

Diagnosis of voiding dysfunction by pressure-flow study in women

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Abstract

Pressure-flow study (PFS) of micturition is the best method to quantitatively analyse voiding function. It allows us to distinguish voiding lower urinary tract symptoms and low urine flow rate caused by bladder outlet obstruction (BOO) from those caused by detrusor

underactivity (DU). Voiding dynamics are significantly different in men and women and the established criteria for urodynamic diagnosis in men do not apply to women. Basic principles of voiding mechanics and voiding patterns in asymptomatic women are analyzed. Although attempts have been made to establish a consensus for diagnosis of BOO in women with pressure-flow cutoff, video-urodynamics criteria and nomograms, currently there is no consensus. There is no standard urodynamic test to diagnose and quantify DU in women for which further investigations are needed. Modified projected isovolumetric pressure (to assess detrusor contraction strength) and pressure-flow cutoff criteria have been used. The diagnosis of voiding dysfunction in women is challenging, requiring PFS with very good quality control and often involves integrating clinical and radiographic data to make the final assessment.

Key words: Bladder outlet obstruction; Pressure-flow studies; Urodynamics; Women; Detrusor underactivity

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Core tip: Pressure-flow study of micturition is the best method to quantitatively analyze voiding function. Voiding dynamics differ significantly between men and women and the established criteria for urodynamic diagnosis in men do not apply to women. Although attempts have been made to establish a consensus for diagnosis of bladder outlet obstruction in women with pressure-flow cutoff, video-urodynamics criteria and nomograms, currently there is no consensus. There is no standard urodynamic test to diagnose detrusor underactivity in women for which further investigations are needed. The diagnosis of voiding dysfunction in women is challenging and often involves consideration of clinical and radiographic data to make the final assessment.

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INTRODUCTION

At present, the best method for quantitative analysis of voiding function is the pressure-flow study (PFS) of micturition, with concomitant recording of intravesical, abdominal, detrusor pressures ($p_{det} = p_{ves} - p_{abd}$) and flow rate^[1]. It is defined by the International Continence Society (ICS) as "the method by which the relationship between pressure in the bladder and urine flow is measured during bladder emptying"^[2].

PFS is able to evaluate normal voiding as well as detrusor underactivity (DU) and bladder outlet obstruction (BOO). BOO is the term employed for defining obstruction during voiding and corresponds to increased detrusor pressure and reduced urine flow rate. DU is defined as a detrusor contraction "of reduced strength and/or duration, resulting in prolonged bladder emptying and/or failure to achieve complete bladder emptying within a normal time span"^[2]. An acontractile detrusor is defined as the one "that cannot be observed to contract during a urodynamic studies resulting in prolonged bladder emptying and/or failure to achieve complete bladder emptying within a normal time span"^[3]. Thus, acontractile detrusor may be considered as a more severe form of DU.

PFS is a well established diagnostic tool for evaluating voiding dysfunction in men. This is the result of extensive studies in patients with benign prostatic enlargement which has led to the development of nomograms, such as de nomogram described by Abrams *et al*^[4], the Passive Urethral Resistance Relation^[5,6] and the ICS nomogram^[1]. However, due to anatomic differences between men and women their voiding dynamics differ significantly. Women usually void at lower detrusor pressures than those observed in men. Therefore the established criteria for urodynamic diagnosis used in men are not well suited for women. Moreover, up to date there is no equivalent prevalent condition such as benign prostatic enlargement causing BOO in women, making the diagnosis more challenging.

In this article we will discuss the basic principles of voiding mechanics, the voiding patterns in asymptomatic women, the urodynamic criteria currently used to assess BOO and DU in women and some quality control issues of the pressure-flow studies in this gender.

BASIC PRINCIPLES OF VOIDING MECHANICS

The detrusor, as it occurs with other muscles, follows the Hill equation. This equation describes the relation between the muscle's force of contraction and its shortening velocity^[7]. For example, for a given muscle length

and its activation degree, a shortening speed of zero will produce that tension attains its isometric value. As the muscle's shortening speed increases, the tension falls and reaches zero at a maximum shortening velocity characteristic of that muscle (Figure 1)^[7,8]. In the case of the bladder, the Hill equation becomes the bladder output relation (BOR). It relates the pressure of the detrusor to urinary flow rate (Figure 2)^[8]. For a given detrusor contraction strength, given that there is no obstruction, the pressure needed to drive urine through the urethra is low meanwhile the flow rate is high. Contrarily, if outlet obstruction is present, the pressure required is high and flow rate low. If obstruction develops progressively, voiding conditions alter gradually from low pressure/high flow towards high pressure/low flow^[9]. Moreover, the BOR curve is not fixed. When the detrusor decompensate and develops hipo-contractility, the curve shifts to lower pressures and flow rates and may cause urinary retention^[9-11].

In other words, voiding arises from the balance between an actively contracting detrusor as source of mechanical energy and the relaxed bladder outlet as a passive conduit with special hydrodynamic characteristics. The detrusor has a specific pattern of energy release in which the outlet determines how the energy provided is converted to attain voiding. Voiding power is proportional to detrusor pressure and to urine flow rate. The detrusor does not produce a particular pressure or flow during voiding. Instead, this muscle is able to provide mechanical power and it is the bladder outlet that dictates the way this power is split into pressure and flow rate, following an inverse relationship (BOR). The maximum detrusor power is proportional to the filling volume of the bladder. This higher detrusor power explains why, for the same voiding pressure, the peak flow rate is higher at larger voiding volumes (therefore the outlet resistance is not lower at larger volumes). Moreover, the collapsed urethra differs from a rigid pipe in that an increase in intraluminal pressure is required to open the lumen before flow can occur. This urethral opening pressure must also be supplied by detrusor contraction and cannot be converted into flow. Consequently, flow rate will be lower than it could be in a rigid conduit of the same size. A special feature of flow in collapsible and distensible tubes is that the pressure-flow relation can be controlled by a small segment acting as a "flow controlling zone". Under physiologic conditions, this zone is at the level of the pelvic floor. Under pathological outflow conditions, the obstruction itself takes over the role of the flow controlling zone^[5].

VOIDING PATTERNS IN ASYMPTOMATIC WOMEN

Most of our knowledge of voiding function has been extrapolated from studies of women with lower urinary tract dysfunction. However, women with and without lower urinary tract symptoms have different voiding patterns.

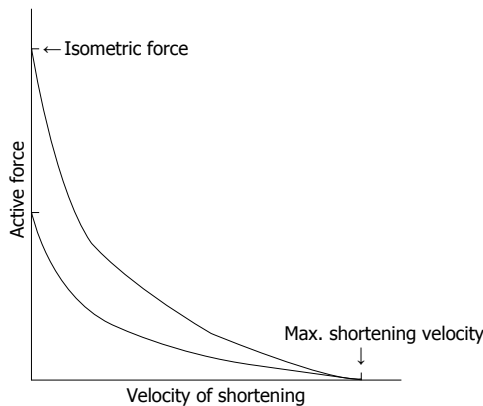


Figure 1 Hill curves relating active force to velocity of shortening at a given muscle length. Curves are shown for two different muscle lengths, corresponding to the same bladder when full (upper curve) and when nearly empty (lower curve: Volume approximately 12.5% of capacity). (From Griffiths^[6]. Assessment of detrusor contraction strength or contractility. *Neurourol Urodyn* 1991; 10: 1; with permission).

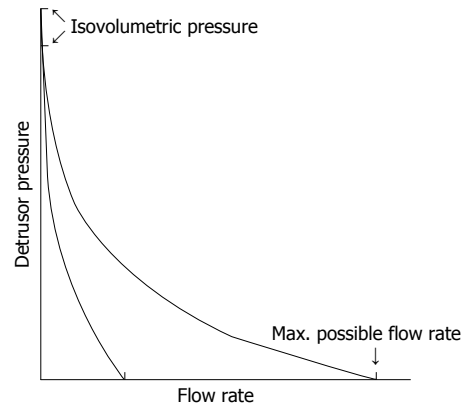


Figure 2 Bladder output relations relating active detrusor pressure to rate of urine flow at a given bladder volume. Curves show Bladder output relations for the same two situations as in Figure 1, corresponding to a full bladder (curve with higher maximum possible flow rate) and a nearly empty bladder (lower maximum possible flow rate; volume approximately 12.5% of capacity). (From Griffiths^[6]. Assessment of detrusor contraction strength or contractility. *Neurourol Urodyn* 1991; 10: 1; with permission).

In their work, Tanagho *et al.*^[12] studied the initiation of voiding by simultaneously using cineradiography and recording pressures in the urethra, bladder, rectum and anal sphincter. They described 5 different voiding patterns: (1) Decrease in urethral closure pressure followed by contraction of the detrusor; (2) detrusor contraction without decrease in urethral pressure; (3) decrease in urethral closure pressure and increase of intravesical pressure due to straining; (4) increase of intravesical pressure due to straining without decrease in urethral pressure; and (5) decrease in urethral closure pressure without straining or contraction of the detrusor. They stated that only patients with low urethral closure pressure voided with negligible or no detrusor contraction. This leads to question if these types of voiding are indeed normal^[12]. Of notice, from our knowledge of the BOR we can asseverate that women with very low bladder outlet resistance who do not strain to void should be using their bladder detrusor to void even if no increase in detrusor pressure is detected.

Few studies have described the voiding patterns of "healthy, continent and/or asymptomatic" women. Furthermore, definitions of what is considered detrusor contraction and straining to void vary between these studies (Table 1)^[13-16]. All women included in these reports voided with a measurable detrusor contraction and variable participation of abdominal muscles (0%-73%). Backman *et al.*^[17] studied 15 normal women of all ages and found that they all initiated voiding by increasing abdominal pressure. However, young women did not use straining during the whole micturition as often as elderly women did. Consequently, the authors argued that the detrusor muscle tends to lose some of its power with age^[17].

BOO

BOO "is the generic term for obstruction during voiding

and is characterized by increased detrusor pressure and reduced urine flow rate"^[2]. Women typically void at lower detrusor pressures than men. Small increases in detrusor pressure or decreases in flow rate, probably considered insignificant in men, could correspond to BOO in women. BOO in women without neurological diseases can be classified as anatomic or functional. Anatomic causes of BOO include high grade pelvic organ prolapse, previous anti-incontinence surgery and urethral disease (stricture, diverticulum). Functional causes of BOO are primary bladder neck obstruction and dysfunctional voiding (also known as learned voiding dysfunction) among other less frequent causes^[18]. Currently, no consensus exists regarding urodynamic criteria to define BOO in women. Attempts have been made to establish a standard for the diagnosis of BOO in women, grouping them into one of three categories: (1) Pressure-flow cutoff criteria; (2) video-urodynamics criteria; and (3) nomograms.

The major studies of pressure-flow cutoff criteria for the diagnosis of BOO in women have been reported by the Department of Urology of the University of Texas Southwestern Medical Center. This group published three articles in which they calculated the best combination of maximum flow rate (Q_{max}) and detrusor pressure at maximum flow rate ($p_{det}Q_{max}$) using receiver operating characteristic curves in women who had a clinical diagnosis of BOO^[19-21]. In two of their studies, control groups included women suffering stress urinary incontinence, whereas a third study included healthy volunteers to correct for effects of low outlet resistance. Their last study included 169 consecutive women with clinically diagnosed obstruction. That is to say, a history of urethral or bladder neck surgery, pelvic examination revealing urethral hyper-elevation or high grade anterior vaginal wall prolapse and altered voiding cystourethrography and/or endorectal coil magnetic resonance imaging. The study reported high-stage anterior vaginal wall prolapse, previous anti-

Table 1 Voiding patterns of “healthy, continent or asymptomatic” women

	Rud <i>et al</i> ^[13]	Rud <i>et al</i> ^[14]	Karram <i>et al</i> ^[15]	Pauwels <i>et al</i> ^[16]
No. of patients	16	6	30	26
Patients condition	Healthy	Healthy	Asymptomatic, continent	Healthy, history free, continent
Age, yr (range)	33 (23-73)	42 (37-54)	34	26
Definitions				
Detrusor contraction	Not defined	Not defined	Increase in detrusor pressure of 5 cm H ₂ O above resting pressure	Increase in detrusor pressure of 15 cm H ₂ O above resting pressure ¹
Strain to void	Not defined	Not defined	Increase in abdominal pressure of at least 10 cm H ₂ O above baseline	Increase in abdominal pressure of at least 10 cm H ₂ O above baseline during the entire voiding phase
Voiding pattern				
Drop in urethral pressure	16/16 (100%)	6/6 (100%)	Not studied	Not studied
Detrusor contraction	16/16 (100%)	6/6 (100%)	30/30 (100%)	26/26 (100%)
Strain to void	0/16 (0%)	0/6 (0%)	22/30 (73%)	11/26 (42%)

¹There was no definition of detrusor contraction but increase in detrusor pressures of at least 15 cm H₂O developed in all women.

incontinence surgery and documented distal urethral obstruction/periurethral fibrosis as causes of anatomic BOO. They excluded patients with neurologic conditions that could affect bladder function, patients with bladder capacity under 100 mL, abdominal strain during voiding greater than 10 cm H₂O, absence of urethral sphincter or pelvic floor relaxation during voiding (evidenced by patch electrode electromyography) together with inability to void for the PFS. Their results showed that “the $p_{det}Q_{max}$ value with a specificity of at least 60% and the greatest sensitivity for the detection of BOO was 25 cm H₂O, and that Q_{max} value resulting in equal sensitivity, specificity, and accuracy (68%) for predicting BOO was close to 12 mL/s” (cutoff criteria: $p_{det}Q_{max} \geq 25$ cm H₂O + $Q_{max} \leq 12$ mL/s)^[21]. It is worth remembering that with voided volumes greater than 140 mL a $Q_{max} \leq 12$ mL/s falls under the 5th percentile of the Liverpool nomogram, and over 110 mL of voided volume a $Q_{max} \leq 12$ mL/s falls under the 10th percentile^[22].

In a retrospective work, Nitti *et al*^[23] described the video-urodynamic criteria used to diagnose BOO in 261 women with non-neurogenic voiding dysfunction, who were able to void during the PFS. They argued that if physiological voiding in women take place at low detrusor pressure the bladder response to obstruction by producing higher voiding pressures might be difficult to notice. BOO was characterized as radiographic proof of obstruction from the bladder neck to the distal urethra when observing a sustained contraction the detrusor of any magnitude. This was generally associated with decrease or delay in urinary flow rate. The authors define radiographic obstruction at the bladder neck when it was either closed or narrow during voiding. Radiographic obstruction of the urethra was diagnosed when they detected a distinct area of narrowing with proximal dilatation. This method allows for diagnosis of the zone of obstruction. In this study 67 patients were considered obstructed and 185 patients unobstructed. Patients with BOO had anatomical (cystocele, urethral stricture, urethral diverticulum, iatrogenic obstruction from incontinence surgery, uterine prolapse and rectocele) and functional causes (dysfunctional voiding and primary

bladder neck obstruction). When urodynamic parameters were compared, the obstructed cases had significantly higher mean $p_{det}Q_{max}$ (42.8 ± 22.8 cm H₂O vs 22.1 ± 11.3 cm H₂O), lower mean Q_{max} (9.0 ± 6.2 mL/s vs 20.2 ± 10 mL/s), and higher mean postvoid residual urine (157 ± 183 mL vs 33 ± 91 mL) than unobstructed cases. However, given that both groups presented wide intervals for each parameter, it was difficult to assign specific cutoff values^[23].

Blaivas *et al*^[24] developed a nomogram to assess BOO in women. They analyzed a database of 600 consecutive women referred for evaluation with urodynamic study. They found BOO in 50 patients when using the following criteria: (1) Free $Q_{max} \leq 12$ mL/s in at least two free-flow studies, combined with a maintained contraction of the detrusor and $p_{det}Q_{max} \geq 20$ cm H₂O in the PFS; (2) evident radiographic proof of BOO with a sustained detrusor contraction ≥ 20 cm H₂O and poor Q_{max} , regardless of free Q_{max} ; and (3) incapacity to void using a transurethral catheter despite maintained detrusor contraction ≥ 20 cm H₂O. This group of patients was compared to 50 age-matched controls with no evidence of obstruction, 20 with normal urodynamic study and 30 patients presenting sphincteric-incontinence. They used two parameters to assess BOO: (1) Free Q_{max} (noninvasive maximum flow rate) instead of invasive Q_{max} , given that many unobstructed patients presented low Q_{max} because of the adverse effect of the transurethral catheter on Q_{max} ; and (2) p_{detmax} (maximum detrusor pressure during voiding) instead of $p_{det}Q_{max}$, because isolated test of the parameters did not reveal a difference considered statistically significant. Also because $p_{det}Q_{max}$ cannot be assessed in presence of urinary retention since there is no measurable flow regardless of the possible presence of a detrusor contraction (whereas p_{detmax} may enable analysis). The analysis reported that the data was distributed in three clusters: (1) Unobstructed group of patients presenting low pressure and high flow; (2) obstructed patients presenting high pressure and low flow; and (3) a group with low-to-intermediate pressure and flow rates, which was subdivided into two categories. A four-zone nomogram was developed (Figure 3). The

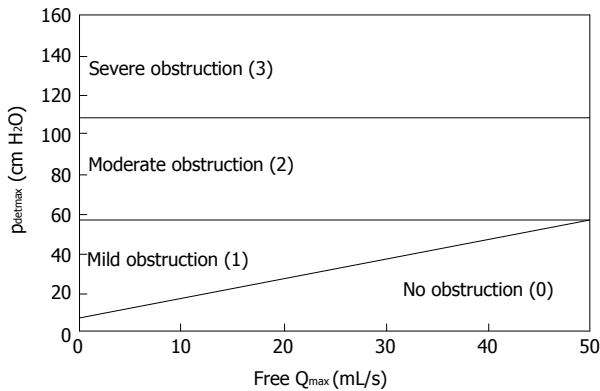


Figure 3 Bladder outlet obstruction nomogram for women. (From Blaivas *et al*^[24]. Bladder outlet obstruction nomogram for women with lower urinary tract symptomatology. *Neurourol Urodyn* 2000; 19: 553; with permission).

boundaries between the four zones were: Between unobstructed and minimally obstructed: (1) A line with slope 1.0 and intercept 7 cm H₂O; *i.e.*, running through the point (0,7) and (50,57); (2) between minimally and moderately obstructed: A horizontal line at P_{detmax} of 57 cm H₂O; and (3) between moderately and severely obstructed: A horizontal line at P_{detmax} of 107 cm H₂O. Using this nomogram, all women with obstruction were correctly classified and further subclassified as mildly obstructed (68%), moderately obstructed (24%), and severely obstructed (8%). The authors found that subjective severity of symptoms (assessed by American Urological Association Symptom Score) was positively correlated to the zones of the nomogram. Of the patients classified as unobstructed, the nomogram correctly identified 80% as unobstructed, 8% as mildly obstructed, and 12% on the borderline between no obstruction and mild obstruction^[24].

DU

DU is defined as a "detrusor contraction of reduced strength and/or duration, resulting in prolonged bladder emptying and/or a failure to achieve complete bladder emptying within a normal time span"^[2]. This definition has remained unchanged through the last terminology report^[3] and is based on two characteristics: (1) A weak strength of detrusor contraction; and (2) a short duration of the detrusor contraction. Both aspects of detrusor contractility seem to be independent. If the detrusor contraction is not adequately sustained, there will be postvoid residual urine^[25].

The diagnosis of DU is based on pressure-flow studies and encompasses low-pressure, and poorly sustained contraction of the detrusor associated to low urinary flow^[26]. There is no standard urodynamic test for diagnosing and quantifying DU and most measures only assess detrusor contraction strength and not duration^[26,27]. It is challenging to make a correct diagnosis since measuring detrusor contraction strength is not easy and the criteria used for men are not applicable to women.

The presence of DU in several clinical groups suggests that its ethiopathogenesis tends to be multifactorial. Among non-neurogenic etiological factors leading to DU in women are: (1) Idiopathic cause due to physiological ageing, unknown causes in younger subjects; (2) myogenic: Long term BOO, overdistension injury, diabetes; (3) iatrogenic: Radical hysterectomy and pelvic surgery, abdominoperineal resection or anterior rectal resection; and (4) pharmacologic: Anticholinergic medication, tricyclic antidepressants^[18,26].

According to the principles of voiding mechanics, detrusor contraction strength is expressed partially as pressure and partially as flow. Therefore the contraction strength is not the same as the pressure of the detrusor. In theory, the isovolumetric detrusor pressure obtained when there is interruption in flow or by continuous occluding with a balloon catheter, provides a good appraisal of detrusor contraction strength^[28]. It also gives more reliable results than those obtained interrupting flow by voluntary contraction of the urethral sphincter due to reflex bladder contraction inhibition^[29]. Because producing mechanical interruption of flow or continuous occlusion with a balloon catheter alters voiding, is difficult to perform and produces discomfort, other methods to estimate detrusor contraction strength have been developed based on the BOR. For example, if we know the slope and curvature of the BOR, we can estimate the isovolumetric detrusor pressure by extrapolating the pressure where it intersects the pressure axis^[30].

Schafer simplified the BOR by using a straight line with a fixed slope of 5 cm H₂O/mL per second, not considering bladder volume, and obtaining the projected isovolumetric pressure (PIP) in men^[5,6,30]. For a given void, PIP is assessed at the point of maximum flow rate. This was done using the following equation: $PIP = P_{detQ_{max}} + 5 Q_{max}$. Schafer proposed that PIP values over 150 cm H₂O meant strong contractions; values from 100 to 150 cm H₂O, normal contractions; values from 50 to 100 cm H₂O, weak contractions; and values below 50 cm H₂O very weak contractions. He developed a contractility nomogram by drawing the corresponding BORs on a pressure-flow diagram, allowing the contraction strength to be classified in four groups^[5,6,30]. Since 100 cm H₂O is a normal PIP value, the ratio $PIP/(100 \text{ cm H}_2\text{O})$ is a coefficient with no dimension for which values over 1 represent normal or strong contractions, and values under 1, weak contractions. The ratio was nominated detrusor coefficient (DECO), and if it is expressed as a percentage it is numerically equal to PIP (in cm H₂O) and identical to the bladder contractility index (BCI) described later by Abrams^[31].

Tan *et al*^[30] compared stop-test isovolumetric pressures with approximate calculations based on pressure flow studies in a cohort of 100 women (mean age 70.1 years; range 53-89) suffering from urgency incontinence. Measurements were documented both pre- and post-treatment with placebo or oxybutynin. This allowed for investigation of test- retest reliability and

Table 2 Comparison of the reference isovolumetric pressure with estimates given by detrusor coefficient/bladder contractility index and projected isovolumetric pressure 1¹

	Reference isovolumetric pressure (cm H ₂ O)	DECO/BCI ($p_{det}Q_{max} + 5 Q_{max}$)	PIP ₁ ($p_{det}Q_{max} + Q_{max}$)
Mean \pm SD (mean)	50 \pm 25 (45)	133 \pm 45 (128)	49 \pm 17 (48)
5 and 95 percentiles	20/112	60/215	29/78
Mean difference (cm H ₂ O) from reference (95%CI: Wilcoxon signed ranks test)	-	86 (76-96; $P < 0.05$)	0.2 (-5 to 5; $P = 0.98$)
Spearman's coefficient of correlation with reference	-	0.21 ($P = 0.06$)	0.52 ($P < 0.01$)

¹Modified from Tan *et al.*^[30]. DECO: Detrusor coefficient; BCI: Bladder contractility index; PIP₁: Projected isovolumetric pressure 1.

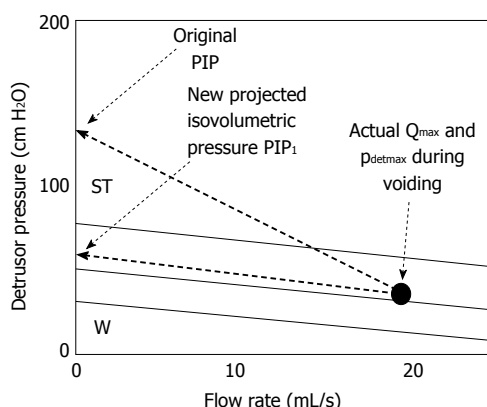


Figure 4 To determine projected isovolumetric pressure 1 the point representing the pressure and flow rate measured during uninterrupted voiding is projected back to the axis with a line of slope -1 cm H₂O/mL per second. (Note that the value of original PIP would be much larger). For this void, the value of PIP₁ is about 60 cm H₂O, and the void falls in the band of typical values (unshaded). Values in the regions shaded gray would represent either ST or W contractions than those typical of the subjects in this group. (From Tan *et al.*^[30]. Stop test or pressure-flow study? Measuring detrusor contractility in older females. *Neurourol Urodyn* 2004; 23: 184 with permission). PIP: Projected isovolumetric pressure; ST: Stronger; W: Weaker.

responsiveness to small changes in contractility. They reported that the Schafer contractility nomogram and related parameters (DECO and BCI) used in men tend to greatly overestimate isovolumetric pressures in women. They suggested a modification called projected isovolumetric pressure 1 (PIP₁) which provided a more reliable estimate. This was based on the formula: $PIP_1 = p_{det}Q_{max} + Q_{max}$ (Figure 4). PIP₁ responded less to small changes in contraction strength than those observed for isovolumetric pressures measured using mechanical interference. Table 2 presents a comparison between the three variables. They concluded that in the group of elderly women with urgency incontinence, 90% of baseline PIP₁ values were observed between 29 and 78 cm H₂O. Thus, "contractions with PIP₁ smaller than about 30 cm H₂O might be considered unusually weak"^[30].

Gotoh *et al.*^[32] studied the pathophysiology and subjective symptoms in 83 women with postvoid residual urine over 100 mL, most of whom had neurological diseases and postoperative problems after pelvic surgery. They defined impaired detrusor contraction in women who had Q_{max} less than 12 mL/s associated to $p_{det}Q_{max}$ less than 10 cm H₂O and significant rise in abdominal

pressure^[32]. In this study, the projected isovolumetric pressure to diagnose low detrusor contraction strength would be 20 cm H₂O, quite lower than the 30 cm H₂O proposed by Tan *et al.*^[30].

QUALITY CONTROL FOR PRESSURE-FLOW STUDIES IN WOMEN

The success of urodynamic studies depends on careful tuning of the equipment and strict quality control over each of the procedures. The ICS recommends using external transducers connected to fluid-filled tubings and catheters for intravesical and abdominal pressure recording. It also recommends circumspect and continuous observation of the signals as they are obtained and an ongoing assessment of their credibility to avoid artifacts which need to be corrected immediately, since they are difficult and often impossible to correct retrospectively^[33]. This is especially true in women if we consider that relatively small changes in detrusor pressure (*i.e.*, 15 cm H₂O) can change the diagnosis from BOO to DU. The urodynamicists needs to avoid: (1) Damping of the abdominal pressure measurement specially during straining to void because it can create false high detrusor pressures; and (2) the use of catheter-mounted transducers or air-filled catheters, in which case the detrusor pressure measured depends on the position of the tip of the catheter within the bladder, with up to 8-10 cm H₂O differences if the tip of the catheter is at the top or at the bottom of the bladder^[34,35]. Finally, it is important to remember that voluntary straining in healthy women can increase free Q_{max} by an average of 30%^[36], making diagnosis of voiding dysfunction even more challenging.

Table 3 summarizes the urodynamic criteria used to define BOO and DU in women.

CONCLUSION

PFS of micturition is the best method to quantitatively analyze voiding function. Voiding dynamics differ significantly between men and women and the established criteria for urodynamic diagnosis in men do not apply to women. Although attempts have been made to standardize the diagnosis BOO in women, currently there is no consensus. There is no standard urodynamic test to

Table 3 Urodynamic criteria to define bladder outlet obstruction and detrusor underactivity in women

Bladder outlet obstruction	
Cutoff criteria ^[21]	$p_{det}Q_{max} \geq 25 \text{ cm H}_2\text{O} + Q_{max} \leq 12 \text{ mL/s}$
Video-urodynamic criteria ^[23]	Radiographic evidence of obstruction between the bladder neck and distal urethra in the presence of a sustained detrusor contraction of any magnitude, usually associated with reduced or delayed urinary flow rate
Nomogram ^[24]	See Figure 3
Detrusor underactivity	
Projected isovolumetric pressure 1 ^[30]	$p_{det}Q_{max} + Q_{max} < 30 \text{ cm H}_2\text{O}$
Cutoff criteria ^[32]	$p_{det}Q_{max} < 10 \text{ cm H}_2\text{O} + Q_{max} < 12 \text{ mL/s}$ "and significant rise in abdominal pressure"

diagnose DU in women for which further investigations are needed. The diagnosis of voiding dysfunction in women is challenging and often involves consideration of clinical and radiographic data to make the final assessment.

REFERENCES

- Griffiths D, Höfner K, van Mastrigt R, Rollema HJ, Spångberg A, Gleason D. Standardization of terminology of lower urinary tract function: pressure-flow studies of voiding, urethral resistance, and urethral obstruction. International Continence Society Subcommittee on Standardization of Terminology of Pressure-Flow Studies. *Neurourol Urodyn* 1997; **16**: 1-18 [PMID: 9021786]
- Abrams P, Cardozo L, Fall M, Griffiths D, Rosier P, Ulmsten U, van Kerrebroeck P, Victor A, Wein A. The standardisation of terminology of lower urinary tract function: report from the Standardisation Sub-committee of the International Continence Society. *Neurourol Urodyn* 2002; **21**: 167-178 [PMID: 11857671]
- Haylen BT, de Ridder D, Freeman RM, Swift SE, Berghmans B, Lee J, Monga A, Petri E, Rizk DE, Sand PK, Schaer GN. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction. *Int Urogynecol J* 2010; **21**: 5-26 [PMID: 19937315 DOI: 10.1002/nau.20798]
- Abrams PH, Griffiths DJ. The assessment of prostatic obstruction from urodynamic measurements and from residual urine. *Br J Urol* 1979; **51**: 129-134 [PMID: 465971]
- Schäfer W. Principles and clinical application of advanced urodynamic analysis of voiding function. *Urol Clin North Am* 1990; **17**: 553-566 [PMID: 1695782]
- Schäfer W. Analysis of bladder-outlet function with the linearized passive urethral resistance relation, linPURR, and a disease-specific approach for grading obstruction: from complex to simple. *World J Urol* 1995; **13**: 47-58 [PMID: 7773317 DOI: 10.1007/BF00182666]
- Hill AV. The heat of shortening and the dynamic constants of muscle. *Proc R Soc London (Biol)* 1938; **126**: 136-193
- Griffiths DJ. Assessment of detrusor contraction strength or contractility. *Neurourol Urodyn* 1991; **10**: 1-18 [DOI: 10.1002/nau.1930100102]
- Griffiths D. Basics of pressure-flow studies. *World J Urol* 1995; **13**: 30-33 [PMID: 7773315]
- Griffiths DJ. The mechanics of the urethra and of micturition. *Br J Urol* 1973; **45**: 497-507 [PMID: 4270633]
- Griffiths DJ, van Mastrigt R. The routine assessment of detrusor contraction strength. *Neurourol Urodyn* 1985; **4**: 77-87
- Tanagho EA, Miller ER. Initiation of voiding. *Br J Urol* 1970; **42**: 175-183 [PMID: 5420157]
- Rud T, Ulmsten U, Andersson KE. Initiation of voiding in healthy women and those with stress incontinence. *Acta Obstet Gynecol Scand* 1978; **57**: 457-462 [PMID: 569418]
- Rud T, Ulmsten U, Westby M. Initiation of micturition: a study of combined urethrocystometry and urethrocystography in healthy and stress incontinent females. *Scand J Urol Nephrol* 1979; **13**: 259-264 [PMID: 575232]
- Karram MM, Partoll L, Bilotta V, Angel O. Factors affecting detrusor contraction strength during voiding in women. *Obstet Gynecol* 1997; **90**: 723-726 [PMID: 9351752]
- Pauwels E, De Laet K, De Wachter S, Wyndaele JJ. Healthy, middle-aged, history-free, continent women--do they strain to void? *J Urol* 2006; **175**: 1403-1407 [PMID: 16516008]
- Backman KA, von Garrelts B, Sundblad R. Micturition in normal women. Studies of pressure and flow. *Acta Chir Scand* 1966; **132**: 403-412 [PMID: 5969907]
- Blaivas J, Chancellor M, Weiss J, Verhaaren M. Atlas of urodynamics, 2nd ed. Oxford: Blackwell Publishing Ltd, 2007: 120-144
- Chassagne S, Bernier PA, Haab F, Roehrborn CG, Reisch JS, Zimmern PE. Proposed cutoff values to define bladder outlet obstruction in women. *Urology* 1998; **51**: 408-411 [PMID: 9510344]
- Lemack GE, Zimmern PE. Pressure flow analysis may aid in identifying women with outflow obstruction. *J Urol* 2000; **163**: 1823-1828 [PMID: 10799191]
- Defreitas GA, Zimmern PE, Lemack GE, Shariat SF. Refining diagnosis of anatomic female bladder outlet obstruction: comparison of pressure-flow study parameters in clinically obstructed women with those of normal controls. *Urology* 2004; **64**: 675-679; discussion 679-681 [PMID: 15491697]
- Haylen BT, Ashby D, Sutherst JR, Frazer MI, West CR. Maximum and average urine flow rates in normal male and female populations--the Liverpool nomograms. *Br J Urol* 1989; **64**: 30-38 [PMID: 2765766]
- Nitti VW, Tu LM, Gitlin J. Diagnosing bladder outlet obstruction in women. *J Urol* 1999; **161**: 1535-1540 [PMID: 10210391]
- Blaivas JG, Groutz A. Bladder outlet obstruction nomogram for women with lower urinary tract symptomatology. *Neurourol Urodyn* 2000; **19**: 553-564 [PMID: 11002298]
- Griffiths D. Detrusor contractility--order out of chaos. *Scand J Urol Nephrol Suppl* 2004; **215**: 93-100 [PMID: 15545203]
- van Koeveringe GA, Vahabi B, Andersson KE, Kirschner-Herrmans R, Oelke M. Detrusor underactivity: a plea for new approaches to a common bladder dysfunction. *Neurourol Urodyn* 2011; **30**: 723-728 [PMID: 21661020]
- Osman NI, Chapple CR, Abrams P, Dmochowski R, Haab F, Nitti V, Koelbl H, van Kerrebroeck P, Wein AJ. Detrusor underactivity and the underactive bladder: a new clinical entity? A review of current terminology, definitions, epidemiology, aetiology, and diagnosis. *Eur Urol* 2014; **65**: 389-398 [PMID: 24184024 DOI: 10.1016/j.eururo.2013.10.015]
- Tan TL, Bergmann M, Griffiths D, Resnick N. Detrusor contractility: order out of chaos. *Neurourol Urodyn* 2002; **21**: 339
- Tan TL, Bergmann MA, Griffiths D, Resnick NM. Which stop test is best? Measuring detrusor contractility in older females. *J Urol* 2003; **169**: 1023-1027 [PMID: 12576837]
- Tan TL, Bergmann MA, Griffiths D, Resnick NM. Stop test or pressure-flow study? Measuring detrusor contractility in older females. *Neurourol Urodyn* 2004; **23**: 184-189 [PMID: 15098212]
- Abrams P. Bladder outlet obstruction index, bladder contractility index and bladder voiding efficiency: three simple indices to define bladder voiding function. *BJU Int* 1999; **84**: 14-15 [PMID: 10444116]
- Gotoh M, Yoshikawa Y, Ohshima S. Pathophysiology and subjective symptoms in women with impaired bladder emptying. *Int J Urol* 2006; **13**: 1053-1057 [PMID: 16903929]

- 33 **Schäfer W**, Abrams P, Liao L, Mattiasson A, Pesce F, Spangberg A, Sterling AM, Zinner NR, van Kerrebroeck P. Good urodynamic practices: uroflowmetry, filling cystometry, and pressure-flow studies. *Neurourol Urodyn* 2002; **21**: 261-274 [PMID: 11948720]
- 34 **Abrams P**. Urodynamics. 3rd ed. London: Springer-Verlag, 2006
- 35 **Gammie A**, Clarkson B, Constantinou C, Damaser M, Drinnan M, Geleijnse G, Griffiths D, Rosier P, Schäfer W, Van Mastrigt R. International Continence Society guidelines on urodynamic equipment performance. *Neurourol Urodyn* 2014; **33**: 370-379 [PMID: 24390971 DOI: 10.1002/nau.22546]
- 36 **Devreese AM**, Nuyens G, Staes F, Vereecken RL, De Weerd W, Stappaerts K. Do posture and straining influence urinary-flow parameters in normal women? *Neurourol Urodyn* 2000; **19**: 3-8 [PMID: 10602243]

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