true volume ($P > .05$). The overall accuracy (94%), sensitivity (97%), and specificity (91%) of the BVI 2500+ were impressive. The latest version of the BVI 3000 series was recently shown to be highly accurate and superior to conventional 2-dimensional ultrasonography.[5]

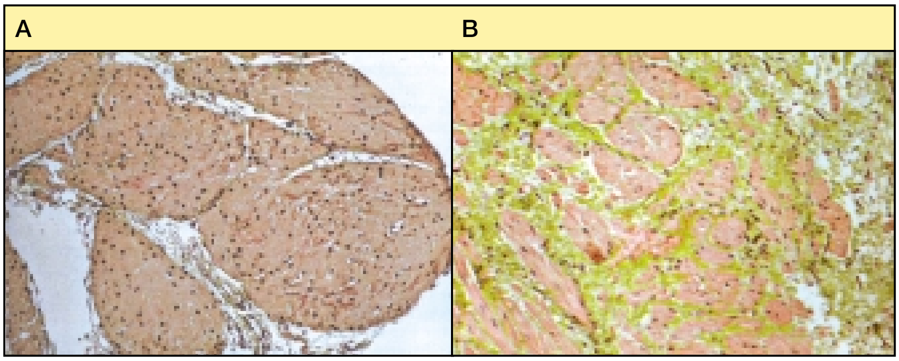


Figure 5. **(A)** *Normal detrusor muscle from a young woman (combined muscle cell, collagen, and elastin stain; original magnification ×150).* **(B)** *Detrusor muscle from a man with prostatic obstruction. Note significant fibrosis (combined muscle cell, collagen, and elastin stain; original magnification ×150).*

Clinical Relevance of the Bladder Scanning Device

Bladder ultrasound is useful in a variety of clinical settings. In pediatric patients, the scanner spares the patient needless catheterization, reduces patient anguish, and minimizes the threat of urethral injuries—which is especially important in this population, because urethral injuries in a child can translate into a lifelong problem. Assessment of PVR is mandatory in a variety of pediatric patients, such as those with voiding dysfunction, spinal cord closure abnormalities (myelodysplasia), UTIs, vesicoureteral reflux, and posterior urethral valves. Various reports support the use of the bladder scanner in the pediatric setting.[6-8]

Nursing homes and rehabilitation facilities often care for patients with urinary retention, urinary incontinence, and UTIs. The bladder scanner is therefore a fundamental clinical tool in these environments.[9-13] For example, PVR measurement screens for overflow incontinence, one of the several types of incontinence, and the noninvasive nature of the procedure reduces the incidence of nosocomial UTIs, which cause urge incontinence.

There are clear advantages to using the bladder ultrasound device in inpatient/ambulatory care settings. A study by Frederickson and colleagues[14] examined 2 similar groups of hospitalized patients, one of which was catheterized depending on ultrasonographic assessment and the other of which was catheterized according to a timed routine schedule. The study measured the number of catheterizations avoided, rate of UTI, supply costs, and patient/provider satisfaction. Use of ultrasound resulted in 38% fewer catheterizations overall, 9% fewer UTIs, significant cost savings, and high patient/provider satisfaction compared with standard catheterization. Other studies corroborate the use of bladder ultrasound in the hospital setting.[15-17]

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Specialists in internal medicine and neurology have found the bladder scanner particularly useful for patients with neurologic disease.[18,19] Voiding dysfunction can directly manifest from multiple sclerosis (MS), spinal cord injury, dementia, Parkinson disease, brain injury, cerebrovascular accidents, and diabetic neuropathy, among other disorders. For example, more than 80% of patients with MS have symptoms of lower urinary tract dysfunction, and more than 96% of MS patients with disease of longer than 10-years duration have urologic findings. A recent meta-analysis of urodynamic findings in 1882 well-defined MS cases demonstrated sphincter dyssynergia in 25% of patients and bladder hypocontractility in 20%.[20] Both of these pathologic entities may elevate PVR, making the bladder scanner an attractive and practical screening tool for such patients with incomplete bladder emptying.

Other Clinical Uses for Bladder Ultrasound

In addition to measuring PVR, the bladder ultrasound device can aid in other procedures, such as suprapubic aspiration; evaluation of intravesical masses, debris, stones, or diverticula; and evaluation of ureteral jets to rule out ureteral obstruction. Recently, bladder ultrasound has been used to determine bladder wall thickness

(BWT) and bladder wall mass (BWM). Increased BWT and bladder weight have been associated with outflow obstruction.[21-24] The hypertrophy is caused by a combination of smooth muscle hypertrophy and collagen deposition (Figure 5). In theory, sonographically measuring BWT and BWM could be a simple, quick, and noninvasive method of screening patients for BOO.

Hakenberg and colleagues[25] established normal BWT to be approximately 3 mm ± 1.1 mm for men and 3 mm ± 1.0 mm for women. Men with documented LUTS and prostatic enlargement had a significantly increased BWT compared with normal controls ($P < .002$).

Manieri and colleagues[26] studied 174 patients with LUTS and found that a BWT of greater than 5 mm at 150 mL was the best cutoff point at which to diagnose BOO. Thirty-seven percent of subjects with BWT less than 5 mm had obstruction, whereas 87.5% of those with BWT greater than 5 mm had obstruction, on the "gold-standard" pressure-flow studies. Receiver operator characteristics analysis showed BWT measurement to be superior to uroflowmetry for the diagnosis of BOO.

Kojima and colleagues[27] used bladder ultrasound to measure BWM in 33 men with obstruction before and after prostatectomy for benign prostatic hyperplasia and found that men with obstruction had bladder weight double that of control subjects. BWM decreased significantly from 52.9 ± 22.6 g to 31.6 ± 15.8 g at 3 months after de-obstructive prostatectomy. Results also demonstrated that a BWM of greater than 80 g may signify irreversible pathologic changes to the bladder detrusor. Although these investigations are intriguing, further studies are needed in order for bladder ultrasound to gain an established role in the assessment of BOO.

Conclusion

The basic evaluation of suspected voiding dysfunction involves fundamental objective tools, such as uroflowmetry and PVR measurement. Physicians should be vigilant in detecting elevated PVRs, which can stem from a variety of causes. The bladder ultrasound device is a simple, accurate, safe, and clinically relevant method of screening for elevated PVR. Research into sonographically measured BWT and BWM as an index for BOO is currently under way. ■

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Main Points

- Uroflowmetry, which measures urine voided per unit time, can help to identify patients who have bladder outlet obstruction (BOO). However, by itself, the procedure cannot definitively diagnose BOO, because it cannot distinguish true obstruction from poor bladder contractility. Thus, this test's utility lies in its ability to identify patients who need further urodynamic studies.
- Measurement of postvoid residual urine volume (PVR) is also useful in assessing voiding dysfunction and identifying potential BOO. PVR measurement can be performed by sterile catheterization or by bladder ultrasound.
- Portable bladder scanners are convenient, noninvasive, accurate, cost-effective, and carry no risk of urethral trauma or urinary tract infection, both of which are associated with catheterization. Use of these devices has been shown to be beneficial in a variety of populations, including patients with neurologic disease, children, and the eldery.
- In addition to measuring PVR, the bladder ultrasound device can aid in other procedures, such as suprapubic aspiration; evaluation of intravesical masses, debris, stones, or diverticula; and evaluation of ureteral jets to rule out ureteral obstruction. Bladder ultrasound has also been used to determine bladder wall thickness and bladder wall mass, both of which have been associated with outflow obstruction.

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