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Modified bladder outlet obstruction index for powerful efficacy prediction of transurethral resection of prostate with benign prostatic hyperplasia

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Abstract

Background: The correlation between modified bladder outlet obstruction index (MBOOI) and surgical efficacy still remains unknown. The purpose of the study was to investigate the clinical value of the MBOOI and its use in predicting surgical efficacy in men receiving transurethral resection of the prostate (TURP).

Methods: A total of 403 patients with benign prostatic hyperplasia (BPH) were included in this study. The International Prostate Symptom Score (IPSS), quality of life (QoL) index, transrectal ultrasonography, and pressure flow study were conducted for all patients. The bladder outlet obstruction index (BOOI) ($P_{det}Q_{max} - 2Q_{max}$) and MBOOI ($P_{ves} - 2Q_{max}$) were calculated. All patients underwent TURP, and surgical efficacy was accessed by the improvements in IPSS, QoL, and Q_{max} 6 months after surgery. The association between surgical efficacy and baseline factors was statistically analyzed.

Results: A comparison of effective and ineffective groups based on the overall efficacy showed that significant differences were observed in PSA, P_{ves} , $P_{det}Q_{max}$, P_{abdr} , BOOI, MBOOI, TZV, TZI, IPSS-t, IPSS-v, IPSS-s, Q_{max} , and PVR at baseline ($p < 0.05$). Binary logistic regression analysis suggested that MBOOI was the only baseline parameter correlated with the improvements in IPSS, QoL, Q_{max} , and the overall efficacy. Additionally, the ROC analysis further verified that MBOOI was more optimal than BOOI, TZV and TZI in predicting the surgical efficacy.

Conclusion: Although both MBOOI and BOOI can predict the clinical symptoms and surgical efficacy of BPH patients to a certain extent, however, compared to BOOI, MBOOI may be a more useful factor that can be used to predict the surgical efficacy of TURP.

Trial registration retrospectively registered.

Keywords: Benign prostatic hyperplasia, Transurethral resection of prostate, Modified bladder outlet obstruction index, Surgical efficacy

Background

Benign prostatic hyperplasia (BPH), whose prevalence progressively increases with age, is one of the most common diseases in middle-aged and elderly men [1]. Currently, static and dynamic obstruction due to benign prostatic enlargement (BPE) or/and benign prostatic obstruction (BPO) is considered as the main

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cause of low urinary tract symptom (LUTS), which has a severe impact on the physical and mental health and quality of life (QoL) of elderly men.

Pressure-flow studies (PFSs) have been recommended as the gold standard for diagnosing bladder outlet obstruction (BOO) by the International Continence Society, among which the BOO index (BOOI) has become best-known and most widely-adopted urodynamic parameter [2, 3]. It is routinely used to evaluate the condition of BPH patients and gauge the efficacy of corrective surgery. Nevertheless, in our previous study, it was observed there was no significant correlation between BOOI and symptoms and the maximum urine flow rate (Q_{max}) in BPH patients [4]. In fact, as the resistance to urination increases with the progression of BOO, many patients undergo abdominal straining to urinate during a PFS. The process of urination involves both detrusor pressure and abdominal pressure, and it is obviously insufficient to only consider the detrusor pressure. Therefore, research has been carried out to assess the correlation between abdominal pressure and BOO, and it has been previously determined that a modified BOOI (MBOOI) that takes into account abdominal pressure can better predict the BOO than the BOOI [5].

The treatments of LUTS secondary to BPH include drug treatment and surgical treatment, among which transurethral resection of prostate (TURP) is still regarded by the current guidelines as the gold standard for surgical treatment [6]. Although TURP is recognized as a safe and effective treatment, significant efficacy is not achieved for all patients. Surgical failure is more likely to occur in patients with detrusor dysfunction and lower baseline BOOI [7]. It has also been found that the degree of preoperative BOO is positively associated with improvement in LUTS and QoL after TURP [8]. Therefore, a preoperative PFS is recommended for optimal selection of patients who are more suitable for surgery by measuring BOOI and assessing detrusor function.

As mentioned above, BOOI ($P_{det}Q_{max}-2Q_{max}$) does not consider the role of abdominal straining in urination, or a predicted BOO may be worse than a MBOOI. Additionally, the correlation between MBOOI and surgical efficacy still remains unknown. Hence, we hypothesized that MBOOI predicts the surgical outcome more optimally than BOOI, and thus, the purpose of this study was to assess the value of MBOOI in predicting the surgical efficacy of TURP by comparing it with BOOI and other parameters.

Methods

Patient cohort

This was a retrospective study that received approval by the Hospital Ethics Committee of GuiZhou Provincial People's Hospital, and written informed consent was obtained (No. 2018054). From November 2015 to March 2020, a total of 403 patients with LUTS/BPH were enrolled in the study. In addition to routine examination, such as digital rectal examination, serum prostate-specific antigen (PSA), and kidney-bladder ultrasound, the International Prostate Symptom Score (IPSS), transrectal ultrasonography (TRUS), and PFS were routinely performed before surgery, otherwise, the patients were not included in the study. The non-inclusion criteria included: (1) bladder calculi, bladder tumor, neurogenic bladder dysfunction, urethral stricture, and other diseases that may affect the function of urination; (2) previous surgery of the prostate and/or bladder and/or urethra; (3) prostate cancer that was confirmed by post-operative pathology. The patients with suspected prostate cancer underwent an ultrasound-guided transrectal prostate biopsy for confirmation or exclusion of cancer. The indications for the operation are as follows: recurrent or refractory urinary retention, overflow incontinence, recurrent urinary tract infections, bladder stones or diverticula, treatment-resistant macroscopic haematuria due to BPH/BPE, or dilatation of the upper urinary tract due to BPO (with or without renal insufficiency), insufficient relief of LUTS after conservative or medical treatments [6]. All patients were followed up and reassessed with IPSS, QoL, and free flowmetry 6 months later.

Assessment of prostatic anatomical parameters

TRUS (Philips EPIQ 5) was used to estimate the total prostate volume (TPV) and transitional zone volume (TZV) by the prostate ellipsoid formula ($height \times width \times length \times \pi/6$). The transitional zone index (TZI) was calculated by TPV and TZV ($TZI = TZV/TPV$) [9].

Assessment of urinary symptoms and urodynamic measurements

Subjective symptoms were assessed by the IPSS and QoL questionnaires, including IPSS total score (IPSS-t), IPSS voiding score (IPSS-v), IPSS storage score (IPSS-s), post-micturitional IPSS score (IPSS-p), and QoL score. A PFS was performed by multichannel urodynamic evaluation (UDS-94-BT, Delphis, Laborie, Canada) to assess objective symptoms. An 8-F double-lumen catheter was transurethraly inserted, and a 10-F single-lumen catheter was transrectally inserted with the patient in a sitting position. The bladder was perfused with physiological saline solution (20–50 ml/

min) until the patient felt a strong desire to urinate (maximum bladder volume), bladder perfusion was then stopped, and the patient was ordered to urinate into the collector. Maximum bladder volume, intravesical pressure (P_{ves}), abdominal pressure (P_{abd}), Q_{max} , and post void residual (PVR) urine volume were simultaneously measured. Detrusor pressure at maximum urine flow rate ($P_{det}Q_{max}$) is equal to P_{ves} minus P_{abd} , and the BOOI ($P_{det}Q_{max}-2Q_{max}$) and MBOOI ($P_{ves}-2Q_{max}$) were calculated by P_{ves} , $P_{det}Q_{max}$, and Q_{max} [10].

Assessment of surgical efficacy of TURP

Surgical efficacy was determined according to the improvement of IPSS, QoL score, and Q_{max} after surgery. The degree of improvement was judged as poor (level 1), fair (level 2), good (level 3), and excellent (level 4). IPSS improvement > 75% was considered excellent, 50–75% good, 25–50% fair, and ≤ 25% none. A QoL improvement of 4–6 score was classified excellent, 3 score good, 1–2 score fair, and 0 score poor. A Q_{max} improvement ≥ 10.0 ml/s was considered excellent, 5.0–10.0 ml/s good, 2.5–5.0 ml/s fair, and < 2.5 ml/s poor. The median of the three aspects (IPSS, QoL score, and Q_{max}) was defined as the overall efficacy level, in which levels 3 and 4 were defined as effective, and levels 1 and 2 as ineffective (Table 1) [11].

Statistical analysis

All statistical values were reported as the mean ± standard deviation. Kolmogorov–Smirnov test was used to determine whether the continuous variables were in line with normal distribution. If the variables were normally distributed, Student’s t-test was applied to compare difference in preoperative factors between two groups according to the overall efficacy. The non-normal distribution variables were conducted with Mann–Whitney U test. Simple linear regression analysis was applied to determine the significant predicting factors for therapeutic effects, and then, stepwise forward binary logistic regression analysis was carried out to determine the factors associated with surgical outcomes of TURP. The receiver operating characteristic (ROC) curves were produced, and the area under the curve (AUC) was subsequently calculated to describe the predictive value of MBOOI in surgical outcomes. All Statistical analysis were processed using IBM SPSS 25.0 for Windows statistical software (Statistical Package for Social Sciences, IBM Corporation, Armonk, NY, USA). All statistical tests were two-sided, $p < 0.05$ was considered to be statistically significant.

Table 1 Surgical efficacy based on the improvements in symptoms, QoL and function

Efficacy grade	Criteria	No. patients (%)
<i>Symptom: Post/pre ratio of IPSS-t</i>		
Excellent	≤ 0.25	161 (39.95)
Good	≤ 0.50	146 (36.23)
Fair	≤ 0.75	69 (17.12)
Poor	> 0.75	27 (6.70)
<i>QoL: Pre-post of QoL index</i>		
Excellent	6,5,4	139 (34.49)
Good	3	125 (31.02)
Fair	2,1	105 (26.05)
Poor	0	34 (8.44)
<i>Function: Post-pre of Q_{max}</i>		
Excellent	≥ 10 mL/s	116 (28.78)
Good	≥ 5 mL/s	172 (42.68)
Fair	≥ 2.5 mL/s	77 (19.11)
Poor	< 2.5 mL/s	38 (9.43)
<i>The overall efficacy: median of efficacy grades of symptom, function and QoL</i>		
Excellent		136 (33.75)
Good		161 (39.95)
Fair		84 (20.84)
Poor		22 (5.46)

IPSS-t = international prostate symptom total score, QoL = quality of life, Q_{max} = maximum urine flow rate

Results

Comparison of baseline characteristics between the effective and ineffective groups based on the overall efficacy

A total of 403 patients between 53–90 years of age diagnosed with BPH were included in the present study. The general characteristics of the study population are shown in Table 2. The surgical efficacy rates according to the improvements in IPSS, QoL, and Q_{max} after surgery were 76.18%, 65.51%, and 71.46% respectively, and the overall efficacy rate of TURP was 73.70%. Kolmogorov–Smirnov test results showed that Q_{max} followed normal distribution, therefore, Student’s t-test was applied to compare difference in Q_{max} between two groups according to the overall efficacy. Mann–Whitney U test was applied to compare difference in other preoperative factors between two groups due to these variables in accordance with normal distribution. A comparison of the overall efficacy in the effective and ineffective groups revealed significant differences in PSA ($p = 0.021$), P_{ves} ($p < 0.001$), $P_{det}Q_{max}$ ($p < 0.001$), P_{abd} ($p < 0.001$), BOOI ($p < 0.001$), MBOOI ($p < 0.001$), TZV ($p = 0.022$), TZI ($p = 0.025$), IPSS-t ($p < 0.001$), IPSS-v ($p = 0.014$), IPSS-s ($p < 0.001$), Q_{max} ($p = 0.010$), and PVR ($p = 0.006$) at baseline, but significant differences were not observed in age ($p = 0.105$),

Table 2 Baseline clinical characteristics and comparison of preoperative characteristics between the two groups classified by the overall surgical efficacy

Variables	Baseline (n = 403)	Effective (n = 297)	Ineffective (n = 106)	p Value
Age (year)	70.94 ± 7.50	71.30 ± 7.44	69.94 ± 7.62	0.105
PSA (umol/L)	4.86 ± 4.98	5.21 ± 5.30	3.88 ± 3.83	0.021
<i>Ultrasonography</i>				
TPV (mL)	52.84 ± 27.63	54.19 ± 28.06	49.05 ± 26.12	0.074
TZV (mL)	24.90 ± 19.45	26.09 ± 19.92	21.59 ± 17.73	0.022
TZI	0.43 ± 0.14	0.44 ± 0.15	0.40 ± 0.12	0.025
<i>Urodynamics</i>				
P _{ves} (cmH ₂ O)	102.72 ± 40.04	110.38 ± 40.58	81.23 ± 29.38	<0.001
P _{det} Q _{max} (cmH ₂ O)	84.92 ± 35.23	90.57 ± 36.07	69.10 ± 27.22	<0.001
P _{abd} (cmH ₂ O)	17.79 ± 16.40	19.81 ± 17.98	12.13 ± 8.65	<0.001
Q _{max} (mL/s)	8.10 ± 3.37	7.84 ± 3.31	8.82 ± 3.43	0.010
BOOI	68.73 ± 35.66	74.89 ± 36.41	51.47 ± 26.90	<0.001
MBOOI	86.52 ± 40.59	94.71 ± 41.04	63.59 ± 28.96	<0.001
PVR (mL)	74.36 ± 78.10	79.54 ± 78.75	59.85 ± 74.73	0.006
<i>International prostate symptom score (IPSS)</i>				
IPSS-t	22.51 ± 5.22	23.10 ± 5.17	20.84 ± 5.03	<0.001
IPSS-v	8.72 ± 3.45	8.99 ± 3.46	7.98 ± 3.34	0.014
IPSS-s	10.25 ± 2.71	10.61 ± 2.65	9.24 ± 2.61	<0.001
IPSS-p	3.51 ± 1.54	3.48 ± 1.54	3.59 ± 1.54	0.520
IPSS QoL	4.73 ± 1.03	4.77 ± 0.99	4.62 ± 1.14	0.357

PSA = prostate-specific antigen, TPV = total prostate volume, TZV = transitional zone volume, TZI = transitional zone index, P_{ves} = intra-vesical pressure, P_{det}Q_{max} = detrusor pressure at maximum urine flow rate, P_{abd} = abdominal pressure, Q_{max} = maximum urine flow rate, BOOI = bladder outlet obstruction index, MBOOI = modified BOOI, PVR = post void residual urine volume, IPSS-t = IPSS total score, IPSS-v = IPSS voiding score, IPSS-s = IPSS storage score, IPSS-p = post-micturitional IPSS score, QoL = quality of life

TPV ($p=0.074$), IPSS-p ($p=0.520$), or QoL ($p=0.357$) (Table 2).

Association of surgical efficacy with preoperative variables

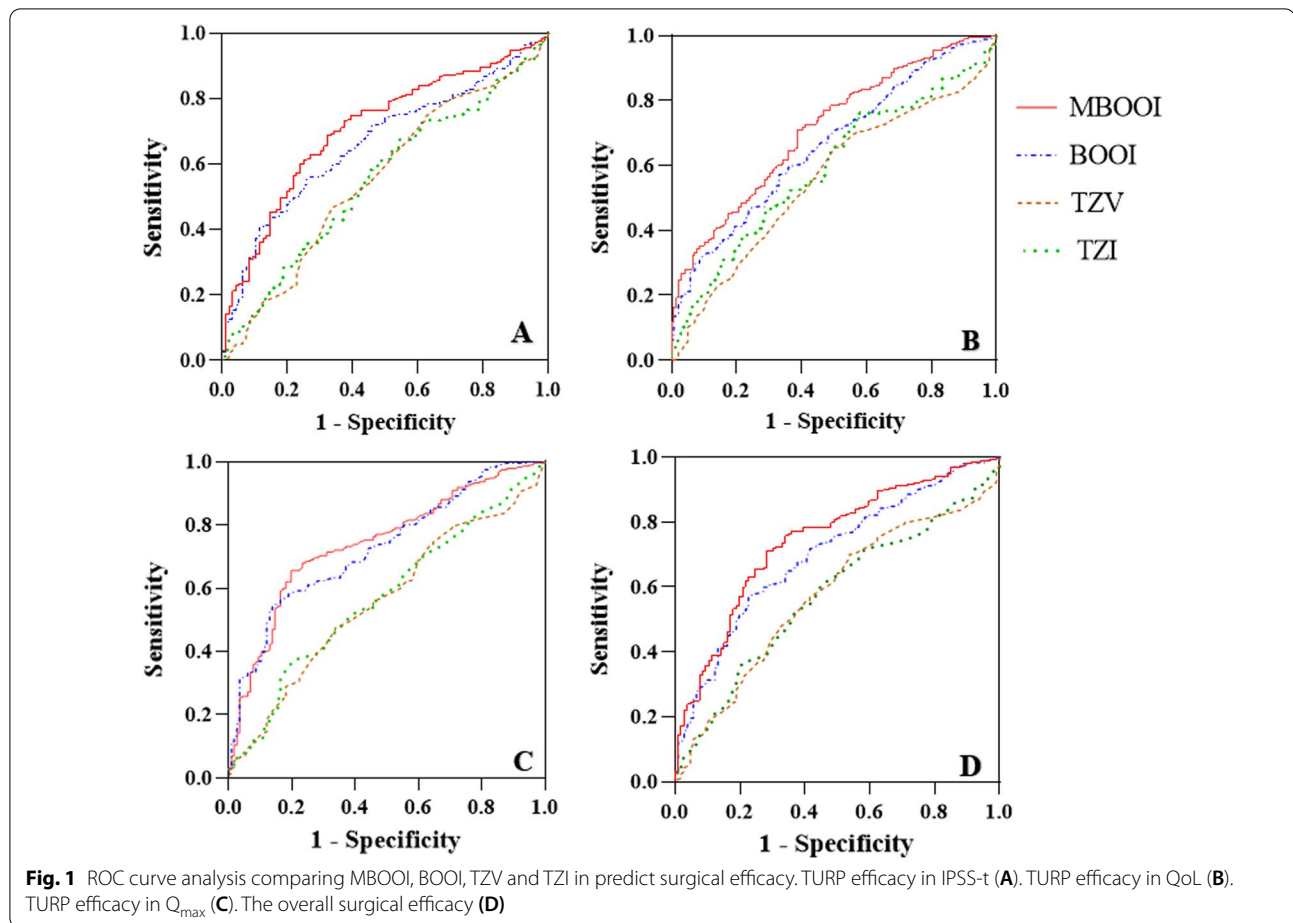
As presented in Table 3, simple linear regression analysis was used to analyze the correlations between preoperative factors and the surgical efficacy in IPSS, QoL, and Q_{max}. All preoperative variables that were significantly correlated with surgical efficacy in IPSS, QoL, and Q_{max} using simple linear regression analysis were analyzed by stepwise forward binary logistic regression. From the results, MBOOI ($p<0.001$) and IPSS-t ($p<0.001$) were correlated with improvement of IPSS-t ($p<0.05$). MBOOI ($p<0.001$), P_{abd} ($p=0.035$) and QoL ($p<0.001$) with improvement of QoL. Meanwhile, MBOOI ($p<0.001$) and Q_{max} ($p<0.001$) with improvement of Q_{max}. In addition, improved MBOOI ($p<0.001$) and IPSS-t ($p=0.009$) were correlated with the overall efficacy of TURP. Particularly, MBOOI was the only preoperative factor correlated with the surgical efficacy in IPSS, QoL, Q_{max} and the overall both (Table 3).

Furthermore, as shown in Fig. 1, the ROC curve was plotted, and the AUC was calculated. ROC analysis further demonstrated that MBOOI (AUC = 0.744,

95% CI 0.691–0.798) was more optimal than BOOI (AUC = 0.701, 95% CI 0.645–0.757), TZV (AUC = 0.575, 95% CI 0.513–0.636), and TZI (AUC = 0.573, 95% CI 0.513–0.634) in predicting the overall surgical efficacy

Table 3 Relationship between the baseline factors and surgical efficacy in IPSS-t, Q_{max}, QoL and the overall surgical efficacy in binary logistic regression

Variables	OR	(95% CI)	p Value
<i>Surgical efficacy in IPSS-t</i>			
MBOOI	1.021	(1.012–1.029)	<0.001
IPSS-t	1.101	(1.049–1.156)	<0.001
<i>Surgical efficacy in QoL index</i>			
P _{abd} (cmH ₂ O)	1.022	(1.001–1.043)	0.035
MBOOI	1.021	(1.013–1.030)	<0.001
QoL	1.962	(1.541–2.498)	<0.001
<i>Surgical efficacy in Q_{max}</i>			
MBOOI	1.026	(1.018–1.035)	<0.001
Qmax (mL/s)	0.793	(0.733–0.857)	<0.001
<i>The overall surgical efficacy</i>			
MBOOI	1.027	(1.018–1.036)	<0.001
IPSS-t	1.064	(1.016–1.115)	0.009



of TURP. With a larger AUC, there was a higher correlation of MBOOI (AUC = 0.708, 95% CI 0.652–0.765) with the improvement in IPSS-t than BOOI (AUC = 0.664, 95% CI 0.606–0.721), TZV (AUC = 0.556, 95% CI 0.491–0.622), and TZI (AUC = 0.543, 95% CI 0.484–0.618). Similarly, compared with BOOI (AUC = 0.661, 95% CI 0.608–0.715), TZV (AUC = 0.558, 95% CI 0.501–0.616), and TZI (AUC = 0.582, 95% CI 0.525–0.639), MBOOI (AUC = 0.710, 95% CI 0.659–0.761) had a larger AUC in improvement in QoL. With regard to the surgical efficacy in Q_{max} , the AUC was 0.742 (95% CI 0.691–0.794) for MBOOI, 0.728 (95% CI 0.676–0.779) for BOOI, 0.559 (95% CI 0.499–0.619) for TZV, and 0.570 (95% CI 0.510–0.630) for TZI (Fig. 1).

Discussion

BOO is one of the main causes of LUTS. IPSS is currently recognized as the most effective method to evaluate the severity of subjective symptoms in BPH patients, and PFS is an objective examination to quantify the condition as well as pre-surgical and post-surgical efficacy. The degree of BOO is classified into three grades by BOOI:

unobstructed ($BOOI \leq 20$), equivocal ($20 < BOOI \leq 40$), and obstructed ($BOOI > 40$) [12]. However, Han et al. noted that BOOI is often inconsistent with endoscopically proven obstruction due to exclusion of the role of abdominal pressure in urination, and thus, they proposed the concept of modified BOOI and proved that modified BOOI can better predict BOO in patients with LUTS/BPH [5]. This finding is consistent with the results of our study, where MBOOI, when compared with BOOI, exhibited a higher correlation not only with IPSS, QoL, and Q_{max} , but also with PSA, TPV, and TZI.

TURP is the standard surgical method for the treatment of BPH in prostate volume ≤ 80 ml. With the improvement of surgical proficiency and technology, TURP is also commonly used in patients with larger prostate, and it is equally safe and effective in large size prostate (> 80 ml) as compare in small size (≤ 80 ml) [6, 13, 14]. TURP is not only the mainstream surgical method at present, but also often the preferred surgical method for BPH. Therefore, in this study, we did not limit the volume of prostate in the included patients. The mean prostate volume (52.84 ± 27.63) in this study was small,

but this is consistent with the results of related studies, the mean PV in each 10-year age group was lower than reported in studies in Asian populations than that in studies on Caucasians and African Americans [15–17]. However, further studies are needed to clarify whether the same results can be obtained from a separate study of large prostate patients, especially prostate volume larger than 80 ml. This study mainly focuses on the prediction of TURP efficacy by MBOOI. Nonetheless, 5–35% of patients postoperatively report persistent symptoms after TURP [18]. Therefore, in clinical practice, it is highly necessary to predict whether invasive surgery will be beneficial for patients. Traditionally, to select appropriate patients for surgery, BOOI with a PFS is recommended. In a study by Seki et al., multiple logistic regression analysis indicated that a higher baseline level of BOOI was associated with greater improvements in IPSS and QoL. Huang et al. conducted a study to establish an efficacy prediction model for transurethral prostatectomy, and found that there was a positive correlation between surgical efficacy with a higher degree of BOO and secondary detrusor cell hypertrophy [19]. Similarly, previous studies have shown that patients with definite BOO derive greater benefit from TURP surgery than those with equivocal and unobstruction [20, 21]. Previous studies indicated that BOOI is an extremely important method for predicting the surgical outcome of TURP.

The limitations of BOOI are emerging. Han et al. followed up 71 patients from 12 to 55 months, and found that 64% of patients were satisfied with the surgical results in the unobstructed and weak bladder contractility group [22]. Although the surgical effect in the BOO-positive group was significantly better than that of those in the BOO-negative group, Kim indicated that being BOO-positive might not be the absolute surgical indication for TURP [23]. Han et al. found that abdominal pressure was correlated with the degree of BOO as defined by cystourethroscopy [5]. In our study, abdominal pressure was a predictive factor for improvement of QoL. Sekido stated that abdominal pressure serves as a compensatory mechanism to promote urination with impaired detrusor and bladder contractions, and an increase in abdominal pressure would reduce the detrusor pressure required to achieve the same flow rate [24]. Consequently, $P_{det}Q_{max}$, which is obtained by subtracting the P_{abd} from P_{ves} for analysis of pressure flow, may lead to a vague interpretation of the P-Q diagrams and an incorrect assessment of outflow impedance [25]. However, the specific mechanism governing abdominal straining in urination remains unknown.

Therefore, in order to better evaluate patients' conditions and predict surgical efficacy, it is vital to determine more valuable parameters that take into account

abdominal pressure. Here, we compared the results of a simple modified method with the traditional BOOI, and the present findings confirm that MBOOI appears to be better at predicting surgical outcomes than BOOI. In one respect, MBOOI, providing clearly better results than BOOI, was significantly related to the changes in IPSS (including IPSS-v, IPSS-s, IPSS-p, IPSS-t), QoL, Q_{max} , and PVR after TURP. However, superior results were observed for the association between MBOOI and surgical outcomes, which were accessed by the improvement in IPSS, QoL, and Q_{max} using binary logistic regression analysis. The result was further verified by ROC analysis with a larger AUC in MBOOI. Additionally, to a certain extent, although some preoperative factors are related to surgical outcomes, such as P_{ves} , $P_{det}Q_{max}$, P_{abd} , BOOI, IPSS-t, QoL, and Q_{max} , they are significantly less effective than MBOOI. Particularly, contrary to the findings of the previous study, an additional finding is that a significant correlation between TZI and surgical efficacy was not observed [26]. In addition, related studies have shown that the surgical effect of TURP is similar to that of green-light laser photo-selective vaporization of the prostate (PVP) and holmium laser enucleation of the prostate (HoLEP), and the PVP and HoLEP were not significantly better than the former [27–29]. Of course, A larger resected prostate tissue weight that is present after enucleation techniques, however, similar efficacy has been reported for enucleation techniques and TURP in the treatment of BPH. One RCT comparing holmium laser enucleation of the prostate (HoLEP) with TURP in BPH patients who completed the 7-yr follow-up found that the functional long-term results of HoLEP were comparable with TURP [28]. Therefore, we boldly assume that MBOOI can be applied to predict the surgical efficacy of enucleation techniques, but there is no relevant research at present, and more studies are needed to further clarify.

To the best of our knowledge, this is the first study to investigate the correlation between MBOOI and efficacy of TURP, and the results confirmed that MBOOI may be a potential candidate that can be used to predict surgical outcomes. The pathophysiology of male LUTS/BPH is highly complex and multifactorial, and the disease and efficacy are unlikely to be determined by a single factor [30]. For more optimal diagnosis and treatment of BPH, our task is to continuously explore the pathophysiological mechanism and determine more valuable indicators. This study provides new directions and ideas for this purpose.

There are several limitations to this study. First of all, one limitation of our implementation is that this is a retrospective study, and compared with non-invasive examination such as ultrasound, PFS as invasive examination may bring the risk of trauma to the patient. However, as

the gold standard for diagnosing BOO, its status in urology is irreplaceable. We routinely completed this examination before TURP surgery, and the surgical efficacy was confirmed by reexamination 3 months after surgery. This study was retrospective and did not cause additional trauma to patients. In addition, some parameters that may influence the surgical outcome reported in the previous studies were not evaluated, such as intravesical prostatic protrusion, prostatic urethral angulation and ultrasonic estimation of bladder weight, detrusor wall thickness, and resistive index, et al. [31–34]. Further studies should carry out to compare the value of those parameters and MBOOI in predicting surgical efficacy. Thirdly, although Park et al. did not find a correlation between the resected prostate tissue ratio and surgical efficacy, there was no insufficient evidence to support this [35]. For example, Milonas et al. found that the volume of resected tissue was an important factor influencing the degree of symptom improvement [36]. Although the relationship between resected prostate tissue weight and surgical efficacy was not considered in our study, we tried to achieve completeness of resection intraoperatively. Additionally, resected prostate tissue weight is closely related to TZV, and our study shows that TZV has little effect in predicting surgical efficacy. Therefore, it is unlikely to radically change our study results. Finally, additional studies with larger samples are needed to further elucidate the relationship and mechanism between MBOOI and abdominal pressure with BPH and the surgical effect.

Conclusions

Although both MBOOI and BOOI can predict the urinary symptoms in men with LUTS/BPH to a certain extent, however, there was a stronger correlation between MBOOI and LUTS. In addition, both AUC of MBOOI and BOOI for surgical efficacy was between 0.70 and 0.8, but MBOOI was slightly higher than that of BOOI. Meanwhile, our study indicates that MBOOI is significantly associated with improvements in IPSS, QoL, and Qmax after TURP. In general, these findings suggest that MBOOI may have greater potential than BOOI for evaluating disease and predicting surgical efficacy in patients with LUTS/BPH. Further research could quite beneficial to explain the role of MBOOI in the progression of disease and surgical prognosis in men with LUTS/BPH.

Abbreviations

BPH: Benign prostatic hyperplasia; BPO: Benign prostatic obstruction; BPE: Benign prostatic enlargement; LUTS: Low urinary tract symptom; QoL: Quality of Life; PFSs: Pressure-flow studies; BOO: Bladder outlet obstruction; BOOI: Bladder outlet obstruction index; Qmax: Maximum urine flow rate; MBOOI: Modified bladder outlet obstruction index; TURP: Transurethral resection of the prostate; PSA: Prostate-specific antigen; TRUS: Transrectal ultrasonography;

TPV: Total prostate volume; TZV: Transitional zone volume; TZI: Transitional zone index; IPSS-s: Storage IPSS; IPPS-t: Total IPSS; IPSS-v: Voiding IPSS; IPSS-p: Post-micturitional IPSS; PVR: Post void residual urine volume; P_{ves} : Intra-vesical pressure; P_{abd} : Abdominal pressure; P_{det} : Detrusor pressure at maximum urine flow rate; ROC: Receiver operating characteristic; AUC: Area under the curve; PVP: Green-light laser photo-selective vaporization of the prostate; HoLEP: Holmium laser enucleation of the prostate.

Acknowledgements

We thank Denise R, Jason Qee, from editorbar language editing, Beijing, China (www.leditorbar.com), for editing the English text of a draft of this manuscript.

Authors' contributions

Conceived and designed the study: HML and YT. Collected the data: HML, ZYS, YB, ZW. Analyzed and interpreted data: HML, YT and GHL. Drafted the manuscript: HML and ZYS. Critical revision of the manuscript: GHL, ZLS. All authors read and approved the final manuscript.

Funding

This study was supported by grants from the research program of National Science Foundation of China (Nos. 81860141 and 82160149), Health and Family Planning Commission of Guizhou Province Foundation (No. 2017-1-032), Science and Technology Foundation of Guizhou Province (No. [2021]378).

Availability of data and materials

The data used in the analysis are not publically available due to data protection, but anonymised data can be made available from corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was carried out in accordance with the Helsinki Declaration. This was a retrospective study that received approval by the Hospital Ethics Committee of GuiZhou Provincial People's Hospital, and written informed consent was obtained (No. 2018054).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interest.

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Received: 13 June 2021 Accepted: 29 November 2021

Published online: 06 December 2021

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