



# Noninvasive Methods to Evaluate Bladder Obstruction in Men

Dean S. Elterman, Bilal Chughtai, Richard Lee, Alexis E. Te, Steven A. Kaplan

*James Buchanan Brady Department of Urology, Weill Cornell Medical College of Cornell University, New York, USA*

## ABSTRACT

*Lower urinary tract symptoms (LUTS) caused by benign prostatic hyperplasia (BPH) commonly affect older men. Fifty percent of men in their sixties and 80% of men in their nineties will be affected. Many of these men will seek care for their bothersome symptoms and decreased quality of life. There is a poor association between LUTS and objective measures such as post void residual, voided volumes, or maximal flow. Pressure flow studies are considered the gold standard for detecting bladder outlet obstruction. These studies tend to be cumbersome, expensive, and have exposure to ionizing radiation. There are several techniques which may offer noninvasive methods of detecting bladder outlet obstruction (BOO) in men.*

## ARTICLE INFO

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## INTRODUCTION

Several etiologies, including bladder outlet obstruction (BOO), poor contractility, and detrusor overactivity may contribute to lower urinary tract symptoms (LUTS) in men. Men with urodynamic BOO tend to have improved outcomes following transurethral prostate surgery compared to men with only LUTS and no BOO (1,2). Therefore diagnosing BOO is important in certain populations where intervention is being considered. Pressure-flow studies, also known as urodynamic studies, remain the gold standard for diagnosing BOO (3,4). It is the only study that

provides reliable and reproducible evidence of BOO. Urodynamic studies will typically demonstrate the etiology of male LUTS, which commonly includes obstruction and/or detrusor overactivity. One clear disadvantage of urodynamics is their invasiveness. Both bladder and rectal catheterization are required (5). Noninvasive techniques for diagnosing BOO have been developed, including Doppler resistive index, Doppler ultrasound urodynamics, and bladder wall thickness. This paper will discuss these noninvasive methods, and their advantages and disadvantages.

### Symptoms

Several large multicenter, international studies have demonstrated the poor correlation between patient reported LUTS and BOO on urodynamics. The International Continence Society conducted a BPH study evaluating 1271 men (6). When the pressure-flow studies of 933 men were compared to their answers on the ICS male questionnaire, there were no correlations noted on either the storage or voiding symptoms (7). Reynard and Abrams were able to demonstrate a weak correlation between symptoms of hesitancy and decreased flow with BOO on urodynamics ( $p = 0.04$  and  $p = 0.002$ , respectively) (8,9). When other symptoms such as intermittency, terminal dribbling, and straining were analyzed, no association to BOO was observed in the same cohort of patients (10,11). The severity of symptoms as determined by validated self-administered questionnaires, such as the International Prostate Symptom Score (IPSS) or the American Urological Association symptom index (AUA-SI), is poorly related to BOO (12,13). Poor scores on these questionnaires do not act as a surrogate to diagnose BOO. Patient reported symptoms should guide management to some extent, however because BOO cannot be determined with questionnaires alone, surgical decision making should incorporate some assessment of BOO.

### Prostate Specific Antigen (PSA)

The relationship between BOO and PSA has been studied (14). Over 300 men were stratified using logistic regression analysis to divide them into groups of varying ranges of PSA. Men with PSA between 4-6 ng/mL had a 65% likelihood of BOO. Men with PSA between 6-10 ng/mL had an 81% increased likelihood of BOO.  $PSA \leq 4$  ng/mL was not a reliable predictor of BOO. Using PSA as a predictor of BOO is not entirely reliable as it may also be elevated by prostate cancer. Men with an elevated PSA would need to also be evaluated for the presence of prostate cancer.

### Post-void Residual (PVR)

One useful adjunct to the evaluation of BOO is measuring a post-void residual (PVR). Patients with BOO do often have increased PVRs

however detrusor under-contractility may also be an underlying etiology (15,16). Additionally, one third of men with BOO will not have a significant PVR. However, in patients with BOO on urodynamics, PVR does decrease following surgical management (2).

The interaction of detrusor contractility, PVR and BOO was recently investigated in 131 patients (17). This showed that there was a weak correlation between PVR and BOO, and PVR alone could not predict BOO. This demonstrates that PVR depends on BOO and detrusor contractility, and conversely PVR cannot predict BOO alone. Briefly, PVR alone cannot be used to diagnose BOO with good sensitivity but is useful in conjunction with other parameters.

### Prostate size

Clinical and imaging modalities, including DRE, trans-rectal ultrasound (TRUS), CT, and MRI, are all utilized to assess prostate size. TRUS tends to be the most frequently used due to its availability and good size estimation [23]. DRE is a poor assessor of prostate size, making TRUS even more useful (18). Studies have investigated BOO and prostate volume. There was a statistically significant correlation between BOO and prostate size ( $r = 0.32$ ,  $p = 0.001$ ) in a retrospective study of 521 men (19). Only men with prostate volumes  $> 40$  mL had a 70% chance of being diagnosed with BOO, though the sensitivity and specificity of prostate volume as a predictor was quite low (49% and 32%, respectively (19)). Prostate volume as a predictor of BOO in men with glands  $< 40$  mL is not helpful. Other studies have also determined statistically significant correlations between BOO and prostate volume, though volumes have not been able to reliably predict BOO (20). Other parameters such as the ratio of prostate volume to transition zone (TZ) volume have also been assessed though they poorly correlate to BOO or symptoms, and are thus not used clinically (21).

### Intraprostatic Protrusion

Intra-prostatic protrusion (IPP) may be measured when the prostate grows into the bladder. IPP may be measured in the sagittal midline using trans-abdominal ultrasound. Measure-

ments are taken from the bladder base in mm and are graded 1,2 or 3. IPP grades are < 5mm, 5-10mm, or > 10mm respectively (22). Bladder volume at the time of measurement may significantly impact the measurement of IPP, thus studies have shown that a bladder volume of 100-200 mL is ideal (23). As the grade of IPP increases, so too will the severity of BOO. Grade 3 IPP can diagnose BOO with 76% sensitivity and 92% specificity. Sensitivity and specificity for diagnosing BOO with Grade 2 IPP drops to 17% and 53%, and 7% and 56% for grade 1 (22). There remain several problems with measuring IPP, including inaccuracy and inconsistency in ultrasound measurement. Differ bladder volumes will also affect the accuracy of IPP measurement, limiting its' utility in many patients.

#### Bladder Wall Thickness and Bladder Weight

One consequence of BOO is detrusor hypertrophy (24). When the bladder wall muscle becomes thicker as a result of prostatic obstruction and compensation, the bladder wall thickness (BWT) becomes a non-invasive parameter to assess BOO (25,26). BWT may result from smooth muscle hypertrophy secondary to BOO, as well as collagen and fibrous tissue, both consequences of obstruction and aging (27,28). Though animal models have demonstrated smooth muscle detrusor hypertrophy with BOO, an increased BWT may be attributable to other causes and is therefore not a reliable tool for non-invasive assessment of BOO (29).

#### Doppler Resistive Indices

When BOO is caused by prostatic obstruction, the detrusor muscle becomes hypertrophied and thickened. However, there is no compensatory increase in blood supply to the bladder resulting in a decrease in blood flow. Animal models have confirmed the relative decrease in detrusor blood flow in obstructed animals (30). Color Doppler ultrasound was used in 29 patients undergoing urodynamics (31). The average arterial blood flows at 3 sites in the bladder as well as the resistive index (RI), the calculated change in blood flow, were measured. When comparing obstructed and non-obstructed patients, RI values were significantly

different between the groups. A predictive BOO regression model demonstrated fairly high accuracy in predicting BOO (86%) but a low negative predictive value (57%) (31). Aside from BOO, advanced age, detrusor overactivity, and atherosclerosis may all cause decrease in detrusor blood flow. Bladder wall resistive indices (RIs) may be evaluated using either transabdominal or transrectal US (32). RI has been correlated with Abrams-Griffiths number ( $r = 0.33$ ,  $p = 0.05$ ), TZ index, and patient age (32). One study was able to show a sensitivity of 85% and specificity of 46% for diagnosing BOO, when the RI was > 0.7. Alas, while using color Doppler US to measure RIs may be interesting, it does not allow for the exclusion of other causes of elevated RIs in the detrusor muscle (32).

#### Near Infrared Spectroscopy (NIRS)

Pulse oximetry and cerebral oxygenation monitoring utilize near infrared spectroscopy (NIRS) to monitor changes in concentrations of chromophores (oxyhemoglobin and deoxyhemoglobin) (33,34). Photons from the near infrared spectrum are absorbed by chromophores. They are absorbed much less by other issues, such as fat, water, and protein (35). Research studies have developed an algorithm to assess BOO in men with LUTS. According to the algorithm, men may be classified as obstructed or non-obstructed based on NIRS data (pattern of chromophore concentration slope of change),  $Q_{max}$ , and PVR (36). A down-sloping chromophore concentration relates to a higher likelihood of obstruction, whereas an up-sloping chromophore concentration relates to a higher likelihood of non-obstruction. NIRS has shown an 80% concordance with urodynamic pressure-flow studies (36). The relation between BOO and chromophore concentration changes is influenced by blood flow and oxidative metabolism which effect oxyhemoglobin concentration changes (36,37). These changes in blood flow and metabolism create the upward and downward slopes of chromophore concentration change in obstructed patients. Chung et al. studied 42 men, of whom 33 (79%) were evaluable, with both urodynamics and NIRS evaluation. The NIRS algorithm relative to the urodynamic diagnosis had an area under the curve of 0.484. Although this is a small

cohort, the NIRS pattern alone was not predictive of BOO in men with LUTS (38).

### Measurement with External Catheter

Non-invasive pressure-flow studies may be performed using an external modified condom catheter (39,40). A pressure transducer may be attached to the open outlet of a condom catheter. When the outlet is occluded, a measurable isovolumetric pressure increase may be recorded. Comparisons have been made between pressure-flow studies, external catheter bladder pressure, and flow rate ( $Q_{\max}$ ) (41). In one study, 30% of patients would be correctly categorized as obstructed or non-obstructed based on flow rate ( $Q_{\max}$ ) alone. A  $Q_{\max} < 4.5$  mL/sec was considered obstructed, while a  $Q_{\max} > 13.8$  mL/sec was non-obstructed. The remaining group of study patients had a combination of  $Q_{\max}$  and external catheter pressure measurement compared to urodynamic pressure-flow diagnosis. According to ICS definitions, if  $Q_{\max}$  and external catheter pressure were either obstructed or equivocal, they had a 90% concordance with pressure-flow diagnoses of BOO. If  $Q_{\max}$  and external catheter pressure were either non-obstructed or equivocal, then concordance with BOO on pressure flow study was merely 67% (42). External bladder pressure measurement using a condom catheter has had several user-reported problems including bad fitting or uncomfortable condoms, leakage from condom, and unreliable pressure readings depending on condom compliance and fit.

### Measurement Using Penile Compression

Inflating a cuff around the penis during voiding, much like a non-invasive blood pressure cuff fitted around an arm, could be inflated to give a cuff pressure equivalent to the isovolumetric pressure of the bladder. A cuff is occluded around the urethra prior to voiding, then released to allow voiding and measure the pressure (40,41,43). A cuff fitted around the penile shaft is inflated to 250 cmH<sub>2</sub>O, then the subject is instructed to void against the occluded urethra. When the bladder contracts, an isovolumetric column of urine forms between the bladder and cuff, and the pressure is transmitted down to the occluding cuff (41,43). Once a column of urine is formed, the patient slo-

wly releases pressure from the cuff, allowing it to deflate until flow is initiated through the cuff. It is at this point that the intraurethral pressure is equal to the cuff pressure. When a flow rate of 1 mL/sec is detected in an uroflow meter, the cuff is rapidly deflated allowing for a surge in flow ( $Q_{\text{surge}}$ ). In one study, where subjects also underwent invasive pressure-flow studies, cuff pressures were higher than measured intravesical pressure. This was accounted for by differences in height between the pressure transducer and the penile cuff (40).

## CONCLUSIONS

While invasive pressure-flow studies remain the gold standard for diagnosing BOO, several non-invasive techniques have been investigated. Though several show promise when used in combination, the diagnostic accuracy of these methods remains less than ideal. There are large variations in sensitivity and specificity of these measures, and clinical application is often challenging from a practical standpoint. Many surrogate markers such as PSA, symptoms and PVR offer some clue as to the presence of BOO, they are clearly not sensitive or specific enough to be used instead of invasive urodynamics. Intraprostatic protrusion and NIRS offer measurable endpoints which can be used as part of the overall clinical picture. Ultimately, we require further studies, with large sample sizes and rigorous, reproducible methodology to find a reliable method to replace invasive pressure-flow studies to diagnose BOO.

## CONFLICT OF INTEREST

None declared.

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**Correspondence address:**

Dr. Steven A. Kaplan  
Department of Urology  
James Buchanan Brady  
Weill Cornell Medical College of Cornell University  
525 East 68th Street, F9West, Box 261  
New York, New York 10065, USA  
E-mail: kaplans@med.cornell.edu