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Clinical comparison of TURP, PVP and holep for small volume BPH

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This retrospective study compares the efficacy and safety of transurethral resection of the prostate (TURP), green-light photoselective vaporization of the prostate (PVP), and holmium laser enucleation of the prostate (HoLEP) in treating small-volume benign prostatic hyperplasia (BPH). Data from 645 patients with small-volume BPH (2012–2022, Zhejiang Provincial People's Hospital) were analyzed. Baseline characteristics, surgical details, complications, and follow-up outcomes were compared. Logistic regression identified risk factors for urinary incontinence (UI) and bladder neck contracture (BNC). TURP was associated with a longer operative duration (53.15 ± 21.96 min) and catheterization time (5.29 ± 1.31 days) compared to PVP (48.53 ± 22.38 min, 4.84 ± 1.05 days) and HoLEP (45.00 ± 19.04 min, 4.79 ± 0.96 days). The incidence of BNC was significantly higher in the TURP group (9.4%) than in the PVP (4.8%) and HoLEP (5.7%) groups. Within 1 month postoperatively, the TURP group had a significantly higher proportion of patients with urinary incontinence. Between 1 and 3 months post-surgery, only UI with need for drug use (UIWD) remained significantly higher in the TURP group (8.2%). Preoperative indwelling catheterization, detrusor underactivity, severely elevated detrusor pressure, and undergoing TURP were identified as independent risk factors for UI. Green-light PVP was found to be a protective factor against BNC (OR = 0.40, *P* = 0.043). Green-light PVP and HoLEP showed similar efficacy and safety, with PVP offering the shortest operative time. TURP was associated with higher rates of BNC and UI. Laser techniques are preferable for high-risk patients.

Keywords Small-volume benign prostatic hyperplasia, Transurethral resection of the prostate, Green-light photoselective vaporization of the prostate, Holmium laser enucleation of the prostate

Benign prostatic hyperplasia (BPH) is a common condition in aging men, which is characterized by the proliferation of smooth muscle, connective tissue, and epithelial cells in the transition zone of the prostate[1,2]. Prostate volume (PV) serves as an essential reference indicator for formulating treatment strategies for BPH. Small-volume BPH, which is typically defined as a PV of ≤ 30 mL, presents unique clinical challenges[3]. In small-volume BPH, the severity of lower urinary tract symptoms (LUTS) does not invariably correlate strongly with PV[4,5]. This suggests that LUTS may arise from factors beyond anatomical enlargement, such as increased smooth muscle tone, bladder dysfunction, and local tissue remodeling[6]. Among these, bladder outlet obstruction (BOO), which refers to increased resistance to urinary flow at the bladder neck or prostatic urethra, plays a central role, even in small-volume BPH. As a result, surgical interventions, such as transurethral resection of the prostate (TURP), holmium laser enucleation (HoLEP), and green-light photoselective vaporization (PVP), remain key options for symptom relief in patients with BOO[7].

TURP has long been regarded as the "gold standard" for treating BPH[8]. In small-volume BPH, the limited surgical space makes precise resection more challenging; also, the use of electrocautery may increase the risk of thermal injury to surrounding tissue, leading to complications such as bleeding and urethral stricture[9]. Reich et al.[4]conducted a multicenter prospective study, reporting the perioperative complications of TURP in patients with small-volume BPH, including postoperative bleeding, transurethral resection syndrome, urethral stricture, and so on. HoLEP, which mimics open surgical enucleation, enables the complete gland removal and is commonly used in patients with large prostates[10]. Porto et al.[11] performed a retrospective study on HoLEP in patients with varying prostate volumes. They found that small-volume BPH (≤ 40 mL) was at a relatively

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higher risk of developing transient urinary retention after the surgery. Kim et al.[12] compared HoLEP and green-light PVP in small-volume BPH and discovered no significant differences in postoperative complications or key outcomes, including International Prostate Symptom Score (IPSS), quality of life (QoL), maximum urinary flow rate (Qmax), and post-void residual urine (PVR). Currently, evidence regarding the safety and efficacy of HoLEP in patients with small-volume BPH (≤ 30 mL) remains limited.

Our study aimed to analyze the applications of TURP, green-light PVP with green laser, and HoLEP in small-volume BPH. We compared the differences among the three in terms of efficacy, safety, recovery, and impact on QoL, thereby providing a basis for clinicians to select the optimal treatment plan.

Methods

Study design

The study was conducted at the Department of Urology, Zhejiang Provincial People's Hospital, People's Hospital of Hangzhou Medical College, Hangzhou, Zhejiang, China. All patients with LUTS due to BPH were assessed at our institution from January 1, 2012, to December 31, 2022. All study participants were informed about the planned procedure and asked to sign the informed consent form. The study was approved by the ethics committee of Zhejiang Provincial People's Hospital. All procedures were conducted in accordance with the Declaration of Helsinki and its amendments.

The inclusion criteria were as follows: prostate size ≤ 30 mL, previous failure of medication therapy (alpha-blockers and 5-alpha reductase inhibitors), or the symptoms significantly impacting the patient's QoL, coupled with the patient's strong inclination towards undergoing surgery. The evaluation of all patients included assessments of age, weight, height, hypertension, diabetes mellitus, heart disease, smoking history, drinking history, preoperative indwelling catheterization (≥ 2 weeks), PV, PVR, Qmax, detrusor pressure at Qmax (PedtQmax), cystometric capacity, IPSS, QoL, preoperative prostate-specific antigen (PSA) levels, bladder contractility index, BOO index, detrusor underactivity, detrusor overactivity, and postoperative complications. The postoperative complications were systematically recorded and categorized, including urethrostenosis, neurogenic bladder, bladder neck contracture (BNC), and urinary incontinence (UI). UI was further classified as urinary incontinence with need for drug use (UIND) and urinary incontinence without need for drug use (UIWND).

The exclusion criteria were as follows: prostate size > 30 mL, history of prior lower urinary tract surgery, confirmed or suspected prostate cancer, presence of bladder stones or significant bladder diverticula, uncontrolled coagulopathy or inability to discontinue anticoagulant therapy, severe cardiopulmonary impairment precluding safe anesthesia, and incomplete baseline or 3 month follow-up data. Figure 1 presents the flowchart for patient selection, including all exclusions. Patients lacking any baseline laboratory or imaging data were removed from the study cohort in accordance with CONSORT reporting standards. If only 3-month follow-up variables were absent, the study staff attempted telephone or SMS retrieval; when this failed, the case was coded as lost to follow-up.

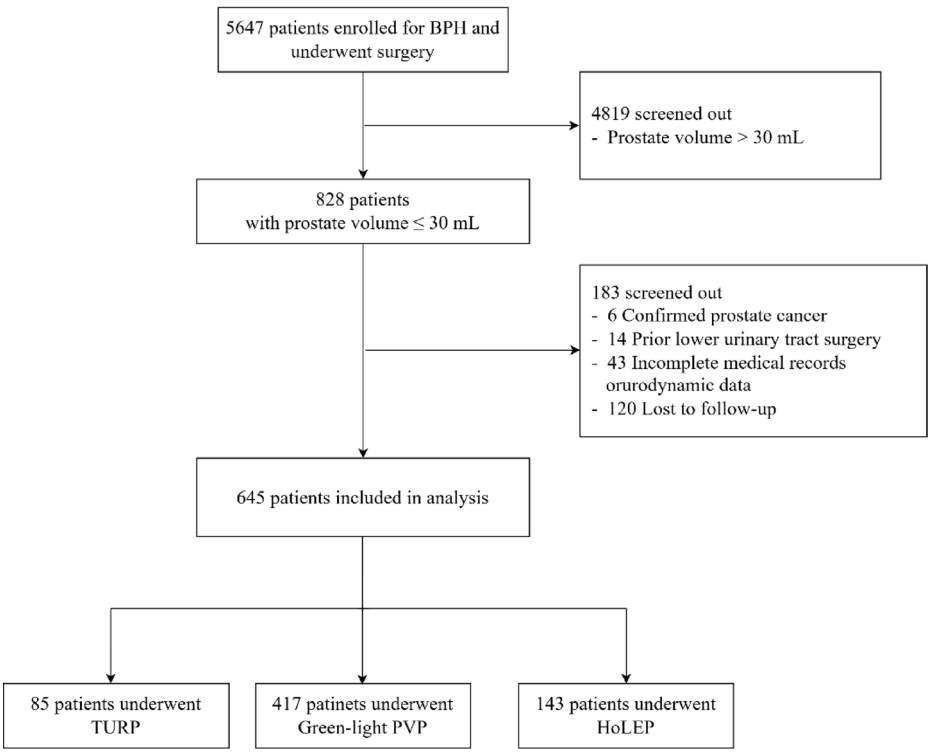

Fig. 1. Flowchart of patient selection and exclusion process.

Surgeon experience and learning curve

In our department, two dedicated surgical teams are responsible for all BPH procedures. Prior to allocating cases to this study, each team completed the required institutional training and surpassed a predefined learning curve (at least 30 independent cases) for TURP, greenlight PVP, and HoLEP. This ensured that all surgeons were fully proficient, minimizing any bias from earlycase inexperience.

Therapeutic regimen

After admission, we completed preoperative assessments (prostate ultrasound, urodynamics, PSA, and blood tests). The anesthesiologists and urologists jointly evaluated comorbidities. Once deemed suitable, patients and urologists engaged in shared decision-making: The benefits and potential complications of all surgical options (TURP, green-light PVP, and HoLEP) were explained to the patients, after which they signed the informed consent form. Postoperatively, a catheter was inserted and removed following bladder irrigation and a 1-day clamp test. The urinary control, complications, IPSS, and QoL were evaluated during a 3-month follow-up.

Statistical analysis

Descriptive statistical methods were employed to thoroughly analyze the demographic characteristics, clinical features, and postoperative complications of patients undergoing different surgical procedures. Meanwhile, a logistic regression model was used to precisely analyze the risk factors for the occurrence of postoperative UI and BNC. The missing data were assessed and handled accordingly: variables with minimal missingness were included using the pairwise deletion method; variables with substantial missingness were excluded from the regression model to avoid bias. The statistical analysis was accomplished using SPSS 25.0 software (IBM, NY, USA) and the R 4.1.1 programming language.

Results

Demographic characteristics of patients

This study included 645 newly diagnosed patients with BPH (≤ 30mL) at the Zhejiang Provincial People's Hospital from January 1, 2012, to December 31, 2022. Among these, 85 patients underwent TURP, 417 patients received green-light PVP, and the remaining 143 patients had *HoLEP*.

Table 1 compares the baseline parameters between the three groups. The Qmax in the TURP group was significantly lower than that in the other two groups. The use of 5α-reductase inhibitors was considerably less in the green-light PVP group than in the TURP group. Significant differences were found in PSA levels and cystometric capacity among the three groups. Decreased PV by TRUS was significantly greater in the HoLEP group compared with the TURP and green-light laser groups. No significant differences were observed in the remaining variables, indicating that the baselines were comparable.

Surgical data and intraoperative/perioperative complications

The data on intraoperative and perioperative complications are presented in Table 2. The surgical and catheter durations were longer in the TURP group compared with the other two groups ($P < 0.05$). The operative time in the green-light PVP group was longer than that in the HoLEP group. No significant difference was observed in the catheter duration between these two groups. Additionally, no significant difference was observed in perioperative complications among the three groups, with the majority being Clavien–Dindo Grade I.

Postoperative complications and follow-up

The postoperative complications and follow-up data according to the Clavien–Dindo classification are listed in Table 3. The incidence of urethral stricture was higher in the TURP group (7.0%) compared with the green-light PVP (2.6%) and the HoLEP groups (2.8%); however, no significant difference was observed among the three groups. Similarly, the incidence of BNC was higher in the TURP group (9.4%) than in the green-light PVP (4.8%) and the HoLEP groups (5.7%); however, no statistically significant difference was found among three groups.

The number of patients experiencing UI within 3 months after TURP was higher compared with that in the other groups. Specifically, the number of patients with UIWD (14.1%) and UIWND (16.4%) within 1 month after surgery was significantly higher than that in the TURP group. Within 1–3 months after surgery, only the UIWD group had a higher proportion of patients (7.1%) compared with the other two groups. Moreover, the IPSS scores of patients in the TURP group were higher than those in the other two groups during the 3-month postoperative follow-up.

Influential factors of UI and BNC

We conducted a logistic regression analysis to further explore the influencing factors for UI and BNC. Patients with preoperative indwelling urinary catheters were more likely to develop UI after surgery [odds ratio (OR) = 2.44, $P = 0.003$, Table 4]. In addition, green-light PVP and HoLEP were better at preserving the urinary continence function in patients, resulting in a lower incidence of UI. Compared with patients suffering from detrusor weakness (PdetQmax ≤ 30), those with normal PdetQmax (30 < PdetQmax ≤ 60, OR = 0.44, $P = 0.012$) or mildly elevated PdetQmax (60 < PdetQmax ≤ 80, OR = 0.49, $P = 0.033$) had a lower risk of developing UI.

Diabetes (OR = 2.16, $P = 0.026$) and hematuria/clot retention (OR = 2.51, $P = 0.047$) were all high-risk factors for the occurrence of BNC(Table 5). Green-light PVP (OR = 0.40, $P = 0.034$) served as a protective factor for the occurrence of BNC. Although no significant difference in BNC incidence was found between the TURP and green-light PVP groups, the logistic regression still suggested green-light PVP as a protective factor for BNC.

Parameters	TURP	Green-light laser	Holmium laser	*p* value
n	85	417	143	
Age, yr	69.00±7.91	67.55±9.31	67.31 ±10.10	0.384
BMI, kg/m^2	22.80±3.73	22.49±3.55	22.68±4.49	0.148
Diabetes (%)	29 (34.1)	176 (42.2)	51 (35.7)	0.205
Hypertension (%)	13 (15.2)	90 (21.6)	26 (18.2)	0.346
Heart disease (%)	11 (12.9)	38 (9.1)	12 (8.4)	0.484
Prior medications				
α-blocker	72 (84.7)	348 (83.5)	123 (86.0)	0.672
5α-reductase inhibitors	43 (50.6)	165 (39.6)[a]	59 (41.3)	0.171
OAB medications	15 (17.6)	48 (11.5)	22 (15.4)	0.212
Smoke history (%)	31 (36.5)	171 (41.0)	57 (39.9)	0.737
Drink history (%)	36 (42.3)	145 (34.8)	56 (39.2)	0.332
Preoperative indwelling catheter (%)	3 (3.5)	25 (6.0)	11 (7.7)	0.174
Acute urinary retention (%)	3 (3.5)	18 (4.3)	5 (3.5)	0.851
PSA level, ng/mL	2.78±1.90	3.18±2.76[a]	3.24±1.88[c]	<0.001
PV by TRUS, ml	23.87±4.08	24.06±4.10[c]	24.92±4.21	0.067
3-month postoperative PV by TRUS, ml	13.52±4.15	14.41±3.89[c]	11.36±4.07	0.054
Decreased PV by TRUS, ml	10.35±3.44[b]	9.65±3.86[c]	13.56±3.51	<0.001
PVR, ml	100.34±36.47	105.25±56.05	98.82±46.41	0.621
Qmax, mL/s	6.49±3.13	7.43±3.67[a]	7.16±3.18[b]	0.074
PdetQmax, cmH_2O	68.73±22.87	69.49±25.99	70.31±20.04	0.889
Cystometric capacity, ml	278.63±100.15	314.14±89.22[a]	262.98±90.31[b,c]	<0.001
BCI	101.16±26.52	106.62±31.69	106.08±25.44	0.302
BOOI	55.76±24.25	54.63±27.06	56.00±21.58	0.831
DU	37 (43.5)	165 (39.6)	54 (37.8)	0.688
DO	57 (67.1)	252 (60.4)	94 (65.7)	0.341
Preoperative IPSS	25.19±3.11	24.87±2.98	24.62±3.78	0.416
Preoperative QoL	5.20±0.71	5.10±0.59	5.04±0.62	0.198

Table 1. Baseline characteristics of all patients and according to surgical procedure. *PV* Prostate volume, *PVR* Postvoid residual urine volume *TRUS* Transrectal ultrasound, *Qmax* Maximum urinary flow rate *PdetQmax* Detrusor contracting pressure at maximum flow rate, *IPSS* International prostate symptom score, *QoL* quality of life *BOOI* Bladder outlet obstruction index, *BCI* Bladder contractility index, *DU* Detrusor underactivity, *DO* Detrusor overactivity.[a]represents the statistical difference between the TURP group and the green-light laser group[b]represents the statistical difference between the TURP group and Holmium laser group[c]represents the statistical difference between the the green-light laser group and Holmium laser group

Parameters	TURP	Green-light laser	Holmium laser	*P* value
Operative time, min	53.15 ± 21.96	48.53 ± 22.38[a]	45.00 ± 19.04[b]	< 0.001
Catheter duration, d	5.29 ± 1.31	4.84 ± 1.05[a]	4.79 ± 0.96[b]	0.001
UTI (%)	5 (5.9)	29 (7.0)	5 (3.5)	0.764
Acute urinary retention requiring a catheter (%)	10 (11.8)	29 (6.9)	10 (7.0)	0.459
Hematuria/clot retention (%)	7 (8.2)	23 (5.5)	6 (4.1)	0.090
Bladder irrigation	5 (5.9)	17 (4.1)	5 (3.5)	0.091
Surgical intervention	2 (2.4)	6 (1.4)	1 (0.7)	0.076
Sepsis (%)	1 (1.2)	1 (0.3)	0 (0)	0.450

Table 2. Operative data and intra/perioperative complications stratified by surgical procedures. *UTI* Urinary tract infection. [a] represents the statistical difference between the TURP group and the green-light laser group. [b] represents the statistical difference between the TURP group and Holmium laser group. [c] represents the statistical difference between the the green-light laser group and Holmium laser group.

Discussion

BPH is a clinically progressive disorder. The hyperplastic prostate tissue can trigger BOO, which leads to LUTS, exerting a substantial impact on patients' QoL[13]. Clinically, drug therapy is initially recommended for small-volume BPH with prominent LUTS, but the compressive effect of the prostate on the urethra is not

Parameters	TURP	Green-light laser	Holmium laser	*p* value
Urethrostenosis (%)	6 (7.0)	11 (2.6)	4 (2.8)	0.105
Urethral stenosis requiring dilation only (CDS II, %)	4 (4.7)	8 (2.8)	3 (2.0)	0.487
Urethral stenosis requiring urethrotomy (CD S III, %)	2 (2.3)	3 (1.2)	1 (0.6)	0.066
Neurogenic bladder (CDS II, %)	5 (5.9)	25 (6.0)	6 (4.2)	0.439
UIND (< 1 month, CDS II, %)	12 (14.1)	28 (6.9)[a]	6 (4.2)[b]	0.030
Urge	3 (3.5)	7 (1.7)	2 (1.4)	
Stress	7 (8.2)	12 (2.9)	3 (2.1)	
Mixed	2 (2.4)	9 (2.2)	1 (0.7)	
UIND (1-3 month, CDS II, %)	7 (8.2)	12 (2.9)[a]	3 (2.1)[b]	0.007
Urge	1 (1.2)	3 (0.7)	1 (0.7)	
Stress	4 (4.7)	5 (1.2)	2 (1.4)	
Mixed	2 (2.4)	4 (1.0)	0 (0.0)	
UIND (3-12 month, CDS II, %)	5 (5.9)	6 (1.4)	1 (0.7)	0.041
Urge	1 (1.2)	1 (0.2)	1 (0.7)	
Stress	3 (3.5)	3 (0.7)	0 (0.0)	
Mixed	1 (1.2)	2 (0.5)	0 (0.0)	
UIWND (< 1 month, CDS I, %)	14 (16.4)	34 (8.1)[a]	9 (6.3)[b]	0.023
Urge	2 (2.4)	5 (1.2)	1 (0.7)	
Stress	7 (8.2)	21 (5.0)	5 (3.5)	
Mixed	4 (4.7)	8 (1.9)	3 (2.1)	
UIWND (1-3 month, CDS I, %)	6 (7.1)	10 (2.3)	3 (2.1)	0.171
Urge	0 (0.0)	1 (0.2)	0 (0.0)	
Stress	3 (3.5)	6 (1.4)	2 (1.4)	
Mixed	3 (3.5)	3 (0.7)	1 (0.7)	
UIWND (3-12 month, CDS I, %)	1 (1.2)	4 (1.0)	0 (0.0)	0.477
Urge	0 (0.0)	0 (0.0)	0 (0.0)	
Stress	1 (1.2)	3 (0.7)	0 (0.0)	
Mixed	0 (0.0)	1 (0.2)	0 (0.0)	
Bladder neck contracture (CDS III, %)	8 (9.4)	20 (4.8)	8 (5.7)	0.241
Time of bladder neck contracture after operation, m	8.00±2.54	9.64±4.40	9.25±1.71	0.460
PVR 3 months after surgery, ml	22.12±16.09	21.48±20.14	19.63±16.66	0.529
Decrease in PVR, ml	79.51±38.68	83.41±58.69	89.78±36.53	0.274
Qmax 3 months after surgery, mL/s	20.89±4.77	22.13±5.36[a]	22.40±5.26[b]	0.090
Increase in Qmax, mL/s	14.41±5.35	14.70±6.21	15.24±5.81	0.537
IPSS 3 months after surgery	7.67±3.15	6.33±3.20[a]	6.11±3.16[b]	0.001
QoL 3 months after surgery	1.36±1.05	1.40±1.09	1.29±0.82	0.550

Table 3. Postoperative long-term complications and follow-up data. *UIND* Urinary incontinence with need for drug use, *UIWND* Urinary incontinence without need for drug use *IPSS*= International Prostate Symptom Score, *QoL* quality of life, *CDS* Clavien-dindo system, *Qmax* Maximum urinary flow rate, *PVR* Postvoid residual urine volume[a]represents the statistical difference between the TURP group and the green-light laser group[b]represents the statistical difference between the TURP group and Holmium laser group[c]represents the statistical difference between the the green-light laser group and Holmium laser group

the dominant factor. Instead, the development of micturition disorders is related to dynamic obstruction, mechanical obstruction, and other factors. Some studies have revealed that there are even more crucial factors such as bladder neck and functional dysregulation, and the efficacy of drug treatment for small-volume BPH is often suboptimal[14,15]. When drug therapy fails to control the symptoms, surgical intervention is necessary[16,17]. Currently, the relatively common surgical methods mainly include TURP, green-light PVP, and HoLEP[14].

Risk factors for BNC

TURP demonstrates enduring efficacy in enhancing the functionality of small-volume BPH. However, this procedure is associated with surgery-related and postoperative complications, including blood loss, dilutional hyponatremia, hypervolemia, BNC, urethral stricture, retrograde ejaculation, and UI[18]. Chen et al.[19] identified TURP as an independent risk factor for BNC in small-volume prostates, consistent with our findings. Additionally, the inability of TURP to effectively manage certain anatomical factors, such as high tension of the circular fibers at the bladder neck, bladder neck sclerosis, or elevation, further contributes to the occurrence of BNC[20,21]. The potential mechanisms by which TURP may induce BNC include thermal injury leading to localized tissue necrosis and subsequent inflammatory responses, which can result in fibrosis[22]. Aberrant

	Univariable analysis			Multivariable analysis		
	OR	95%CI	P	OR	95%CI	P
Age	1.01	0.98-1.03	0.370			
Hypertension	1.31	0.78-2.19	0.287			
Diabetes	0.87	0.56-1.34	0.560			
Preoperative indwelling catheter	2.44	1.27-4.51	0.005	2.66	1.36-5.06	0.003
PV	1.01	0.97-1.07	0.478			
PVR	0.99	0.99-1.01	0.855			
Qmax, mL/s	1.04	0.98-1.10	0.145			
PdetQmax, cmH_2O						
≤30		Reference			Reference	
>30 and ≤60	0.32	0.17-0.59	<0.001	0.44	0.23-0.84	0.012
>60 and ≤80	0.38	0.20-0.72	0.002	0.49	0.25-0.94	0.033
>80	0.78	0.41-1.48	0.459	0.86	0.45-1.66	0.668
Cystometric capacity, ml	1.01	0.99-1.02	0.701			
Preoperative IPSS	0.94	0.88-1.02	0.143			
Preoperative QoL	1.173	0.680-2.032	0.343			
Surgery						
TURP		Reference				
Green-light laser	0.44	0.26-0.76	0.002	0.43	0.24-0.76	0.003
Holmium laser	0.28	0.15-0.56	<0.001	0.33	0.15-0.67	0.002
Operative time, min	1.01	0.98-1.04	0.947			
Catheter duration,d	1.15	0.95-1.38	0.139			
Hematuria /clot retention	0.43	0.10-1.24	0.177			
UTI	1.062	0.245-3.204	0.923			

Table 4. Univariate and multivariate logistic regression analysis on urinary incontinence. *PV* Prostate volume, *PVR* Postvoid residual urine, *TRUS* Transrectal ultrasound, Qmax Maximum urinary flow rate, *PdetQmax* Detrusor contracting pressure at maximum flow rate, IPSS international prostate symptom score, *QoL* Quality of life *UTI* Urinary tract infection

collagen deposition during the postoperative healing process may also contribute to the development of BNC[23]. In contrast, laser-based techniques, including HoLEP and green-light PVP offer more precise tissue ablation with minimal collateral thermal damage, thus potentially reducing the risk of fibrotic complications and preserving the integrity of the bladder neck[18,24].

Additionally, postoperative hematuria or clot retention emerged as significant risk factors for BNC in our study. Blood clots exert compressive pressure on local tissue, inducing ischemia and hypoxia. The latter may also act as foreign bodies, triggering an inflammatory cascade and promoting fibrotic proliferation[25]ultimately leading to contracture. Although Nicholson et al.[26] suggested that systemic comorbidities such as hypertension, diabetes, and cardiovascular disease might increase BNC risk, only hypertension was identified as a significant predictor in our cohort.

Risk factors for UI

UI is one of the complications causing maximum worry among patients before surgery and of maximum concern among urologists. Although the mechanism underlying UI remains unclear. At present, the prevailing view is that any damage to the urethral sphincter during the surgical procedure can give rise to sphincter incompetence, thereby triggering the onset of postoperative stress UI[27]. Regarding the pathogenesis of postoperative urge UI, Zhao et al.[28] demonstrated that patients with preoperative terminal detrusor overactivity not only had significantly higher baseline overactive bladder symptom scores (11.0 vs. 8.1 for phasic or no detrusor overactivity, $P<0.05$) but were also more likely to report persistent urge UI in three months (42.9% vs. 7.7%, $P=0.037$). In this study, the incidence of transient UI, as well as UIND within 3 months after surgery, was higher in the TURP group compared with the green-light PVP or HoLEP group. Although the long-term incidence of UI showed no significant difference among the three procedures, the short-term advantage of PVP and HoLEP in terms of UI prevention highlights their potential value in reducing early-stage complications, thus warranting more in-depth exploration to optimize surgical choices for patients.

As a pivotal determinant governing bladder micturition function, detrusor pressure is intricately and closely related to postoperative UI. Cornwell et al.[29], in a single-surgeon HoLEP series, found that a higher preoperative PdetQmax was significantly associated with UI at 6-week follow-up (mean PdetQmax 95 cmH_2O in patients with no UI vs. 60 cm H_2O in patients with UI, $P<0.01$), although this pressure effect diminished by 12 months. In our study, patients presenting with normal or mildly elevated detrusor pressure had a significantly lower risk of postoperative UI compared with those with detrusor weakness. Thus, both our findings and those of Cornwell emphasize that detrusor hemodynamics, whether elevated or diminished, play a crucial role in the development

	Univariable analysis			Multivariable analysis		
	OR	95%CI	P	OR	95%CI	P
Age	1.02	0.98-1.05	0.413			
Hypertension	1.31	0.57-2.74	0.499			
Diabetes	2.08	1.06-4.13	0.031	2.16	1.09-4.32	0.026
Preoperative indwelling catheter	2.25	0.81-5.34	0.083			
PV	1.05	0.97-1.11	0.224			
PVR	1.01	0.99-1.02	0.089			
Qmax, mL/s	1.03	0.94-1.13	0.609			
PdetQmax, cmH_2O						
≤30		Reference				
>30 and ≤60	0.39	0.11-1.08	0.097			
>60 and ≤80	0.56	0.20-1.26	0.200			
>80	0.57	0.29-1.03	0.069			
Bladder capacity, ml	1.00	0.99-1.01	0.514			
Preoperative IPSS	1.08	0.97-1.19	0.130			
Preoperative QoL	0.65	0.38-1.12	0.124			
Surgery						
TURP		Reference			Reference	
Green-light laser	0.42	0.20-0.94	0.042	0.40	0.18-0.97	0.034
Holmium laser	0.50	0.20-1.25	0.138	0.49	0.18-1.37	0.175
Operative time, min	1.01	0.98-1.03	0.445			
Catheter duration,d	1.03	0.75-1.38	0.828			
Hematuria /clot retention	2.81	1.62-6.15	0.043	2.51	1.43-5.54	0.047
UTI	2.55	1.23-6.46	0.063			

Table 5. Univariate and multivariate logistic regression analysis on bladder neck contracture. *PV* Prostate volume, *PVR* Postvoid residual urine, *TRUS* Transrectal ultrasound, *Qmax* Maximum urinary flow rate, *PdetQmax D*etrusor contracting pressure at maximum flow rate, *IPSS* International prostate symptom score, *QoL* Quality of life, *UTI* Urinary tract infection

and resolution of early postoperative UI. Patients with detrusor weakness, have difficulty effectively emptying the bladder, leading to an increase in residual urine volume in the bladder and a rise in intravesical pressure, thus triggering overflow UI[30]. The long-term high-pressure state impairs and destabilizes the function of the bladder detrusor muscle in patients with severely elevated detrusor pressure. After surgery, the detrusor muscle is prone to involuntary strong contractions, with an abnormal urethral sphincter, which results in urge or mixed UI.

Comparison of surgical techniques

The widespread application of medical lasers has led to the rapid adoption of green-light PVP and HoLEP in the treatment of small-volume BPH. A series of studies compared on the application of TURP individually with green-light PVP and HoLEP in the treatment of small-volume BPH[9,31,32]. In these comparative analyses, both PVP and HoLEP have demonstrated more favorable intraoperative performance; also, the incidence of postoperative complications such as UI and urethral stricture is also lower. However, at present, only one retrospective study has compared the efficacy and safety of PVP and HoLEP in small-volume BPH (< 40 mL), and the high-quality evidence is also lacking[12]. Our study revealed that green-light PVP and HoLEP yielded similar results in terms of improvements in both subjective and objective parameters.The only difference was in the surgical duration, where HoLEP had an edge. Compared with TURP, HoLEP is not a protective factor for the occurrence of BNC. The incidence of BNC in the HoLEP group was lower than that in the TURP group. However, no significant difference was observed between the two groups, which might be due to the small sample size of the two patient groups. Hypertension, diabetes, and heart disease all could increase the risk of BNC. However, only hypertension was identified as a risk factor for BNC in this study.

Study limitations

The present study had several limitations. First, the relatively small sample sizes in both the TURP and HoLEP groups might have limited the statistical power to detect significant differences between groups, potentially leading to type II errors. Second, the limited follow-up duration restricted our ability to comprehensively observe and evaluate long-term complications, thereby underestimating their true incidence. Third, the retrospective design introduced inherent biases and confounding factors impacting the internal validity of the study. These limitations should be considered when interpreting the generalizability of our findings. Also, future prospective studies with larger cohorts and longer follow-up are warranted to confirm our results.

In summary, although TURP is an effective treatment for small-volume BPH, its association with higher rates of postoperative BNC and short-term UI highlights potential drawbacks compared with minimally invasive

laser techniques such as green-light PVP and HoLEP. The varying mechanisms of tissue injury and healing between these approaches, along with patient-related factors such as diabetes, hematuria, detrusor dysfunction, and prolonged catheterization, emphasize the importance of individualized surgical planning. These findings support the use of laser-based procedures as a preferable option for patients at higher risk of complications, thereby facilitating more personalized and safer clinical decision-making. Importantly, integrating shared decision-making into the clinical workflow allows patients to weigh the trade-offs of different surgical techniques based on personalized risk profiles, recovery expectations, and long-term functional outcomes. This patient-centered approach not only improves satisfaction and adherence but also aligns treatment strategies with individual values and preferences. However, further studies are warranted to assess long-term outcomes and compare these established methods with emerging modalities such as aquablation and Rezum water vapor therapy, which may offer additional benefits in managing small-volume BPH.

Conclusions

Greenlight PVP and HoLEP provide comparable symptom relief and improvements in urinary flow for patients with small-volume BPH, with PVP having the shortest operative time. However, TURP is associated with higher rates of BNC and early *UI*. Detrusor dysfunction, prolonged catheterization, diabetes, and hematuria/clot retention have emerged as key predictors of these complications. Accordingly, laser-based approaches are preferable for patients with small prostates and the aforementioned risk factors. Prospective, long-term studies, ideally including newer options such as aquablation and Rezum, are needed to confirm these findings.

Data availability

The databases used and analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions

XHH and JM conceived the study, participated in the investigation, and drafted the manuscript. KHX and YKY carried out the data curation and helped to draft the manuscript. XYZ and YFW participated in the data analysis. LQ performed data visualization and validation. DHZ and HBW carried out supervision and writing - review & editing. HBW provided funder for this study. All authors read and approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

This study was approved by the Ethics Committee of Zhejiang Provincial People's Hospital. All patients signed informed consent prior to treatment. All procedures were conducted in accordance with the Declaration of Helsinki and its amendments.

Additional information

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