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 prostate hyperplasia (BPH) were included in this study. The International Prostate Symptom Score (IPSS), quality of life (QoL) index, transrectal ultrasonography, and pressure flow study (PFS) 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_{abd}, BOOI, MBOOI, TZV, TZI, IPSS-t, IPSS-v, IPSS-s, Q_{max}, and PVR at baseline ($P<0.05$). Compared with BOOI, the results of Pearson's correlation analysis showed that there was a more optimal correlation of MBOOI with preoperative variables, as well as with the changes postoperative($P<0.05$). 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: 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.

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 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: (i) bladder calculi, bladder tumor, neurogenic bladder dysfunction, urethral stricture, and other diseases that may affect the function of urination; (ii) previous surgery of the prostate and/or bladder and/or urethra; (iii) prostate cancer that was confirmed by postoperative 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 × width × length × π/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 transurethrally 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, intra-vesical 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 ($P_{det}Q_{max}$ -2Qmax) and MBOOI (P_{ves}-2Q_{max}) were calculated by P_{ves}, $P_{det}Q_{max}$, and Q_{max} [10]. In addition, the differences in these parameters before and after surgery were calculated (including ΔIPSS-t, ΔIPSS-v, ΔIPSS-s, ΔIPPS-p, ΔQoL, ΔQ_{max}, and ΔPVR).

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. Student's *t*-test was applied to compare difference in preoperative factors between two groups according to the overall efficacy. Pearson's correlation analysis was used to describe the relationships of BOOI and MBOOI with preoperative factors and the changes in IPSS, QoL, Q_{max}, and PVR. 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.

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%. A comparison of the overall efficacy in the effective and ineffective groups revealed significant differences in age, PSA, P_{ves}, $P_{det}Q_{max}$, P_{abd}, BOOI, MBOOI, TZV, TZI, IPSS-t, IPSS-v, IPSS-s, Q_{max}, and PVR at baseline ($P<0.05$), but significant differences were not observed in TPV, IPPS-p, or QoL (Table 2).

Comparison of the correlation of BOOI and MBOOI with the baseline characteristics and the changes (ΔIPSS, ΔQoL, ΔQmax and ΔPVR) after TURP

Table 3 shows the correlation of MBOOI with preoperative variables, with statistically significant differences observed in age (r=0.220), PSA (r=0.123), TPV (r=0.102), TZV (r= 0.142), TZI (r=0.216), IPSS-t (r=0.235), IPSS-v (r=0.154), IPSS-s (r=0.200), IPSS-p (r=0.121), QoL (r=0.145), and Q_{max} (r=-0.164) ($P<0.05$). Pearson's correlation test results also showed that both ΔIPSS-t (r=0.379), ΔIPSS-v (r=0.183), ΔIPSS-s (r=0.378), ΔIPSS-p (r=0.154), ΔQoL (r=0.314), ΔQ_{max}(r=0.234), and ΔPVR (r=0.130) increased with MBOOI ($P<0.05$). Moreover, the correlations between MBOOI and preoperative variables were more obvious than those with BOOI, as were postoperative changes (ΔIPSS, ΔQoL, ΔQ_{max}, and ΔPVR) (Table 3, Figure 1).

Association of surgical efficacy with preoperative variables

As presented in Table 4, simple linear regression analysis was used to analyze the correlations between preoperative factors and the surgical efficacy in IPSS, QoL, and Q_{max}. There were significant correlations between P_{ves}, $P_{det}Q_{max}$, P_{abd}, BOOI, MBOOI, TZI, and improvement in IPSS-t ($p<0.05$). Simultaneously, correlation analysis of preoperative variables indicated that there were significant correlations between Pves, $P_{det}Q_{max}$, P_{abd}, BOOI, MBOOI, TZI, IPSS-t, QoL, and Q_{max} at baseline and improvement in QoL ($p<0.05$). With respect to the improvements in Q_{max}, significant correlations with P_{ves}, $P_{det}Q_{max}$, BOOI, MBOOI, IPSS-t, Q_{max} and PVR were observed ($p<0.05$) (Table 4). 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 and IPSS-t were correlated with improvement of IPSS-t ($p<0.05$), MBOOI, P_{abd} and QoL with improvement of QoL ($p<0.05$), MBOOI and Q_{max} with improvement of Q_{max} ($p<0.05$). In addition, improved MBOOI and IPSS-t were correlated with the overall efficacy of TURP ($p<0.005$). Particularly, MBOOI was the only preoperative factor correlated with the surgical efficacy in IPSS, QoL, Q_{max}, and the overall both ($p<0.05$) (Table 4).

Furthermore, as shown in Figure 2, 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 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 0.491-0622), 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 0.252-0.639), 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 (Figure 2).

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, as the standard surgical method for the treatment of BPH, is not only the mainstream surgical method at present, but also often the preferred surgical method for BPH [6]. 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 [13–15]. Therefore, this study mainly focuses on the prediction of TURP efficacy by MBOOI. Nonetheless, 5%-35% of patients postoperatively report persistent symptoms after TURP [16]. 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 [17]. Similarly, previous studies have shown that patients with definite BOO derive greater benefit from TURP surgery than those with equivocal and unobstruction [18, 19]. 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 [20]. 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 [21]. 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 [22]. 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 [23]. 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 [24].

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 [25]. 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, one limitation of our implementation is that this is a retrospective study. 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 [26–29]. Further studies should carry out to compare the value of those parameters and MBOOI in predicting surgical efficacy. Third, 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 [30]. For example, Milonas et al. found that the volume of resected tissue was an important factor influencing the degree of symptom improvement [31]. 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

There was a stronger correlation between MBOOI and urinary symptoms in men with LUTS/BPH. More importantly, our study indicates that MBOOI is significantly associated with improvements in IPSS, QoL, and Q_{max} after TURP. 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 ultrasonograpy
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
$P_{det}Q_{max}$
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

Declarations

Ethics 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.

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.

Competing interests

The authors declare that they have no interests of conflict in this article.

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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.

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Tables

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

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

Note: IPSS-t = international prostate symptom total score, QoL=quality of life,

Q_{max}=maximum urine flow rate.

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	0.110
PSA (umol/L)	4.86±4.98	5.21±5.30	3.88±3.83	0.017
Ultrasonography				
TPV (mL)	52.84±27.63	54.19±28.06	49.05±26.12	0.100
TZV (mL)	24.90±19.45	26.09±19.92	21.59±17.73	0.041
TZI	0.43±0.14	0.44±0.15	0.40±0.12	0.027
Urodynamics				
P_{ves} (cmH2O)	102.72±40.04	110.38±40.58	81.23±29.38	<0.001
$P_{det}Q_{max}$(cmH2O)	84.92±35.23	90.57±36.07	69.10±27.22	<0.001
P_{abd} (cmH2O)	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	0.026
International prostate symptom score (IPSS)				
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	0.010
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	0.529
IPSS QoL	4.73±1.03	4.77±0.99	4.62±1.14	0.214

Note: 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.

Table 3 Correlation of BOOI, MBOOI with the baseline factors and the changes in IPSS, QoL, Qmax, and PVR after surgery

Variables	BOOI		MBOOI	
	r-value	p-value	r-value	p-value
Baseline characteristics				
Age (year)	0.206	<0.001	0.220	<0.001
PSA (umol/L)	0.121	0.015	0.123	0.013
TPV (mL)	0.106	0.033	0.102	0.041
TZV (mL)	0.139	0.005	0.142	0.004
TZI	0.201	<0.001	0.216	<0.001
IPSS-t	0.193	<0.001	0.235	<0.001
IPSS-v	0.121	0.015	0.154	0.002
IPSS-s	0.169	0.001	0.200	<0.001
IPSS-p	0.103	0.039	0.121	0.015
QoL	0.109	0.029	0.145	0.004
Q_{max} (mL/s)	-0.159	0.001	-0.164	0.001
PVR (mL)	0.043	0.388	0.054	0.283
Absolute value of post-pre in IPSS, QoL, Q_{max}, and PVR				
△IPSS-t	0.324	<0.001	0.379	<0.001
△IPSS-v	0.135	0.007	0.183	<0.001
△IPSS-s	0.339	<0.001	0.378	<0.001
△IPSS-p	0.143	0.004	0.154	0.002
△QoL	0.253	<0.001	0.314	<0.001
△Q_{max} (mL/s)	0.230	<0.001	0.234	<0.001
△P VR(mL)	0.118	0.018	0.130	0.009

Table 4 Relationship between the baseline factors and surgical efficacy in IPSS-t, Q_{max}, QoL and the overall surgical efficacy

Variables	Simple linear regression			Binary logistic regression
	Standardized coefficient β	t-value	p-value	OR (95%CI)
Surgical efficacy in IPSS-t				
TZI	-0.117	-2.359	0.019	
P_{ves} (cmH_2O)	-0.329	-6.970	<0.001	
$P_{det}Q_{max}$(cmH_2O)	-0.279	-5.811	<0.001	
P_{abd} (cmH_2O)	-0.204	-4.171	<0.001	
BOOI	-0.290	-6.063	<0.001	
MBOOI	-0.337	-7.168	<0.001	1.021(1.012-1.029)**
IPSS-t	-0.285	-5.952	<0.001	1.101(1.049-1.156)**
Surgical efficacy in QoL index				
TZI	0.125	2.515	0.012	
Pves (cmH_2O)	0.298	6.260	<0.001	
$P_{det}Q_{max}$(cmH_2O)	0.233	4.799	<0.001	
P_{abd} (cmH_2O)	0.228	4.687	<0.001	1.022(1.001-1.043)*
BOOI	0.253	5.239	<0.001	
MBOOI	0.314	6.634	<0.001	1.021(1.013-1.030)**
IPSS-t	0.129	2.595	0.010	
QoL	0.530	12.500	<0.001	1.962(1.541-2.498)**
Q_{max} (mL/s)	-0.114	2.298	0.022	
Surgical efficacy in Q_{max}				
P_{ves}(cmH_2O)	0.162	3.283	0.001	
$P_{det}Q_{max}$(cmH_2O)	0.147	2.966	0.003	
BOOI	0.230	4.719	<0.001	
MBOOI	0.234	4.821	<0.001	1.026(1.018-1.035)**
IPSS-t	0.118	2.372	0.018	
Qmax (mL/s)	-0.449	-10.050	<0.001	0.793(0.733-0.857)**

PVR (mL)	0.183	3.733	<0.001	
The overall surgical efficacy				
MBOOI				1.027(1.018-1.036)**
IPSS-t				1.064 (1.016-1.115)*

Note：*p<0.05, **p<0.001.

Figures

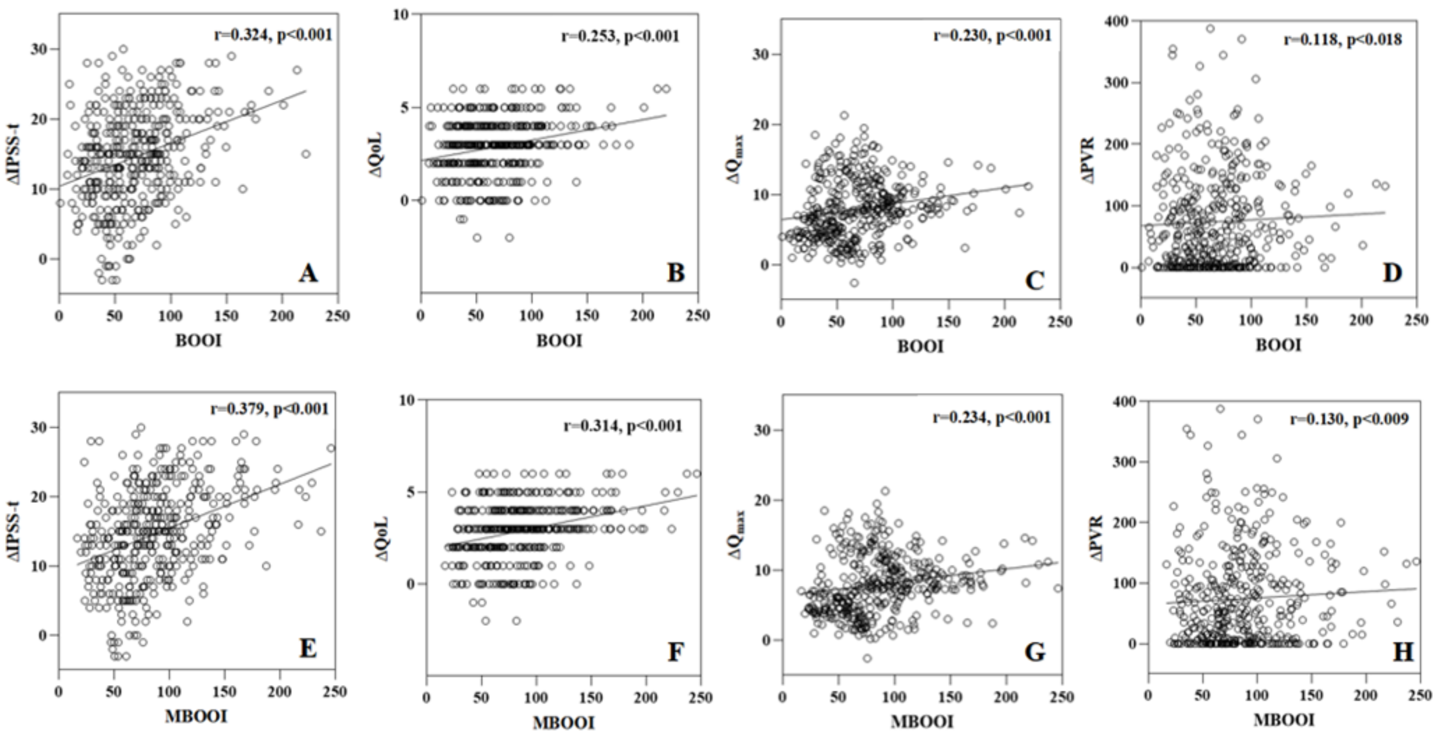

Figure 1

Correlation between BOOI, MBOOI and the postoperative changes in IPSS-t, QoL, Qmax, PVR. Correlation between BOOI and △IPSS-t (A), △QoL (B), △Qmax (C), △PVR (D). Correlation between MBOOI and △IPSS-t (E), △QoL (F), △Qmax (G), △PVR (H).

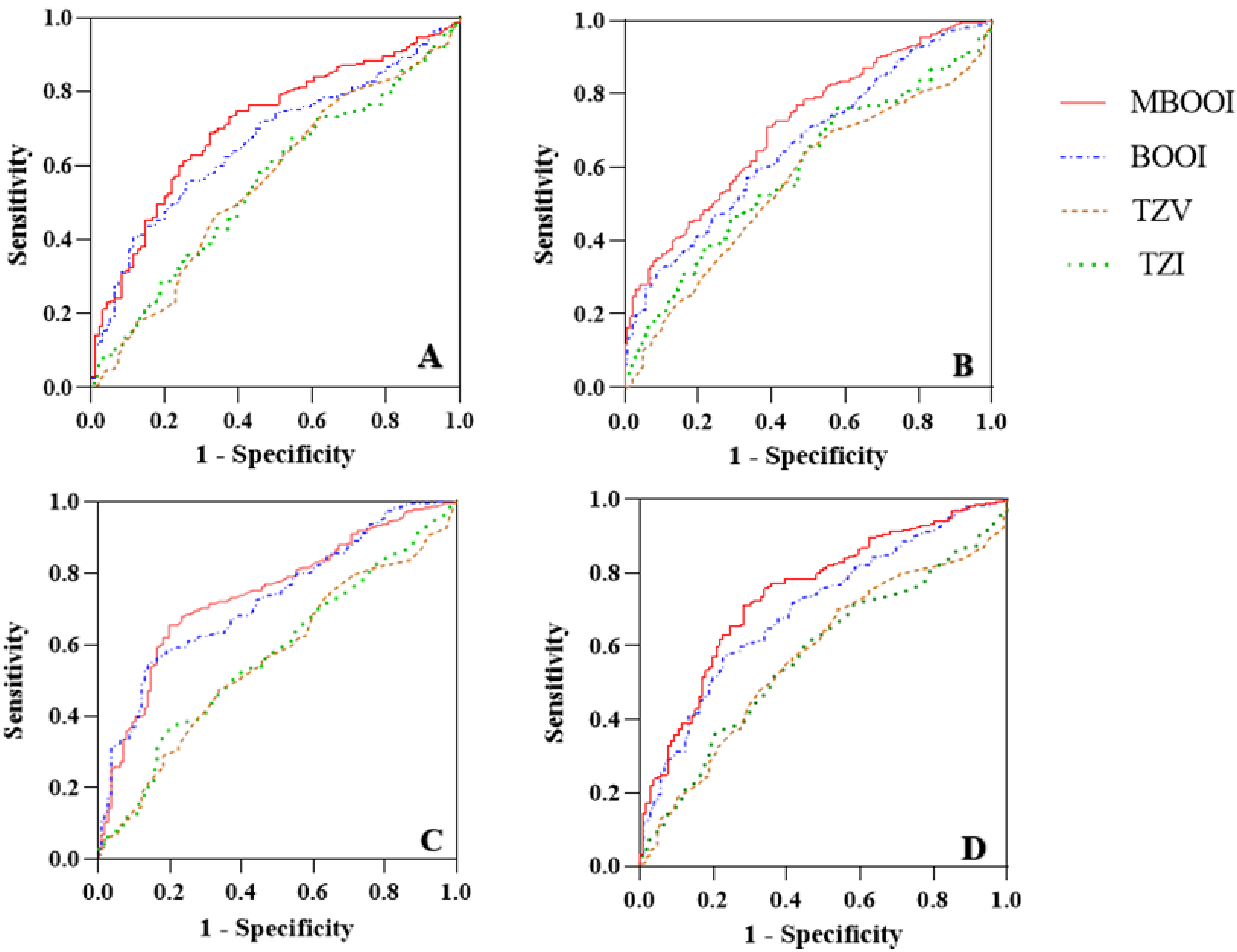

Figure 2

ROC curve analysis comparing MBOOI, BOOI, TZV and TZI in predict surgical efficacy. TURP efficacy in IPSS-t (A). TURP efficacy in QoL (B). TURP efficacy in Qmax(C). The overall surgical efficacy (D).