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Urodynamic diagnosis of subvesical obstruction – significance of bladder outlet obstruction index and bladder contractility index

Urodinamska dijagnoza subvezikalne opstrukcije – značaj indeksa opstrukcije vrata mokraćne bešike i indeksa kontraktilnosti mokraćne bešike

Dimitrije Jeremić*†, Saša Vojinov*†, Stevan Stojanović*†, Ivan Levakov*†, Mladen Popov*†, Miloš Maletin*†, Ines Kalači†, Zoran Ružić‡, Tanja Lakić*§, Filip Dožić†, Dragan Grbić†

University of Novi Sad, *Faculty of Medicine, ‡Faculty of Agriculture, Department of Veterinary Medicine, Novi Sad, Serbia; University Clinical Center of Vojvodina, †Urology Clinic, §Center for Pathology and Histology, Novi Sad, Serbia

Abstract

Background/Aim. The bladder outlet obstruction (BOO) index (BOOI) is used during urodynamic testing to diagnose BOO. The bladder contractility index (BCI) is a urodynamic parameter used inconsistently. The aim of this study was to examine the correlation between BOOI and BCI. **Methods.** A retrospective study was conducted from 2021 to 2023, including 176 male patients. Using the *t*-test, analysis of variance, and correlation analysis, BOOI and BCI were analyzed. **Results.** High BOOI values (40–80) and weaker bladder contractility (BCI < 100), as potential causes of lower urinary tract symptoms (LUTS), coexisted in 11.37% of cases. A high BCI value (> 150) was associated with a significant number of patients (7.39%) with high BOOI values (> 40), acting as a compensatory mechanism that masked the true causes of LUTS. Patient groups with BCI < 100 and > 150 showed an inverse correlation with BOOI, as expected. Values of BOOI 20–39 and BCI 101–149 were considered a "gray zone". The correlation between $P_{det}Q_{max}$ and Q_{max} was not statistically significant (r = -0.2006), making BOO a factor that could influence this relationship. Additionally, the intraurethral catheter positioned during urodynamic testing significantly affected this correlation. As expected, a negative correlation was observed between Q_{max} and BOOI (r = -0.44841, $p < 0.001$), while BCI and Q_{max} had a positive linear correlation (R^2 = 0.2255, $p < 0.001$). The correlation between the two observed indices, BOOI and BCI, showed a positive linear correlation, presenting a physiological mechanism for BOO compensation (R^2 = 0.3292, $p < 0.001$). **Conclusion.** In combination with BCI, BOOI is sufficient for establishing a definitive diagnosis in the analyzed patient groups. It is recommended that BOOI, BCI, and Q_{max} always be used in combination. Q_{max}, as a measure mostly valued on uroflow, may be insufficient for diagnosis in unequivocal clinical cases.

Key words:
male; ureteral obstruction; urinary bladder; urination disorders.

Apstrakt

Uvod/Cilj. Indeks opstrukcije vrata mokraćne bešike [*bladder outlet obstruction* (*BOO*) *index* – BOOI] koristi se prilikom urodinamskog ispitivanja sa ciljem postavljanja dijagnoze BOO. Indeks kontraktilnosti mokraćne bešike (*bladder contractility index* – BCI) je urodinamski parametar koji se nekonzistentno koristi u praksi. Cilj rada bio je da se ispita korelacija između BOOI i BCI. **Metode.** Retrospektivna studija sprovedena je u periodu 2021–2023 godine i obuhvatila je 176 bolesnika muškog pola. Korišćenjem *t*-testa, analize varijanse i analize korelacije, analizirani su BOOI i BCI. **Rezultati.** Visoke vrednosti BOOI (40–80) i slabija kontraktilnost bešike (BCI < 100), kao mogući uzročnici simptoma od strane donjeg urinarnog trakta (*lower urinary tract symptoms* – LUTS) koegzistirale su u 11,37% slučajeva. Visoka vrednost BCI (> 150) povezana je sa značajnim brojem bolesnika (7,39%) sa visokim vrednostima BOOI (> 40), delujući kao kompenzatorni mehanizam koji prikriva prave uzroke LUTS. U grupama bolesnika sa BCI < 100 i > 150 pokazana je obrnuta korelacija sa BOOI, kao što je i očekivano. Vrednosti BOOI 20–39 i BCI 101–149 smatrane su „sivom zonom". Korelacija $P_{det}Q_{max}$ i Q_{max} nije pokazala statističku značajnost (r = -0,2006), što čini BOO faktorom koji može uticati na ovaj odnos. Pored ovoga, intrauretralni kateter postavljen tokom urodinamskog ispitivanja značajno je uticao na ovaj odnos. Kao što je očekivano, uočena je negativna korelacija između Q_{max} i BOOI (r = -0,44841, p < 0,001), dok su BCI i Q_{max}

Correspondence to: Dimitrije Jeremić, University of Novi Sad, Faculty of Medicine, Hajduk Veljkova 3, 21 000 Novi Sad, Serbia. E-mail: dimitrije.jeremic@mf.uns.ac.rs

imale pozitivnu linearnu korelaciju (R^2 = 0,2255, p < 0,001). Korelacija između dva ispitivana indeksa, BOOI i BCI, pokazala je pozitivnu linearnu povezanost, što ukazuje na postojanje fiziološkog mehanizma za kompenzaciju BOO (R^2 = 0,3292, p < 0,001). **Zaključak.** U kombinaciji sa BCI, BOOI je dovoljan za postavljanje definitivne dijagnoze u posmatranim grupama bolesnika. Preporuka je da se BOOI, BCI i Q_{max} uvek koriste u kombinaciji. Q_{max}, kao mera koja se najviše analizira prilikom urofloumetrije, može biti nedovoljna za dijagnozu u jasnim kliničkim slučajevima.

Ključne reči:
muškarci; ureter, opstrukcija; mokraćna bešika; mokrenje, poremećaji.

Introduction

The term lower urinary tract symptoms (LUTS) is generic and encompasses storage, voiding, and post-micturition symptoms, with a multifactorial etiology. Bladder outlet obstruction (BOO) refers to subvesical obstruction, also multifactorial in origin, and is defined by reduced urinary flow rate and increased detrusor pressure [1]. By its nature, BOO can be caused by a variety of causes, divided into two groups: anatomic and functional. Anatomic obstruction is mainly caused by benign prostatic enlargement (BPE), resulting in benign prostatic obstruction (BPO), bladder neck sclerosis, and urethral strictures. Functional BOO can be caused by detrusor-sphincter dyssynergia, functional obstruction of the bladder neck, and dysfunctional voiding. Histological diagnosis of benign prostatic hyperplasia (BPH) and consequent BPE/BPO results in elevation in detrusor pressure during voiding and clinically presents as a combination of obstructive and irritative symptoms of LUTS [2]. Detrusor underactivity (DU) has been defined by the International Continence Society (ICS) as a low detrusor pressure or short detrusor contraction resulting in prolonged bladder emptying and/or a failure to achieve complete bladder emptying within a normal time span. It is a common finding in 11–40% of aging males [3]. Its clinical presentation is similar to BPO, manifesting as obstructive, irritative voiding symptoms or their combination, making it hard to distinguish BOO from DU. Urodynamic studies are not recommended as part of the routine diagnostic algorithm prior to operative treatment for BPO [4].

Although BOO index (BOOI) determines the degree of BOO, it is important to identify patients with DU in order to improve the results of de-obstructive surgery [3]. Since BOOI is widely used during urodynamics, it is essential to define parameters and urodynamic findings, such as bladder contractility (BC) index (BCI), which can help identify men without DU who will benefit most from operative de-obstructive surgery.

The aim of this study was to assess BOOI and BCI and their correlation. The analysis focused primarily on the relationship between BOOI and BCI, but also on the precise correlation between Q_{max} and $P_{det}Q_{max}$. Considering that DU may significantly complicate the evaluation of patients using uroflowmetry and urodynamics, correlations between BOOI/Q_{max} and BCI/Q_{max} were also examined.

Methods

This single-center, retrospective observational cohort study included 176 male patients in a three-year period from 2021 to 2023. The study was conducted at the University Clinical Center of Vojvodina, Novi Sad, Serbia, and it was approved by the Ethics Committee of the University Clinical Center of Vojvodina (No. 00-292, from August 26, 2024).

Inclusion criteria were as follows: patients aged between 50 and 80 years; age-adjusted prostate-specific antigen (PSA) < 2.6 ng/mL for patients aged 50–60 years and < 4 ng/mL for those older than 60 years; International Prostate Symptom Score (IPSS) ≤ 18; prostate volume between 40 and 80 mL; intravesical prostatic protrusion grade 0 or 1; residual urine < 100 mL; uroflowmetry Q_{max} < 10 mL/s; obstructive pattern of voiding on uroflowmetry; negative urine culture in previous 14 days; no prior medical treatment or treatment limited to phytotherapy or an alpha blocker (tamsulosin); completed urethrocystoscopy.

Exclusion criteria included: patients aged < 50 or > 80 years; PSA > 4 ng/mL; IPSS > 19; prostate volume < 40 or > 80 mL; residual urine > 100 mL; Q_{max} > 10 mL/s; normal voiding pattern on uroflowmetry; treatment with 5-alpha reductase inhibitors or previous prostate surgery; positive urine culture.

All patients underwent urodynamics analysis using the Medical Measurement System Software (MMS) Solar Blue, Enschede, the Netherlands. Patients were positioned supine, and all urodynamics recordings consisted of cystometry and pressure-flow study (filling and voiding phase). BOOI and BCI values were subsequently calculated.

Subvesical obstruction is defined by the BOOI on urodynamics, calculated using the equation: BOOI = $P_{det}Q_{max}$ - $2Q_{max}$, where P_{det} is detrusor pressure at peak flow rate and Q_{max} is the peak flow rate [5] (Table 1) (Figure 1).

Table 1
Subvesical obstruction defined by BOOI

BOOI	Inference
< 20	Unobstructed
20–40	Equivocal
> 40	Obstructed

BOOI – bladder outlet obstruction index; P_{det} – detrusor pressure at the peak flow rate; Q_{max} – peak flow rate; ICS – International Continence Society.
***Note*: BOOI = $P_{det}Q_{max}$ - $2Q_{max}$ according to ICS.**

BCI is a urodynamic parameter that represents the strength of BC, calculated using the formula: BCI = $P_{det}Q_{max}$

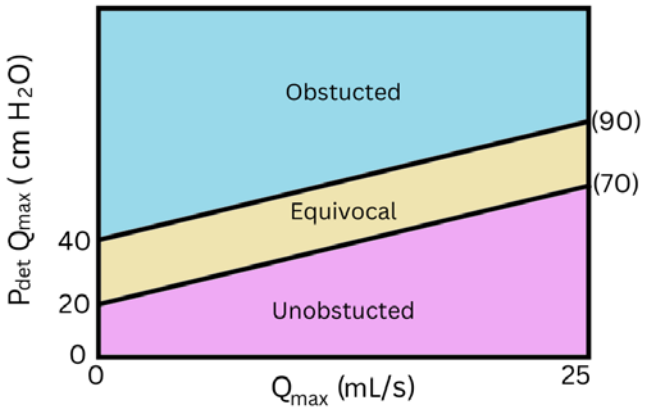

Fig. 1 – Presentation of the BOOI nomogram according to ICS. For abbreviations, see Table 1.

Table 2

Bladder contractility index (BCI) according to ICS

BCI	Contractility
> 150	Strong
100–150	Normal
< 150	Weak

***Note*: BCI is calculated as follows: BCI = $P_{det}Q_{max}$ + 5Q_{max}.**
For abbreviations, see Table 1.

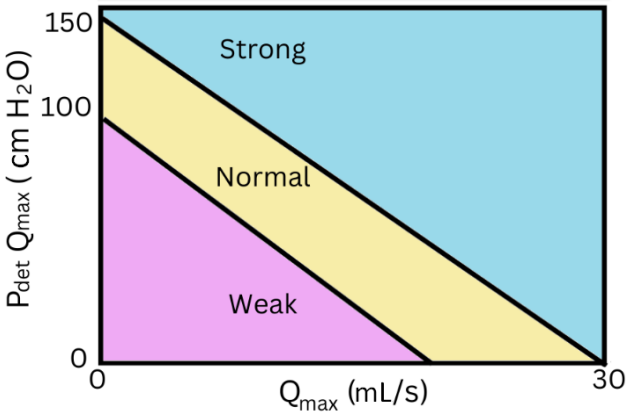

Fig. 2 – Presentation of bladder contractility normogram according to ICS. For abbreviations, see Table 1.

+ 5Q_{max} [5]. The results can be divided into three groups: strong, normal, and weak (Table 2) (Figure 2).

Statistical analysis

All statistical analyses were conducted using R Statistical Software (v4.1.2; R Core Team 2021). The independent samples *t*-test was applied to compare continuous variables between two independent groups, while analysis of variance (ANOVA) was employed for comparison across different patient categories based on BOO and BC. To assess associations between different urodynamic parameters—BOOI, BCI, $P_{det}Q_{max}$, and Q_{max}—correlation analysis was performed. The value of $p < 0.01$ was considered statistically significant.

Results

After the collection of data, patients were divided into nine groups according to values of BOOI and BCI (Figure 3).

High values of BOOI (> 40) could be accompanied by weak BC (BCI < 100) in 11.37% of patients (Group 9*), suggesting a possible cause of LUTS (Table 3). Strong BC (BCI > 150) was associated with BOOI > 40 in a significant number of patients (7.39%), showing that a strong BC might

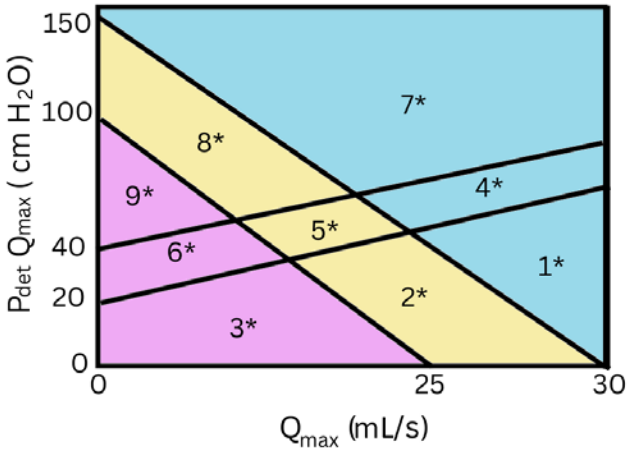

Fig. 3 – Composite nomogram permitting categorization of patients into nine zones based on the BOOI and BCI, with Q_{max} on the abscissa and $P_{det}Q_{max}$ on the ordinate. For abbreviations, see Tables 1 and 2.
***Note*: The asterisk (*) represents a legend for each group, and numbers from 1 to 9 represent groups of patients.**

Table 3

BOOI and BCI correlation

Parametres	BCI					
	≤ 100		101–149		≥ 150	
BOOI						
> 80	9*	0 (0)	8*	11 (6.25)	7*	10 (5.68)
60–80	9*	2 (1.14)	8*	7 (3.98)	7*	2 (1.14)
40–59	9*	18 (10.23)	8*	15 (8.52)	7*	1 (0.57)
20–39	6*	23 (13.07)	5*	17 (9.66)	4*	2 (1.14)
< 20	3*	40 (22.73)	2*	25 (14.21)	1*	3 (1.70)

For abbreviations, see Tables 1 and 2.
All values are given as numbers (percentages).
***Note*: The asterisk (*) represents a legend for each group, and numbers from 1 to 9 represent groups of patients.**

Table 4

Patients were divided into nine categories according to BOOI and BCI

Group	BOOI	BCI	Number of patients (%)
1*	< 20	≥ 150	3 (1.7)
2*	< 20	101–149	25 (14.21)
3*	< 20	≤ 100	40 (22.73)
4*	20–39	≥150	2 (1.14)
5*	20–39	101–149	17 (9.66)
6*	20–39	≤ 100	23 (13.07)
7*	> 40	≥150	13 (7.39)
8*	> 40	101–149	33 (18.73)
9*	> 40	≤ 100	20 (11.37)

For abbreviations, see Tables 1 and 2.
***Note*: The asterisk (*) represents a legend for each group, and numbers from 1 to 9 represent groups of patients.**

serve as a compensating mechanism of severe BPO (Group 7*). Group of patients with BOOI 20–39 and BCI 101–149 (Group 5*) could be considered "gray zone" depending on the level of other observed values for definitive clinical interpretation. This zone is particularly important in clinical decision-making and everyday practice. For better visualization of trends, patients with BOOI > 40 were further subdivided into three groups: BOOI 40–59, BOOI 60–80, and BOOI > 80, corresponding to Groups 9*, 8*, and 7* depending on BCI values. Among patients (6.25%) with BOOI > 80 and BCI values between 101–149, distinguishing whether LUTS was primarily due to BOO or BC became more challenging. As expected, groups with BCI < 100 and >150 showed an inverse correlation with BOOI.

Patients were divided into nine categories, ranging from Group 1* with no evident obstruction and preserved BC to Group 9* with evident obstruction and decreased contractility (Table 4).

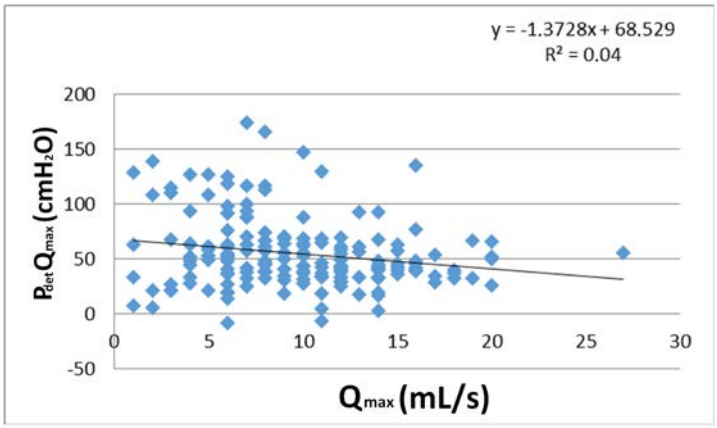

Fig. 4 – Q_{max} and $P_{det}Q_{max}$ correlation.
For abbreviations, see Table 1.

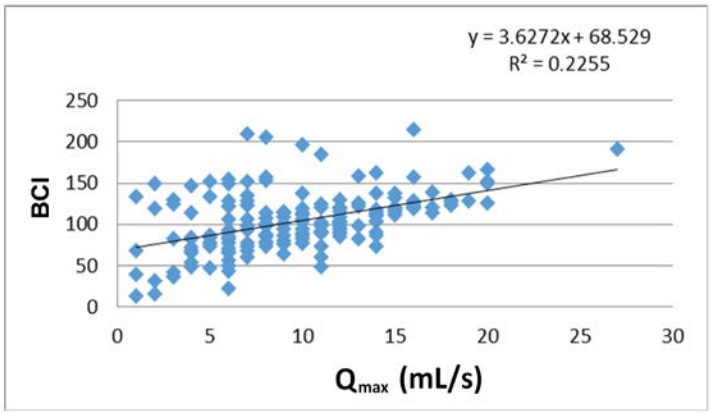

Fig. 5 – BCI and Q_{max} correlation.
For abbreviations, see Tables 1 and 2.

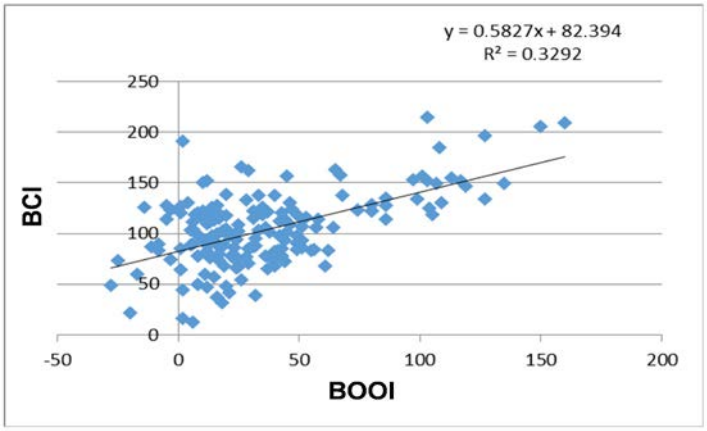

Fig. 6 – BOOI and BCI correlation.
For abbreviations, see Tables 1 and 2.

Analysis of $P_{det}Q_{max}$ and Q_{max} showed no statistically significant correlation (r = -0.2006) (Figure 4).

A slightly negative correlation could be observed between Q_{max} and BOOI (r = -0.44841, $p < 0.001$).

To assess the effect of BC on maximal flow, BCI and Q_{max} were analyzed, showing a positive correlation (R^2 = 0.2255, $p < 0.001$) (Figure 5).

A positive linear correlation between the observed indices BOOI and BCI was found (R^2 = 0.3292, $p < 0.001$) (Figure 6). Although there was linear correlation between all observed parameters, it was evident that this linear dependence was not strong enough to rely on a single parameter, emphasizing the need to assess both parameters routinely.

Discussion

DU is a frequent disorder affecting both male and female patients, causing significant morbidity and a reduction in quality of life. Its prevalence is surprisingly high, affecting 40.2% of male and 13.3% of female patients undergoing urodynamic studies for LUTS without any identifiable anatomical cause [6]. DU is defined as a contraction of reduced strength and/or duration, resulting in inadequate bladder emptying [7]. The most common symptoms related to DU include incomplete emptying, prolonged voiding, weak stream, hesitancy, and bladder hyposensitivity.

BOO, as defined by the ICS, is characterized as elevated detrusor pressure with reduced urine flow rate due to subvesical obstruction on urodynamic studies during the voiding phase. Subvesical obstruction is a polymorph in origin; the most frequent cause of subvesical obstruction in elderly males is caused by BPH, subsequent BPE, and resulting BPO [8].

The coexistence of BOO and DU presents a challenge for accurate diagnosis and treatment. Since DU has a high prevalence in concordance with BOO, it is important to identify patients with coexisting DU, making treatment options for BPH, as the most frequent cause of BOO, much more effective. Although some studies have investigated DU as a consequence of long-term BOO, no direct causal relationship has been established [9, 10]. On the other hand, long-term obstruction does lead to detrusor hypertrophy, changes in vasculature and innervation, possibly leading to detrusor overactivity and DU. Without treatment, long-term obstruction will lead to deterioration of detrusor function and decompensation. Recent studies, though limited, confirmed low levels of urothelial E-cadherin expression and increased expression of β3 and M3 in a group of patients with BOO and DU compared to patients with BOO and normal detrusor contractility [11]. The deposition of collagen in the detrusor may be a point at which DU persists despite de-obstructive treatment [12]. Transurethral resection of the prostate (TURP) and laser prostatectomy are recommended and effective treatment options for BPO unresponsive to medical therapy; however, unrecognized DU is a factor that can decrease the efficiency of operative treatment.

In our study, among the group of patients with BCI ≤ 149, it is evident that as the BOOI level decreases, the number of patients increases. This suggests that patients with weaker BC often do not have substantial subvesical obstruction, meaning that routine operative de-obstruction would not provide the expected improvement in voiding [13]. The group of patients with BCI 101–149 gives us a much sparser patient distribution. In a group of patients with BCI ≥ 150, the correlation was inverse to that seen in the BCI ≤ 149 group. This correlation may be a manifestation of activated bladder compensation mechanisms in order to overcome significant subvesical obstruction, eventually leading to possible bladder decompensation and obstructive consequences to the upper urinary tract [14, 15].

There is an ongoing debate regarding the exact mechanism of DU as a consequence of BOO, with hyperplasia and hypertrophy being the primary mechanisms. Further, myocyte damage may be provoked by reactive oxygen species, which damage muscle fibers, leading to the deposition of collagen, extracellular matrix remodeling, and ultimately, decompensation [14, 16]. In a study by Yang et al. [17] analyzing predictive factors for alleviation of LUTS symptoms after bipolar TURP, BCI and BOOI, among others, were identified as important predictors of the level of improvement following operative de-obstruction. A combination of BOOI and BCI is recommended in everyday use, as it enables the identification of patients who are most likely to benefit from surgery.

Q_{max} is the most valued and observed uroflowmetry parameter. According to the ICS, the Q_{max} cut-off of 10mL/s has a 47.0% sensitivity and a 70.0% specificity for diagnosing BOO [18]. A meta-analysis of 16 studies found that the Q_{max} value of 10 mL/s had a sensitivity and specificity of 68.3% and 70.5%, respectively, for the diagnosis of BOO [19]. $P_{det}Q_{max}$ represents intravesical pressure and is directly related to BC, but indirectly represents the degree of bladder outlet resistance (the more pronounced BOO, the higher the elevation in $P_{det}Q_{max}$). No statistically significant correlation was observed between $P_{det}Q_{max}$ and Q_{max}. In a study conducted by Tammela et al. [20], 216 patients in 11 centers were evaluated, and no statistically significant correlation was found between $P_{det}Q_{max}$ and Q_{max}.

BOOI, as a parameter of subvesical obstruction, was correlated to Q_{max}. When BC is normal, it is presumed that there is an inverse correlation: when BOOI is higher, a lower Q_{max} can be expected. Results of this study showed that Q_{max} and BOOI have a slight inverse correlation (r = -0.44841, $p < 0.001$). Since those two parameters should have a strong inverse correlation, we must presume that there is a contributing factor responsible for this weak interdependence. An additional factor that may lead to oscillation in BOOI and Q_{max} correlation is detrusor contractility and BCI. If we consider a high prevalence of DU, this may be a frequent and significant factor leading to a decrease in Q_{max}, despite lower values of BOOI. It is implied that BOOI, BCI, and Q_{max} are good prognostic factors of LUTS improvement after operative de-obstruction [21].

In order to assess the influence of BC on maximal flow, BCI and Q_{max} were correlated, and the analysis showed a statistically significant positive correlation (R^2 = 0.2255, $p < 0.001$). A positive correlation between higher Q_{max} and higher BCI is expected; however, this is not always observed in urodynamic analysis. The degree of BOO can influence and alter this correlation [22]. Van Dort et al. [23] found statistically significant differences in prostate size, as well as differences in urodynamic parameters between constrictive and compressive BOO. The findings of this study may provide the missing link, offering an elegant explanation for obstructive voiding difficulties in a subgroup of patients with small prostates.

Although a positive linear correlation between the observed parameters (BOOI and BCI) was found

($R^2 = 0.3292$, $p < 0.001$), it is evident that this linear dependence is insufficient for just one parameter to be observed and utilized. This emphasizes the need to assess both parameters regularly, especially in complicated, specific groups of patients with neurological LUTS [24, 25].

Conclusion

Patients with BCI ≤ 149 and BOOI in the unobstructed range would not have benefited from operative de-obstruction. In contrast, patients with BCI ≥ 150 showed an inverse correlation compared to the group with BCI ≤ 149. This is a group that would benefit the most from operative de-obstruction, possibly due to an activated bladder compensatory mechanism, but demanding in terms of diagnosis. As the bladder outlet and urethra are more than a rigid tube, elasticity and compression of surrounding tissue may contribute to the weak correlation between $P_{det}Q_{max}$ and Q_{max}. It is presumed that BOOI and Q_{max} should be in strong inverse correlation, but the results of this study showed that there is just a weak inverse correlation, bringing other factors into focus (BC and degree of BOO). BCI showed a positive correlation with values of Q_{max}. A positive linear correlation was also found between BOOI and BCI, but it is not sufficient to rely on a single parameter.

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