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Small prostate associated with higher incidence of detrusor underactivity and tendency of combination with bladder stone in patients with bladder outlet obstruction

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Abstract

Benign prostate hyperplasia is the leading cause of lower urinary tract symptoms due to bladder outlet obstruction (BOO) in elderly male patients. The impact of prostate volume (PV) on clinical and urodynamic characteristics was evaluated in those patients with BOO requiring prostate de-obstruction maneuvers in this study. We retrospectively reviewed the clinical data of 301 patients underwent transurethral resection of prostate due to combination with urinary retention (UR) alone and bladder stone (BS) alone. The present study investigated the differences of subjective symptoms, sonographic parameters, and urodynamic characters and assessed the proportion of UR to BS as well as the incidence of detrusor underactivity (DU) in those patients according to PV. There was not a difference of age, international prostate symptoms scores, post-voiding residual, and peak flow rate (Qmax) among 3 groups (all $P > .05$), whereas increasing of intravesical prostate protrusion (IPP), bladder wall thick (BWT), detrusor pressure at Qmax, bladder contractility index, bladder outlet obstruction index (BOOI), and quality of life scores with enlargement of PV was found (all $P < .05$). Correlations between PV and IPP ($R = 0.251$), Qmax ($R = -0.188$), post-voiding residual ($R = 0.215$), BWT ($R = 0.170$), and quality of life scores ($R = 0.165$) at large prostate and relationships between BWT and BOOI ($R = 0.246$) and bladder contractility index ($R = 0.239$) in moderate prostate as well as IPP and BOOI ($R = 0.204$) in large prostate were significantly found (all $P < .05$). Significant higher proportion of UR was found in patients with moderate (18%) and large prostate (47.6%) when compared to that of small prostate (3.7%), whereas higher proportion of BS was found in patients with small prostate (96.7%) compared to that of moderate (82%) and large (52.4%) prostate. Lower incidence of DU was discovered in large prostate (31.9%) compared with small (55.6%) and moderate (47.2%) prostate. BOO patients with small prostate were associated with less severity of BOO but higher incidence of DU and had a tendency of occurrence of BS, which gave a support for the theory that multifactor involved in the formation of BS rather than BOO only.

Abbreviations: BCI = bladder contractility index, BOO = bladder outlet obstruction, BOOI = bladder outlet obstruction index, BPH = benign prostate hyperplasia, BPO = benign prostate obstruction, BS = bladder stone, BWT = bladder wall thick, DU = detrusor underactivity, IPP = intravesical prostate protrusion, IPSS = International prostate symptoms scores, LUTS = lower urinary tract symptoms, MetS = metabolic syndrome, Pdet.Qmax = detrusor pressure at Qmax, PFS = pressure-flow studies, PV = Prostate volume, PVR = post-voiding residual, Qmax = peak flow rate, QOL = quality of life scores, SVUDS = sonography videourodynamic studies, TURP = transurethral resection of prostate, UDS = urodynamic studies, UR = urinary retention.

Keywords: bladder outlet obstruction, bladder stone, detrusor underactivity, prostate volume, urinary retention, sonography videourodynamic studies

NX and GG contributed equally to this work.

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1. Introduction

Benign prostate hyperplasia (BPH) is a histologic diagnosis, which is defined as the proliferation of smooth muscle, connective tissue, and grandular epithelial cells within the prostatic transition zone, in the aging male with increasing prevalence that starting at more than age 40 years and reaching 60% at age 60 and 80% at age 80.[1,2] As enlargement of prostate size, mechanical obstruction may result from intrusion into the urethral lumen or bladder neck that lead to bladder outlet obstruction (BOO), which is urodynamically diagnosed by invasive pressure-flow studies (PFS), and lower urinary tract symptoms (LUTS) resulting from the secondary response of bladder detrusor to overcome BOO may be complained, if persistent, bladder dysfunction and renal impairment can eventually occur.[3]

In the recent decades, no strong correlation between prostate size and LUTS has been found despite several studies conducted across the world, and the consensus of LUTS independent of BPH is globally gaining acceptance.[4] However, prostate size is a predictor of progression of benign prostate obstruction (BPO), and higher incidence of decreased flow rates and acute urinary retention was reported in men with prostate volume (PV) ≥ 30 mL compared to < 30 mL.[5] Urodynamic studies (UDS) is considered "golden standard" for evaluating BOO and play an important role in clarification of pathophysiology of LUTS and similar urodynamic dysfunction of BOO patients with small PV(<30 mL) was found compared to those with large PV.[6] Therefore, it has been obvious that interrelations among BPH, LUTS, BOO, and PV are complicated.

Surgical options should be considered if medical treatments fail to relieve LUTS suggestive of BPO or some secondary issues, including recurrent or refractory urinary retention, bladder stone (BS), refractory macrohematuria and recurrent urinary infections.[7] Establishing the causes and extent of BOO is of paramount important for management decision, especially when surgical options is considered, since improvement are reportedly obtained in male patients with ascertained BOO.[2] As multichannel UDS is not the preferred method due to invasive nature, several noninvasive indices, including prostatic urethral length, resistive index of the prostate, bladder sonomorphologic parameters, bladder neck angle, intravesical prostatic protrusion (IPP), and voiding diary, were investigated and reportedly associated with BOO in patient with LUTS suggestive of BPH.[5,8–11]

To best of our knowledge, no noninvasive variables can replace the multichannel UDS in evaluation of BOO and bladder detrusor underactivity (DU) and interrelations among PV, non-invasions indices, clinical and urodynamic features are not available in the literature enrolled patients with BOO requiring prostate de-obstruction interventions. In the present study, the relationship between sonomorphological parameters and invasive indices measured by sonography videourodynamic studies (SVUDS) according to PV were evaluated. Subsequently, we assessed the proportion of urinary retention (UR) alone to BS alone, and DU in those patients with urodynamically diagnosed BOO and underwent surgical treatment.

2. Materials and methods

We retrospectively reviewed medical data of ≥60 years old male patients with urodynamically and preoperatively proved BOO, who underwent transurethral resection of prostate due to UR alone or combination of transurethral resection of prostate (TURP) and cystolitholapaxy due to BS alone from August 2019 to January 2023 at Shaoyang Central Hospital. The ethical committee of the Central Hospital of Shaoyang approved this study program (KY 2023-002-07) and we obtained informed consent from each patient. A detailed clinical evaluation was performed, including a complete history, physical examination, urinalysis, symptom quantification with the International Prostate Symptom Score (IPSS), and quality of life (QOL). Exclusion criteria in the present study included voiding volume <150 mL, previous prostatic surgery, urethral stenosis, neurogenic bladder, utilization of medication that affects micturition, proven prostate or bladder carcinoma, and pelvic radiotherapy. Patients with abnormal urinalysis received treatment prior to TURP.

The SVUDS combined an ultrasound scan with multichannel UDS (Andromeda, German) and could synchronously integrate urodynamic measurement values with sonographic images sequences by own software (AUDACT 7.17.5). PV, IPP, and bladder wall thickness (BWT) were measured by a single urologist through transabdominal ultrasound scan (Mindray, ShenZhen, China) at a bladder volume of 150 to 200 mL using 4-MHz curvilinear probe during SVUDS according to the previous reports.[12] Peak flow rate (Qmax) was measured by uroflowmetry. The SVUDS determined detrusor pressure at Qmax (Pdet.Qmax), BOO index (BOOI; calculated as Pdet.Qmax – 2Qmax) and bladder contractility index (BCI; calculated as Pdet.Qmax + 5Qmax). A BOOI of > 40 indicates definite BOO, 20 to 40 is equivocal and < 20 indicates no BOO.[5] A BCI < 100 is considered as a diagnosis of DU. In this study, the BOOI of all enrolled patient are more than 40. All SVUDS were underwent by a urologist (Ning Xiao) in accordance with the Good urodynamic Practices of International Continence Society.[13]

After measurement of PV, patients were divided into 3 groups according to PV and previous study conducted by Aprikian et al (Group 1, small volume, PV < 30 mL; Group 2, moderate volume, 30 mL ≤ PV ≤ 60 mL; Group 3, large volume, PV > 60 mL).[14] Mann–Whitney *U* test was conducted to determine the differences in age, IPSS, QOL, IPP, BWT, Qmax, BOOI, and BCI among 3 groups. The proportion of UR alone or BS alone and the incidence of DU were compared among 3 groups using chi-square test. Distribution-free Spearman correlation test was used to measure the relationships between invasive UDS indices and sonomorphologic parameters determined during SVUDS in each group. All statistical analyses were performed using SPSS for Windows (version 27.0, Statistical Package for Social Science, Chicago, IL). A *P* value of <.05 was considered statistically significant.

3. Results

A total of 301 consecutive male patients were included in this analysis. Patients characteristics were: age, 71years (25–75th percentile, 65–76); PV, 65 mL (25–75th percentile, 46–90); IPSS score, 22 (25–75th percentile, 16–28); QOL score, 5 (25–75th percentile, 4–6); IPP, 1.8 cm (25–75th percentile, 1.1–2.5); BWT, 4.25 mm (25–75th percentile, 3.5–5.2); PVR, 62 mL (25–75th percentile, 20–129); Qmax, 6 mL /s (25–75th percentile, 3.9–8.15); Pdet.Qmax, 73.2 cm H_2O (25–75th percentile, 62.8–88.6); BOOI, 60 (25–75th percentile, 48.3–76.9); BCI, 106.6 (25–75th percentile, 90.7–124.9).

The characteristics of 3 groups of enrolled patients (n = 301) are summarized in Table 1. No differences in age, IPSS, PVR, and Qmax among 3 groups were found (all *P* > .05), whereas IPP, BWT, Pdet.Qmax, BCI, and BOOI increased significantly with enlargement of PV (all *P* < .01), and increasing in QOL was also found (*P* = .025), as indicated in Table 1 and Figure 1. Although higher Pdet.Qmax, BCI, and BOOI in patients with large volume prostate were discovered compared to respectively small and moderate prostate (all *P* < .01), its differences between small and moderate prostate were not found (all *P* > .05).

Table 2 showed correlations between PV and noninvasive clinical indices, including IPP, Qmax, PVR, BWT, IPSS, and QOL according to prostate volume. No correlation between PV and these indices was demonstrated in small prostate, and only PV was positively related to IPP (*R* = 0.262) in moderate prostate. Whereas, correlations between PV and IPP (*R* = 0.251), Qmax (*R* = -0.188), PVR (*R* = 0.215), BWT (*R* = 0.170), and

Table 1

Clinical, sonomorphologic, and urodynamic characteristics of all patients.

	Group 1	Group 2	Group 3	*P*
	(n = 27)	(n = 89)	(n = 185)	
Age	66 (60, 73)	68.5 (65, 75)	71 (67, 77)	.061
IPSS	23 (17, 28)	23 (17, 29)	22 (15, 27)	.264
QOL	4 (4, 6)	5 (4, 6)	5 (4, 6)	.025
IPP	0.88 (0, 1)	1.39 (1, 1.89)	2.3 (1.7, 2.8)	<.01
BWT	3.5 (3.2, 3.6)	4.0 (3.4, 5.0)	4.8 (4.0, 5.6)	<.01
PVR	35 (15, 60)	70 (10, 130)	70 (25, 129)	.110
Qmax	6.4 (4.1, 9.7)	5.75 (3.9, 7.9)	6.5 (3.9, 8.3)	.677
Pdet.Qmax	71.6 (61.9, 75.8)	71.9 (60.7, 84.7)	76.1 (65.8, 94.9)	<.01
BCI	103.7 (90.9, 119.0)	101.7 (85.4, 122.2)	111.0 (95.8, 129.1)	<.01
BOOI	51.8 (44.2, 61.2)	57.9 (47.4, 75.1)	61.8 (49.8, 82.1)	<.01

BCI = bladder contractility index; BOOI = bladder outlet obstruction index; BWT = bladder wall thick; IPP = intravesical prostate protrusion; IPSS = International Prostate Symptom Score; Pdet. Qmax = detrusor pressure at Qmax; PVR = post-voiding residual; Qmax = peak flow rate; QOL = quality of life.

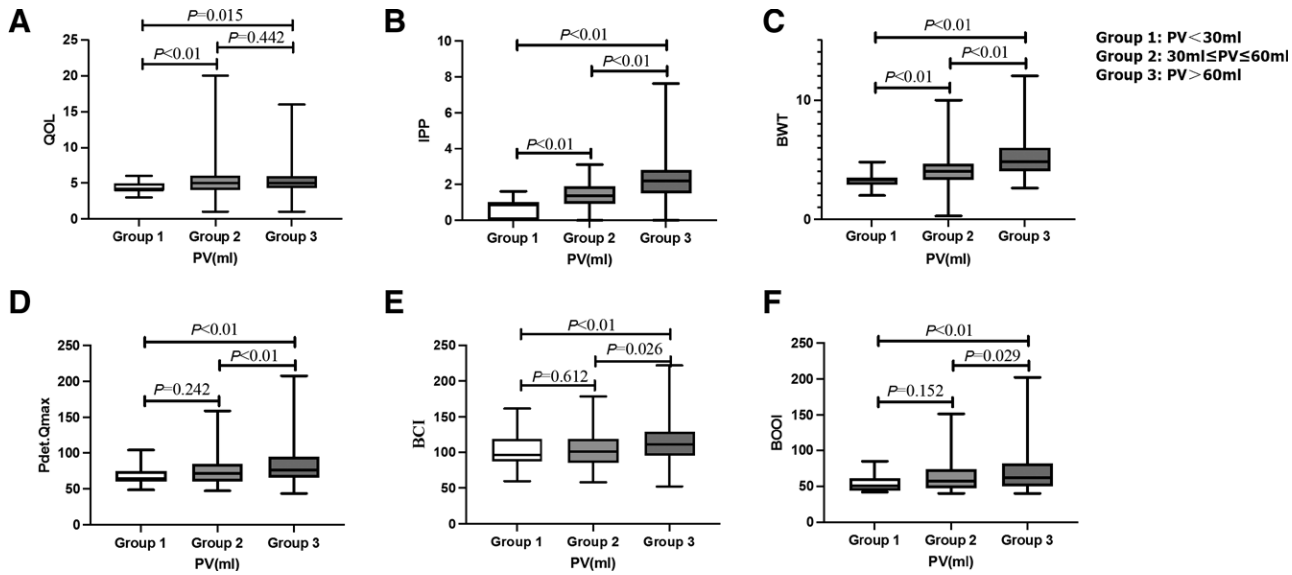

Figure 1. Comparison of QOL (A), IPP (B), BWT (C), Pdet.Qmax (D), BCI (E), and BOOI (F) between small, moderate, and large prostate. BCI = bladder contractility index; BOOI = bladder outlet obstruction index; BWT = bladder wall thick; IPP = intravesical prostate protrusion; Pdet.Qmax = detrusor pressure at Qmax; QOL = quality of life.

Table 2

Correlations between PV and IPP, Qmax, PVR, BWT, IPSS, and QOL according to PV.

PV (mL)	$C_{PV.IPP}$	$C_{PV.Qmax}$	$C_{PV.PVR}$	$C_{PV.BWT}$	$C_{PV.IPSS}$	$C_{PV.QOL}$
<30	0.223	0.234	0.024	0.089	0.230	0.218
30–60	0.262*	-0.019	0.016	0.023	0.073	0.052
>60	0.251**	-0.188*	0.215**	0.170*	0.122	0.165*

BWT = bladder wall thick; $C_{PV.BWT}$ = correlation between PV and BWT; $C_{PV.IPSS}$ = correlation between PV and IPSS; $C_{PV.PVR}$ = correlation between PV and PVR; $C_{PV.Qmax}$ = correlation between PV and Qmax; $C_{PV.QOL}$ = correlation between PV and QOL; IPP = intravesical prostate protrusion; IPSS = International Prostate Symptom Score; PVR = post-voiding residual; QOL = quality of life; Qmax = peak flow rate.

* $P < .05$.

** $P < .01$.

QOL ($R = 0.165$) at large prostate were found. Associations between noninvasive indices, including PV, IPP, and BWT, and invasive urodynamic indices, including BOOI and BCI, were investigated and showed in Table 3. All of PV, IPP, and BWT were not related to BOOI and BCI in small prostate, and weak correlations between IPP and BOOI ($R = 0.291$) and between BWT and BOOI ($R = 0.246$) and BCI ($R = 0.239$) were found in moderate prostate. However, only IPP was found to have a weak association with BOOI ($R = 0.204$) in large prostate.

Table 4 and Figure 2A showed the proportion of UR alone or BS alone in patients with BOO according to PV. Only 1 (3.7%) UR occurred in the patients with small prostate, but significant higher proportion of UR found in patients with moderate (18%) and large prostate (47.6%) when compared to small prostate. However, higher proportion of BS was found in patients with small prostate (96.7%) compared to moderate (82%) and large (52.4%) prostate. Table 5 and Figure 2B demonstrated that lower incidence of DU was proved urodynamically in patients

Table 3

Correlations between noninvasive sonomorphologic parameters (PV, IPP, and BWT) and urodynamic indexes (BOOI and BCI) according to PV.

PV (mL)	$C_{PV.BOOI}$	$C_{PV.BCI}$	$C_{IPP.BOOI}$	$C_{IPP.BCI}$	$C_{BWT.BOOI}$	$C_{BWT.BCI}$
<30	0.353	0.364	0.120	-0.091	-0.126	0.027
30–60	-0.109	-0.060	0.291**	0.069	0.246*	0.239*
>60	0.127	-0.056	0.204**	-0.041	0.143	0.010

BCI = bladder contractility index; BOOI = bladder outlet obstruction index; BWT = bladder wall thick; $C_{BWT.BCI}$ = correlation between BWT and BCI; $C_{BWT.BOOI}$ = correlation between BWT and BOOI; $C_{IPP.BCI}$ = correlation between IPP and BCI; $C_{IPP.BOOI}$ = correlation between IPP and BOOI; $C_{PV.BCI}$ = correlation between PV and BCI; $C_{PV.BOOI}$ = correlation between PV and BOOI; IPP = intravesical prostate protrusion; PV = prostate volume.

* $P < .05$.

** $P < .01$.

Table 4

Comparison in the proportion of BS alone to UR alone according to different PV.

	Combined status			
PV (mL)	BS	UR	X^2	*P*
<30	26 (96.7)	1 (3.7)	2.330	.039
30–60	73 (82.0)	16 (18.0)		
<30	26 (96.7)	1 (3.7)	16.855	<.01
>60	97 (52.4)	88 (47.6)		
30–60	73 (82.0)	16 (18.0)	23.916	<.01
>60	97 (52.4)	88 (47.6)		

BS = bladder stone; PV = prostate volume; UR = urinary retention.

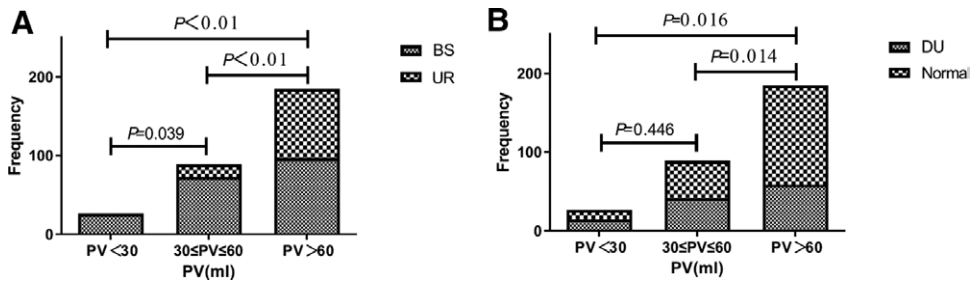

Figure 2. (A) The proportion of BS to UR according to PV; (B) comparison in the incidence of DU between different PV. BS = bladder stone; DU = detrusor underactivity; PV = prostate volume; UR = urinary retention.

Table 5

Comparison in the incidence of DU between different PV.

	Detrusor contractility			
PV (mL)	DU	Normal	X^2	*P*
<30	15 (55.6)	12 (44.4)	0.580	.446
30–60	42 (47.2)	47 (52.8)		
<30	15 (55.6)	12 (44.4)	5.807	.016
>60	59 (31.9)	126 (68.1)		
30–60	42 (47.2)	47 (52.8)	6.043	.014
>60	59 (31.9)	126 (68.1)		

DU = detrusor underactivity; PV = prostate volume.

with large prostate (31.9%) compared with small (55.6%) and moderate (47.2%) prostate, whereas no significant difference in the incidence of DU was detected between small and moderate prostate ($P = .446$).

4. Discussion

LUTS have been regarded as the most prevalence complaints in the elderly men, in which BOO suggestive of BPH is one of the most common causes. Specific treatment recommendations can be offered for certain groups of patients complaining LUTS suggestive of BPO, watchful waiting or medical therapy, such as alpha-blocker, 5-α reductase inhibitors, and combination therapy, is generally advised for those with mild and moderate symptom. However, on the other end of the therapeutic range, patients with UR, BS, recurrent urinary tract infection, recurrent gross hematuria, or renal insufficiency have absolute indications for surgical management.[15] The configuration of prostate and

urodynamic manifestation in patients responsive to watchful waiting or medical therapy for BPH has been not considered to be analogous to that of patients eventually underwent surgical management.[10] In the present study, diverse characteristics of sonographic parameters, clinical condition and UDS were also discovered with enlargement of PV in BOO patients requiring TURP.

Urodynamic studies has been regarded as the gold standard to diagnose the BOO, and PFS can differentiate DU from BOO, and often are recommended in cases of failure in medical therapy or indication for surgery.[16] Although weak to moderate correlations have been found between subjective scores or objective parameters and the severity of BOO, UDS has not been replaced by noninvasive parameters with high sensitivity and specificity.[17–19] In this study, PV positively correlated with BOOI which is urodynamically surrogate of the severity of BOO. However, there are controversial results in determining relationships between PV and symptoms, sonomorphic and urodynamic parameters in patients with BPH in the literature. Given the invasive and expensive nature of UDS and our tertiary referral hospital, UDS always was conducted preoperatively in BOO patients requiring BPH-related surgical interventions, in whom mostly were combined with UR alone and BS alone in the present study. Therefore, the fact that BOO patients with BS alone and UR alone, representing the indications for BPH-related surgery, were enrolled in this study may contribute to different conclusion from previous studies, by which the hypothesis that characteristics of BPH responsive to medical therapy do not bear close resemblance to that of need surgery also was proved.[10]

In this study, it was found that moderate or larger PV was associated with stronger detrusor contractility than small PV as some previous researches, in which a lower incidence of DU occurred in patients with larger PV than smaller PV and a small PV was considered as a predictor for DU in elderly patients with LUTS.[6,20] PV positively related to IPP, which has been regarded as an independent risk factor in forecasting the severity of BOO, but only IPP was correlated to BOOI in moderate and large prostate and no relationship between PV, and IPP and BCI, which has been considered as a surrogate of degree of detrusor contractility, was found in the present study. As BCI and BOOI, Pdet.Qmax in larger prostate was also found to be significantly higher than small and moderate prostate. Consequently, there was a tendency that larger PV and more obvious correlations between sonographic parameters and invasive urodynamic indexes existed. However, the score of QOL in moderate and large prostate was higher than small. Therefore, it was suggested that the grade of PV related to the extent of IPP and BOO and symptoms progression, and larger PV and more remark relationship became. Hence, increasing detrusor contractility was attributed to initial detrusor compensation due to increasing BOO with enlargement of PV in patients requiring BPH-related prostatic surgery.

It was found that the mean BWT of 4.6 mm in our study was similar to the mean BWT of 4.77 mm found by Eze et al and significant increasing BWT and IPP was also found with increasing size of prostate.[18] In moderate prostate, BWT positively related to BOOI and BCI that indicated compensatory detrusor hypertrophy and potential impairment of detrusor contractility, but the correlations were not significant in large prostate. Nevertheless, it was suggested that coexisting large PV, high IPP, and thickened BWT may be an indicator of clinical progression of BPH and eventual need for surgical therapy. Renal injury may be prevented by early recognition and management of this condition in patients with BPH.[17]

To our knowledge, there has been few reports about the proportion of each indication for surgery intervention in BPH patients with BOO no responsive to medical therapy. Although the consensus over indications for BPH-related surgery was existed across the world, BPH patients from different area may suffer from different indications for the surgery. Due to our tertiary referral hospital, nearly 70% of BPH patients requiring surgical management combined with UR alone and BS alone (not presented in this study), in which patients with BS alone (65.1%, 196/301) was more common compared to UR alone (34.9%, 105/301). Consequently, the prostate configuration and urodynamic characteristics of patients enrolled in this study may be a representative case of BOO patients requiring BPH-related surgical therapy in our area, where located in southwestern area of china mainland.

In the present study, 34.9% (105/301) of total patients had at least once of UR and proportion of UR was significantly increasing with enlargement of PV. However, remarkable reducing in the incidence of BS was found from 96.7% (26/27) in patients with small prostate to 52.4% (97/185)in large prostate. To the best of our knowledge, we reported the first evaluation in the proportion of UR alone to BS alone in BOO patients requiring BPH-related surgical management and found that, with PV increasing, the proportion of BS was decreasing, and UR evolved with almost opposite tendency. It is not clear why there was a significant difference in the proportion of BS alone and UR alone according to PV in BOO patients requiring prostate de-obstruction maneuver. It was reasonable that larger PV was associated with higher IPP, which related to higher degree of BOOI and incidence of UR. Our finding was similar to the report conducted by Eze et al, in which more acute urinary retention and chronic urinary retention was found in patients with IPP ≥ 10 mm when compared to ≤ 10 mm.[17] In White men and African, IPP has been proved to significantly predict the outcome of trial without catheter in patients with AUR due to BPO.[21,22]

Urinary stasis due to BOO has been historically considered an important contributor of forming BS, but recent studies suggested that the role of BOO in formation of BS was minor.[23] In a study conducted by Childs et al, it was suggested that metabolic abnormalities, including low urinary PH and low urinary magnesium as well as elevated urinary uric acid supersaturation and nephrolithosis history, facilitated formation of BS and no just urinary stasis.[24] There has been reported to find a tendency that patients with BPH and concomitant BS have smaller size prostate than that of patients with BPH alone.[25] Although a similar tendency was not assessed thoroughly in this study, it was suggested that patients with small PV had a higher proportion of BS compared to that of UR. To explain this, it was suggested that formation of BS in BOO patients with small PV may represent a unique type of BOO other than large PV. Although the association between metabolic syndrome (MetS) and BS has been not discovered across the world, patients with MetS has been reported to have a propensity of occurrence of LUTS and nephrolithiasis and a significant higher incidence in male patients compared to female was found.[26–28] Cantiello et al find that MetS may trigger peri-urethral fibrosis through prostate inflammation and is regarded as an independent risk for chronic prostatitis.[29] Therefore, we hypothesized that the formation of BS may partly be derived from disorder metabolic conditions and peri-urethral BOO in patients with MetS, who presented LUTS and chronic prostatitis and may not always have a large prostate due to fibrosis. Although more studies will be needed to test the hypothesis in the future, our study gave a support for the theory that multiple factors were attributable to the formation of BS rather than urinary stasis resulted from BOO only.

Although increasing incidence of BS or DU in patients with relatively small prostate has respectively been reported in the literature, a simultaneously and significantly higher incidence of both BS and DU in small prostate compared to that of larger prostate in BPH patients underwent surgical therapy was first found in our study. Takahashi et al conducted a research that enrolled more than 900 male patients underwent PFS to differentiate DU from BOO, in which the optimal cutoff of PV determined by ROC curves was 34.8 mL and suggested that a

smaller PV was a predictive factor for DU.[30] With increasing of PV, higher BOOI and BCI was found in a report by Kang et al, in which BOO patients with small prostate significantly associated with a propensity of DU was ascertained.[6] Luo et al also found that PV was considered as an independent predictor for Pdet.Qmax and 46.05 mL was set as the optimal cutoff of PV with a AUC of 0.739.[20] Although there was not enough power to prove the similar finding mentioned above in this study, the significant difference of incidence of DU between small, moderate, and large PV was in accordance with previous studies. Therefore, we hypothesized that BOO patients with small PV may have a higher incidence of CP, and long duration of CP without effective treatment may precipitate dysfunction of voiding phase, especially poor relaxation of external sphincter (PRES), which was reported to present DU of low-pressure-low-flow tracing.[31]

Several limitations of the present study should be carefully noted. First, the medical data in this study were obtained for clinical purposes, not for research aim. Second, relatively small size and retrospective nature of the present study should be considered. Third, our tertiary referral hospital was associated with unavoidable selection and attribution bias in this study because most of BPH patients enrolled were likely to have endured the prolonged status of BOO resulted from failure for medical therapy and have to admit our hospital to receive surgical management due to combination with UR alone and BS alone. Therefore, more general populations, such as community-based patients, may facilitate the evaluation of generalizability of our resulted. Finally, a part of BPH patients with BOO were not enrolled in the study due to the equation of BOOI because some BOO patients with DU were likely to be not diagnosed with BOO due to maximal detrusor pressure <40 cm H_2O.

5. Conclusion

Higher IPP and BOO as well as thicker BWT and stronger ability of detrusor contractility were positively correlated with enlargement of PV, and small prostate was found to be associated with less severity of BOO, weaker detrusor contractility, and higher proportion of BS compared to larger prostate (≥60 mL), and significant increasing proportion of UR was demonstrated with increasing PV in BOO patients with BS alone and UR alone. It was suggested that a part of patients with small prostate was associated with less severity of BOO but higher incidence of DU and had a tendency of occurrence of BS, which gave a support for the theory that multifactor involved in the formation of BS rather than BOO only.

Author contributions

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Investigation: Ning Xiao, Yao Huang.
Methodology: Ning Xiao.
Project administration: Ning Xiao.
Resources: Ning Xiao.
Software: Ning Xiao, Yao Huang, Gaoyu Pan.
Validation: Ning Xiao
Visualization: Ning Xiao
Writing—original draft: Ning Xiao, Guangrong Guo, Qi Tang.
Writing—review & editing: Ning Xiao.

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