

# Pressure-flow nomogram for women with lower urinary tract symptoms

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## Abstract

**Introduction:** Results of urodynamic studies performed in female patients are often difficult to interpret. The objective of the study was to develop a nomogram that would help in diagnosing functional bladder outlet obstruction (BOO) in neurologically intact women with any kind of lower urinary tract symptoms.

**Material and methods:** From the urodynamic database adult women were chosen with maximal flow rate ( $Q_{max}$ )  $\leq 12$  ml/s in a pressure-flow study. Four criteria were used to identify a group of patients suspected of BOO: thickened bladder wall, presence of bladder diverticula, subjective improvement on  $\alpha$ -blockers and improvement of voiding symptoms on any form of treatment. The line separating high and low pressure zones on the pressure-flow chart was established according to the position of patients who met at least one of them.

**Results:** Sixty-seven patients were investigated. Twenty-one women met at least one of the specified criteria. They had significantly higher voiding pressures ( $p_{det(Q_{max})}$  35 cm H<sub>2</sub>O vs. 16.5 cm H<sub>2</sub>O;  $p = 0.002$ ). A new nomogram with one separating line ( $p_{det(Q_{max})} = 1.5 \times Q_{max} + 10$ ) was proposed. The difference in the distribution of women fulfilling the criteria between high pressure zone and low pressure zone was highly significant (19/35 vs. 2/32;  $p < 0.0001$ ). Sensitivity, specificity, positive and negative predictive values of our nomogram in identifying patients suspected of BOO was 90.5%, 65.2%, 54.3% and 94% respectively.

**Conclusions:** The new nomogram can be considered a screening test which efficiently excludes obstruction among women with low  $Q_{max}$  in a pressure-flow study.

**Key words:** female, nomograms, urinary bladder neck obstruction, urination disorders, urodynamics.

## Introduction

Lower urinary tract symptoms (LUTS) can be misleading and urodynamic studies often give unexpected results. Low maximal flow rate ( $Q_{max}$ ) found in a female patient is usually considered as one of them. The incidence of decreased flow rate in women is not clearly specified, and has been reported between 2.7% and 39%, depending on the population and the definition used [1, 2]. There are a number of conditions that may cause decreased urinary flow in female patients. Both anatomical (high grade cystocele, anti-incontinence procedure, urethral diverticulum, urethral stricture) and functional (dysfunctional voiding, primary bladder neck obstruction or subclinical neurogenic detrusor-sphincter dyssyner-

gy) obstruction may be responsible for that observation. Despite a number of rules and nomograms proposed so far for diagnosing bladder outlet obstruction in a female population, no universally accepted tool for the analysis of pressure-flow studies (PFS) in women exists [3–9]. Videourodynamics remains the gold standard but this examination is not performed routinely in most urodynamic units.

The aim of this study was to create a pressure-flow nomogram that would aid in diagnosing functional bladder outlet obstruction in neurologically intact women who undergo urodynamic examination of any kind of LUTS.

## Material and methods

The study was approved by the local Institutional Review Board. Written, informed consent was obtained from all patients participating in the study. The search in databases of two urodynamic units was done in order to find adult female patients with low  $Q_{max}$  on PFS, who underwent their examinations in the period 1997–2008. A threshold of  $Q_{max} \leq 12$  ml/s was used to ensure high sensitivity in selecting cases with voiding dysfunction. Patients with diseases of the central and peripheral nervous system (except for vertebral disc disease and diabetes mellitus without pronounced neurological deficits), with brain stroke in history, during pregnancy, with locally advanced or disseminated neoplastic processes, with severe heart or pulmonary failure, and with severe insufficiency of any other organ or system were excluded from the analysis. Furthermore, women after anti-incontinence procedures, with pelvic organ prolapse grade  $> 2$ , with urethral strictures or diverticula and with other anatomical forms of obstruction were also excluded. Those who met the criteria were contacted and invited for a check-up. Information on LUTS present at the time of urodynamic evaluation, evolution of their severity, therapies used, their subjective efficacy and coexistent diseases was gathered from urodynamic notes and data collected using structured questionnaires. Type and severity of LUTS present at the time of a follow-up visit were assessed by the Urogenital Distress Inventory-6 (UDI-6) and the International Prostate Symptoms Score (IPSS) questionnaires. The IPSS has the advantage of being more specific for voiding symptoms and it has already been used for quantifying LUTS in women [10, 11]. Ultrasound examination of the urinary tract was performed during follow-up visits for the evaluation of bladder wall thickness (BWT) and upper urinary tract. Serum creatinine was measured as a screening test for renal failure. History taking and completing questionnaires were the only obligatory elements of the follow-up. It was permissible to complete questionnaires and send

them by mail. Those women who chose this opportunity were also interviewed by phone.

Urodynamic studies (UDS) were performed using Duet® or Duet Encompass® units (Dantec, Skovlunde, Denmark) equipped with Duet v8.06 and v8.61 software (Dantec, Skovlunde, Denmark). Transducers were zeroed to atmospheric pressure at the level of the upper rim of the pubic bone. Seven Fr double lumen urethral catheters and balloon rectal catheters with water transducers were used.

All tracings were reassessed independently by two investigators. Differences were discussed and consensus values were used for further analysis. If reliable, values of  $Q_{max}$  and pressures were recorded. For all calculations in this study the amplitude of detrusor contraction was used instead of absolute detrusor pressure ( $p_{det}$ ) values. Special attention was paid to the correct  $p_{det}$  value when a significant  $p_{abd}$  decrease during voiding was observed. Manual smoothing of traces was done when necessary.

Ultrasound examination of the urinary tract was performed with the Voluson® 530D/MT system (Kretztechnik, Austria) and the 2–5 MHz probe (S-AB2-5 Kretztechnik, Austria). The BWT was measured with the same probe at a volume of 200–400 ml. The BWT of posterior or lateral walls more than 3 mm was regarded as abnormal.

Having all clinical data patients were divided into two groups: one consisting of patients with clinical signs or symptoms of bladder outlet obstruction (group O) and the other comprising all other patients (group N). The following criteria were applied for selection of group O: 1) thickened bladder wall, 2) bladder diverticula, 3) improvement of any LUTS when using  $\alpha$ -blockers; 4) improvement of voiding (obstructive) LUTS with any form of therapy. Women from both N and O groups were positioned on a pressure-flow (pQ) graph. The boundary that would separate patients from both groups most accurately was sought.

## Statistical analysis

Statistical calculations were performed with Statistica 9.0 software. Shapiro-Wilk test was used for testing normality. Mann-Whitney  $U$  test was used for checking significance of differences in continuous variables between independent groups. For dichotomous variables the  $\chi^2$ , the Yates' correction  $\chi^2$ , or the V-square test was used depending on the sample size and expected values. Statistical significance in this study was set at  $p < 0.05$ .

## Results

In our databases we identified 151 women with maximum flow rate  $\leq 12$  ml/s who account for

**Table I.** Values of urodynamic parameters for patients from O and N groups. For cm H<sub>2</sub>O, ml/s and ml median values are given

Variables	Group O					Group N	Value of <i>p</i> for O vs. N
	Total	Diverticula	BWT > 3 mm	Improvement on α-blockers	Improvement of obstructive symptoms		
Group size, <i>n</i>	21	1	5	13	13	46	–
$Q_{max}$ [ml/s]	8	8	8	8	8	10	0.6
$p_{det(Qmax)}$ [cm H <sub>2</sub> O]	35	26	40	32	35	16.5	0.002
$p_{detopen}$ [cm H <sub>2</sub> O]	31	27	40	28	31	17	0.02
$p_{det.max}$ [cm H <sub>2</sub> O]	42	32	41	42	43	23	0.006
$p_{ves(Qmax)}$ [cm H <sub>2</sub> O]	66	99	63	59	65	59	0.3
Patients using straining, <i>n</i> (%)	10 (48%)	1 (100%)	3 (60%)	6 (46%)	6 (46%)	21 (46%)	0.9
Voided volume [ml]	311	311	366	334	291	238	0.1
Post-void residual [ml]	29	148	0	60	0	116	0.8

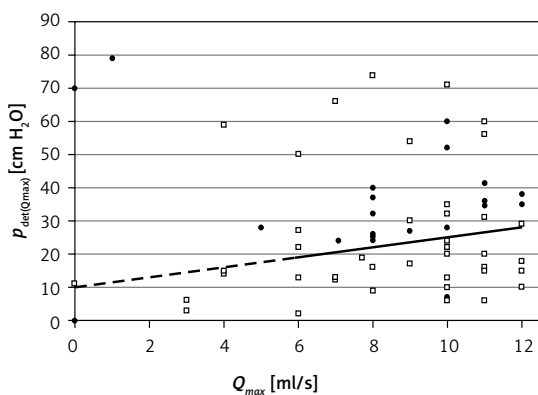
6.2% of 2453 female patients who underwent UDS in the period 1997–2008. Sixty-seven of those who met the inclusion and exclusion criteria underwent investigations described by the protocol. At the time of UDS the patients were at the age of 18 to 78 (median 53). The UDS revealed detrusor overactivity in 8 patients, reduced compliance of the bladder in 5 cases, and use of pronounced abdominal straining when voiding in 31 (46%) of those examined.

Median time from a baseline UDS study to a follow-up evaluation was 57 (35; 86) months. Forty-eight women attended the visit and underwent previously specified examinations. In 19 cases history taking and completing the questionnaires was done by mail and by phone. No case of upper urinary tract dilatation was found

on ultrasound examination. In 5 women BWT was > 3 mm and in 1 patient bladder diverticula were found. No case of postrenal kidney injury was diagnosed in the investigated group.

Twenty-one women who met at least one of the four defined criteria were included in group O while the remaining 46 women constituted group N. Medians of urodynamic parameters for both groups as well as for subgroups according to the criteria of choice for group O are presented in Table I. Three women who could not void were not excluded from the analysis. Their data were plotted on the graph as [0 ml/s;  $p_{det.max}$ ].

When values of  $Q_{max}$  and  $p_{det(Qmax)}$  of individual patients were plotted on a pressure-flow graph (Figure 1) we noted a distinctive distribution of patients from group O that let us draw one straight line constituting a lower border of the area where all but two of those patients were localized. The criteria used for establishing the parameters of the separating line were as follows: high sensitivity of the nomogram (limiting the number of false negative cases), the course of the line almost parallel to cases with the lowest  $p_{det(Qmax)}$  for each  $Q_{max}$ , a simple formula. The straight line described by the equation  $p_{det(Qmax)} = 1.5 \times Q_{max} + 10$  fulfilled all those conditions. The proposed nomogram consists of two zones. In the low pressure zone 32 patients were found including 2 from the O group. In the high pressure zone 35 patients were found including 16 from the N group. The difference in the distribution of patients from O and N groups was highly significant ( $p < 0.0001$ ). Based on those numbers, sensitivity, specificity and accuracy of our nomogram in identifying patients from the O group



**Figure 1.** Pressure-flow graph which shows values of  $Q_{max}$  and  $p_{det(Qmax)}$  of all patients. Empty squares (□) represent group N and black circles (●) group O. The boundary is described by the formula  $p_{det(Qmax)} = 1.5 \times Q_{max} + 10$

were calculated as 90.5%, 65.2% and 73.1%, respectively. Positive predictive value was 54.3% while negative predictive value was 94%. Instead of using the nomogram one can apply a formula: BOO possible if  $(p_{\text{det}(Q_{\text{max}})} - 1.5 \times Q_{\text{max}}) > 10$ .

Despite the wide range of  $p_{\text{det}(Q_{\text{max}})}$  among patients localized in the high pressure zone of the nomogram no distinctive clinical features were found to grade the obstruction.

Evaluation of symptoms with structured questionnaires revealed a trend towards a higher subjective improvement rate among patients with high voiding pressure. Despite that, the two groups did not differ significantly in type of symptoms present and reported at the final evaluation (Table II).

## Discussion

Diagnosing bladder outlet obstruction in women still remains an unsolved problem a challenge although many attempts have been made to deal with it. Videourodynamics is not available in many countries and, because of radiation exposure, it is not done routinely in most urodynamic units. The

BOO may be associated with a variety of LUTS; thus it may be found unexpectedly and a simple tool for analyzing PFS is desired. Some authors have suggested using cut-off values for  $Q_{\text{max}}$  or  $p_{\text{det}(Q_{\text{max}})}$  to screen for obstruction [4, 8], while Blaivas and Groutz constructed a nomogram using results of free uroflowmetry ( $Q_{\text{max}}$ ) and PFS ( $p_{\text{det},\text{max}}$ ) [5]. We made an attempt to create a new nomogram based on our data, being convinced that urethral resistance has to be calculated from values of  $Q_{\text{max}}$  and  $p_{\text{det}(Q_{\text{max}})}$  measured at the same time, and that a  $Q_{\text{max}}/p_{\text{det}(Q_{\text{max}})}$  ratio should be used to define obstruction. None of the available methods meet both conditions.

A group of patients with prospectively defined clinical features suggesting BOO let us create a nomogram that divides subjects with low  $Q_{\text{max}}$  at PFS into those with low and with high  $p_{\text{det}(Q_{\text{max}})}$ . The methodology used to develop the tool resembles that used by Blaivas and Groutz or by Abrams and Griffiths [5, 12]. Their nomograms were also based on retrospective groups of patients with bladder obstruction confirmed by other methods.

The decision to establish the separation line between the two zones may be a matter of dis-

**Table II.** Type, severity and incidence of LUTS. For presenting symptoms and for description of the LUTS dynamics, numbers and percentages of patients who reported them are given. More than one presenting symptom could be chosen. Incidence and severity of LUTS at follow-up are presented as medians of answers to specific questions of the UDI-6 questionnaire. UDI-Q1 – first question of the UDI-6, UDI-Q2 – second question of UDI-6, etc

Variable	Low pressure zone (n = 32)		High pressure zone (n = 35)		Value of p
Presenting symptoms:					
Weak stream	11	34%	23	66%	0.01
Frequency	17	53%	21	60%	0.6
Pain	14	44%	9	25%	0.1
Incontinence	7	22%	8	23%	0.9
At follow-up:					
UDI-Q1 (frequency)	2		2		0.3
UDI-Q2 (urgency UI)	0		0		0.5
UDI-Q3 (stress UI)	0		0		0.2
UDI-Q4 (dribbling)	0		0		0.7
UDI-Q5 (obstruction)	1		2		0.4
UDI-Q6 (pain)	1		1		0.5
Total IPSS	14.5		10		0.2
QoL	4		4		0.5
LUTS dynamics:					
Improvement	15	47%	22	63%	0.2
No change	12	37%	10	29%	0.4
Deterioration	5	16%	3	8%	0.6

cussion but both its slope and position roughly follow localization of O group patients with the lowest  $p_{\text{det}(Q_{\text{max}})}$  for a given  $Q_{\text{max}}$ . At least 2 cm H<sub>2</sub>O distance from the line to the nearest patient from the O group was used to increase sensitivity at the expense of lower specificity. With its very high negative predictive value, it can be considered a screening test which efficiently excludes obstruction, but does not allow the final diagnosis. Since there were few patients with  $Q_{\text{max}} < 6$  ml/s and none of them was from group O, the separating line for the range of 0–6 ml/s is an extrapolation of the line drawn for  $Q_{\text{max}}$  6–12 ml/s. The position of the boundary is close to the proposal of Lemack and Zimmern, who analyzed their patients with anatomical obstruction using receiver operating characteristic curves and found that the combination of  $Q_{\text{max}} \leq 11$  ml/s and  $p_{\text{det}(Q_{\text{max}})} \geq 21$  cm H<sub>2</sub>O gives the most accurate results [13]. Comparison with the only available nomogram for women by Blaivas and Groutz is not possible in our dataset. It can be done in a prospective study assessing their ability to predict a prespecified outcome.

Significant differences in clinical presentation may be observed between women divided by the nomogram. Women with low  $Q_{\text{max}}$  and high  $p_{\text{det}(Q_{\text{max}})}$  present more often with obstructive symptoms and tend to improve with time more often than patients with low  $p_{\text{det}(Q_{\text{max}})}$ , who suffer more often from frequency and pain (Table II). However, a significant minority presents with pronounced storage symptoms. Functional obstruction may trigger detrusor overactivity [14, 15], thus we suppose that our nomogram would help to identify patients with that type of symptoms who would respond to  $\alpha$ -blockade better than to anticholinergic therapy. Further work-up including cystourethrography, videourodynamics and endoscopy is often necessary for women with low  $Q_{\text{max}}$  and high voiding pressure. This observation may be explained by presence of different BOO forms, dysfunctional voiding and primary bladder neck obstruction being the most common [16]. Our nomogram cannot be used as a sole tool for qualifying to surgical treatment of BOO in women, since the type of the obstruction has to be well established first [17]. Women with low voiding pressure may be treated according to their symptoms, sparing the costs and bother caused by additional examinations.

In conclusion, this is the first pressure-flow nomogram aimed at a specific group of female patients with LUTS without anatomical obstruction or neurological disorders. We recommend using it as a screening tool for women with symptoms suggestive of BOO or low  $Q_{\text{max}}$  in PFS to exclude obstruction. Unless validated on other series of patients, one has to use this tool with caution.

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