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ARTICLE

Urodynamic de-obstruction and symptom improvement after thulium laser vaporization (ThuVAP): evidence from a prospective paired study

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Background: *Thulium laser vaporization of the prostate (ThuVAP) is an established treatment for benign prostatic obstruction, but its impact on urodynamic parameters remains poorly defined. This study aimed to quantify the de-obstructive efficacy of ThuVAP through pre- and postoperative urodynamic comparisons and to assess the relationship between urodynamic improvement and symptom relief.*

Methods: *In a prospective single-center cohort (June 2022–June 2024), men with urodynamically confirmed obstruction underwent standardized ThuVAP with a 200-W thulium:YAG system. Baseline and 6-month invasive urodynamics and 12-month clinical follow-up were performed. The primary endpoint was the change in the bladder outlet obstruction index (BOOI); secondary endpoints included Qmax, postvoid residual volume (PVR), bladder voiding efficiency (BVE), detrusor pressures, and International Prostate Symptom Score (IPSS).*

Results: *Sixty-four patients (mean age 67 years; prostate volume 52 mL) were analyzed. BOOI decreased from 55.9 ± 17.2 to 21.3 ± 11.2 ($p < 0.001$), with obstructed cases dropping from 79.7% to 7.8%. Schäfer grade fell from 3.6 to 0.3 ($p < 0.001$). Detrusor pressure halved, Qmax rose from 7.9 to 20.8 mL/s, PVR declined from 121 to 22 mL, and BVE improved from 64% to 94% (all $p < 0.001$). Low compliance and involuntary detrusor contractions (IDC) decreased notably. IPSS improved from 26.2 to 3.4 ($p < 0.001$) and correlated with the magnitude of urodynamic de-obstruction.*

Conclusions: *ThuVAP provides substantial, objectively verified relief of bladder outlet obstruction with consistent improvements in voiding efficiency and symptoms. The correlation between urodynamic and clinical outcomes underscores the procedure's efficacy and the utility of urodynamics in documenting therapeutic benefit.*

Key Words: benign prostatic hyperplasia, bladder outlet obstruction, thulium laser, urodynamic, vaporization

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Introduction

Benign prostatic obstruction (BPO), most commonly resulting from benign prostatic hyperplasia (BPH), is the leading cause of male lower urinary tract symptoms (LUTS).[1] BPO arises from two principal pathophysiological components: (1) prostatic urethral compression (static component) and (2) increased smooth muscle tone within the prostatic stroma (dynamic component).[2] Beyond LUTS, BPO may lead to secondary bladder dysfunction (BD), manifesting as either detrusor overactivity (DO) or detrusor underactivity (DU).[3]

Over the past two decades, treatment options for BPH-related LUTS have broadened considerably. While transurethral resection of the prostate (TURP) remains the gold standard for men with moderate prostate enlargement, laser-based procedures have become well-established alternatives owing to their comparable efficacy and favorable safety profile. In fact, certain laser techniques are now considered first-line surgical options in selected scenarios—such as in patients with large prostates or with increased bleeding risk—where conventional TURP may be less optimal. Among these, holmium and thulium laser systems are the most widely adopted.[4,5]

The thulium:YAG laser, introduced for BPO surgery in 2005, is a solid-state, continuous-wave water-targeted laser with a wavelength of approximately 2013 nm.[6,7] It enables precise cutting with consistent vaporization regardless of tissue vascularity. Its shallow penetration depth (0.1–0.2 mm) minimizes collateral thermal injury, while its excellent coagulative capacity ensures reliable hemostasis.[8] Thulium laser prostatectomy can be performed via different techniques, including vaporization (ThuVAP), vaporesection (ThuVARP), and enucleation (ThuLEP).[9] ThuVAP, in particular, has been shown to be effective and safe;[10,11] however, most available evidence focuses on peri-operative and short-term functional outcomes, with limited reporting of detailed urodynamic parameters, leaving uncertainty about its precise impact on bladder outlet function.[12,13]

Given this gap, the primary aim of this study was to evaluate the functional impact of ThuVAP on bladder outlet function by comparing comprehensive pre- and postoperative urodynamic findings. A secondary objective was to investigate the relationship between objective urodynamic de-obstruction and subjective symptom relief.

Materials and Methods

Study design and ethical considerations

We conducted a prospective, single-center study at Monaldi Hospital (Naples, Italy) between June 2022 and June 2024. The study adhered to the principles outlined in the Declaration of Helsinki for medical research involving human subjects[14] and was approved by the University of Campania Luigi Vanvitelli-A.O.R.N. dei Colli Ethics Committee (approval number: 11566/2022). All participants provided written informed consent for inclusion of their data in the study database and for their use in scientific publications.

Patient selection and eligibility criteria

Consecutive male patients with BPO secondary to BPH who were refractory to medical therapy and were candidates for ThuVAP at our institution were considered for inclusion.

Eligible patients were aged ≥40 years, had moderate-to-severe LUTS defined by an International Prostate Symptom Score (IPSS) ≥8[15] or the presence of an indwelling urinary catheter despite optimized BPH medical therapy, a prostate volume ≤80 mL on transrectal ultrasonography, and urodynamically confirmed bladder outlet obstruction (BOO) according to International Continence Society (ICS) criteria.[16,17]

Exclusion criteria comprised prior prostatic surgery; suspected or documented prostate cancer (PCa); history of pelvic radiotherapy; neurogenic lower urinary tract dysfunction; history of bladder cancer; presence of bladder stones; previous urethral stricture or urethral reconstruction; chronic bacterial prostatitis; recurrent urinary tract infections (UTIs); chronic pelvic pain syndrome; uncontrolled diabetes. Patients with severe, uncontrolled comorbidities that contraindicated anesthesia or endoscopic surgery were excluded. Men with psychiatric disorders or an inability to complete the questionnaires were also excluded, as were subjects with missing data. Ongoing anticoagulant or antiplatelet therapy that could not be discontinued was not considered an exclusion criterion.

Patient assessment and measured outcomes

All patients underwent a comprehensive baseline evaluation, including demographic data, general clinical parameters, and BPO-specific history. Preoperative assessment comprised digital rectal examination (DRE), serum prostate-specific antigen (PSA) measurement, transrectal ultrasonography (TRUS) for prostate volume determination, IPSS, uroflowmetry with postvoid residual (PVR) volume determination, and invasive urodynamic testing. The presence of a median lobe was determined intraoperatively by endoscopic identification of intravesical protrusion; no ultrasound measurements or dimensional cut-off criteria were applied. No fixed PSA cutoff was applied as a sole exclusion criterion. In cases of elevated PSA and/or abnormal DRE, patients underwent mpMRI and, when indicated, targeted and/or systematic prostate biopsy. All patients with clinical suspicion or histological confirmation of prostate cancer were excluded from enrollment.

Urodynamic studies were performed at baseline (T0) and at 6 months postoperatively (T1) in accordance with ICS standards,[17] and were conducted in all cases by the same experienced functional urologist to ensure methodological consistency. The primary outcome was the change in the Bladder Outlet Obstruction Index (BOOI) from T0 to T1. According to the International Continence Society (ICS) definition, a BOOI ≥40 was considered obstruction, 20–40 equivocal, and <20 as no obstruction.[18] Secondary urodynamic outcomes included functional, normal, and strong desire to void capacities (first desire to urinate [FDU], normal desire to urinate [NDU], strong desire to urinate [SDU]); maximum cystometric capacity (MCC); low bladder compliance (LBC, defined as ≤20 mL/cmH_2O;)[19] presence of involuntary detrusor contractions (IDC) and detrusor pressure at IDC; detrusor pressure at opening of flow (P_{det} at opening); detrusor pressure at maximum flow ($P_{det}Q_{max}$); maximum detrusor pressure during voiding ($P_{det, max}$); maximum urinary flow rate during the pressure-flow study (Q_{max}); time to maximum flow (tQ_{max}); voiding time (VT); postvoid residual volume (PVR) and proportion with PVR ≥ 100 mL; bladder voiding efficiency (BVE); bladder outlet obstruction index (BOOI), proportion with BOOI ≥ 40; bladder contractility index (BCI); and Schäfer nomogram grade.[20]

The International Prostate Symptom Score (IPSS) questionnaire, defined a priori as a secondary clinical endpoint, was administered at baseline (T0) and at 6 months postoperatively (T1). Free uroflowmetry was obtained at baseline and subsequently at 3, 6, and 12 months postoperatively.

Perioperative variables—such as operative time, catheterization time, length of hospital stay, and need for blood transfusion—were recorded for all patients. Intraoperative complications and postoperative adverse events were systematically documented, with postoperative events classified according to the Clavien-Dindo (CD) grading system.[21] During follow-up, any initiation or resumption of medical therapy for BPO or any surgical re-intervention for persistent obstruction was recorded. All patients completed a minimum follow-up of 12 months.

Surgical technique and perioperative management

All patients underwent preoperative urine culture, and surgery was performed only in cases with negative results or after resolution of a documented UTI, confirmed by repeat culture following appropriate antibiotic therapy. Perioperative antibiotic prophylaxis, in accordance with the institutional protocol, consisted of a single intravenous dose of ceftriaxone (1 g) administered 30–60 min before the start of the procedure.

In all cases, a high-power continuous-wave thulium:YAG laser (Cyber TM, Quanta System, Italy) was used, delivering 200 W for vaporization and 30 W for hemostasis through an 800 μm end-firing fiber. The laser was operated via a 26 Ch continuous-flow resectoscope (KARL STORZ SE & Co. KG, Tuttlingen, Germany) with a 12° lens and an Iglesias working element, under continuous 0.9% saline irrigation. Vaporization was performed using a two- or three-lobe approach, depending on the presence of a median lobe. The procedure began with bladder neck incisions at the 5 and 7 o'clock positions using a painting technique. When a prominent median lobe was present, vaporization was initiated at this site before proceeding to the lateral lobes. All lobes were vaporized down to the prostatic capsule.

Upon completion of the procedure, a 20 Ch three-way Dufour catheter was inserted. Per protocol, all patients left the operating room with slow continuous bladder irrigation to minimize clot formation and retention. Irrigation was usually discontinued within the first 12 h. Catheter removal was routinely scheduled between postoperative days (POD) 1 and 3, depending on the individual patient's clinical course. As part of the postoperative protocol, patients were advised to take ibuprofen primarily as an anti-inflammatory measure to reduce transient urinary discomfort and irritative symptoms, especially after catheter removal. The medication was prescribed for up to 7 days, with subsequent use on an as-needed basis. No nutraceutical agents were administered. All pharmacological treatments for BPO were discontinued from the time of surgery. The use of tadalafil 5 mg once daily for potential concomitant erectile dysfunction was not permitted during the study period.

Statistics

Sample size calculation was performed a priori based on the primary outcome (change in BOOI from T0 to T1). Assuming an expected postoperative BOOI reduction of ≥20 points, as a conservative and clinically meaningful target, and an estimated standard deviation of the paired differences of 23,[22,23] a paired two-tailed t-test with $\alpha = 0.05$ and 80% power yielded a minimum required sample size of 13 patients. To account for a potential 20% attrition rate, the planned enrollment was increased to 16 patients.

Continuous variables were expressed as mean ± standard deviation [SD] or median (interquartile range [IQR]), depending on the distribution assessed by the Shapiro–Wilk test. Categorical variables were reported as absolute frequencies and percentages. Comparisons between T0 and T1 for continuous variables were performed using the paired t-test or Wilcoxon signed-rank test, as appropriate according to their distribution. Paired dichotomous variables were compared using McNemar's test. For paired categorical outcomes with more than two levels, the Stuart–Maxwell test for marginal homogeneity was applied. Continuous paired variables were analyzed with paired t-tests or Wilcoxon signed-rank tests as appropriate. Continuous variables were graphically illustrated using paired dot plots or bar plots, while categorical variables were visualized using stacked bar charts.

The primary association between urodynamic deobstruction and symptom relief was assessed using ANCOVA with IPSS at 6 months as the dependent variable, BOOI at 6 months as the main predictor, and baseline IPSS as a covariate. Additional models adjusted for baseline BOOI and clinically relevant covariates (age, prostate volume, Q_{max}, PVR). Sensitivity analyses included the correlation between changes (ΔIPSS vs. ΔBOOI) and responder analyses based on BOOI thresholds (unobstructed < 20; obstructed > 40; equivocal 20–40).

All statistical tests were two-tailed, and p-values < 0.05 were considered statistically significant. Analyses were conducted using R software v.4.5.1 (R Foundation for Statistical Computing, Vienna, Austria) within the RStudio environment v.2025.05.1+513 (Posit, Boston, MA, USA).

Results

During the study period, 110 men were screened; 72 met eligibility criteria, and 68 consented to participate. Thirty-eight men were excluded, mainly due to prostate volume >80 mL (n = 20), suspected prostate cancer (n = 10), and other exclusion criteria (n = 8). Of the 68 enrolled patients, 64 (94.1%) completed the 6-month urodynamic follow-up and were included in the per-protocol analysis. In this cohort, the mean age was 67.2 ± 7.1 years, and the mean prostate volume was 51.6 ± 6.7 mL. Baseline characteristics are reported in Table 1. Four patients were lost within the first 6 months for reasons unrelated to the study. At 12 months, 60 patients (88.2%) remained in clinical follow-up; in total, eight patients had been lost to follow-up, due to inability to recontact (n = 1), loss for personal reasons (n = 2), intercurrent medical illness unrelated to the procedure (n = 1), and other reasons within the first 6 months (n = 4) (Table 1).

The primary endpoint, BOOI, decreased markedly from 55.9 ± 17.2 at baseline to 21.3 ± 11.2 at 6 months

TABLE 1. **Baseline characteristics of patients**

Characteristic	Mean (SD)/n (%)
Age (years), Mean (SD)	67.2 (8.1)
BMI (kg/m^2), Mean (SD)	27 (2.5)
Prostate volume (mL), Mean (SD)	51.6 (6.7)
Median lobe, n (%)	15 (23)
PSA (ng/mL), Mean (SD)	2.9 (3.3)
Diabetes, n (%)	9 (14)
Smoke habitus, n (%)	27 (42)
Hypertension, n (%)	31 (48)
Anticoagulants, n (%)	18 (28)
BPO therapy*, n (%)	
Alpha-blockers	42 (65)
5-ARI	38 (59)
Antimuscarinics or beta-3 agonists	7 (10)
Tadalafil 5 mg	15 (23)
Nutraceuticals	39 (60)
Indwelling bladder catheter, n (%)	
No	51 (79.7)
Yes	13 (20.3)
IPSS (points), Mean (SD)	26.2 (3.2)
Q_{max}** (mL/s), Mean (SD)	8.0 (3.3)
PVR** (mL), Mean (SD)	93.1 (36.8)

Note. *The listed drugs were used as monotherapy or as part of combination therapy; **From free uroflowmetry at baseline. Abbreviations: SD, standard deviation; BMI, body mass index; PSA, prostate-specific antigen; BPO, benign prostatic obstruction; 5-ARI, 5-α reductase inhibitor; IPSS, International Prostate Symptom Score; Q_{max}, maximum flow rate; PVR, post-void residual.

($p < 0.001$), with the proportion of obstructed patients falling from 79.7% to 7.8% ($p < 0.001$) (Figure 1).

At 6 months, 5/64 patients (7.8%) remained obstructed by BOOI criteria. None required re-intervention by 12 months. Of these, one patient resumed alpha-blocker therapy, while the others were managed with clinical monitoring, as they reported satisfactory improvement and only mild residual symptoms on IPSS. Pressure–flow studies confirmed a substantial reduction in detrusor pressures: both $P_{det}Q_{max}$ and P_{det} at opening decreased by more than 50%, and the Schäfer nomogram grade dropped from 3.6 to 0.3 (all $p < 0.001$). Voiding efficiency improved consistently: Q_{max} more than doubled (7.9 to 20.8 mL/s), PVR dropped from 121 to 22 mL, and BVE increased from 64% to 94% (all $p < 0.001$), while changes in VT and tQ_{max} did not reach statistical significance. Detrusor contractility strengthened, with BCI rising from 114 to 140 ($p < 0.001$); the proportion of patients with BCI > 150 increased from 3.1% to 32.8% ($p < 0.001$). Cystometric measures demonstrated higher bladder volumes across filling phases (all $p < 0.001$). The prevalence of LBC decreased from 19% to 3% ($p < 0.001$). IDC was observed in 22% at baseline and 11% at 6 months ($p = 0.07$), with detrusor pressure at IDC decreasing significantly ($p = 0.02$). All urodynamic data are detailed in Table 2.

Free uroflowmetry confirmed sustained improvements, with Q_{max} rising from 8.0 to 24.5 mL/s at 6 months ($p < 0.001$) and remaining stable at 12 months. PVR decreased by over 90% (93 to 6 mL, $p < 0.001$), while the proportion of patients with elevated PVR fell from 79.6% to 4.6% and stabilized thereafter. Uroflowmetry changes are fully reported in Table 3.

Total IPSS score significantly improved from 26.2 ± 3.2 at baseline to 3.4 ± 2.7 at 6 months ($p < 0.001$). Significant reductions were also observed in the voiding and storage subscores and in the quality-of-life item (all $p < 0.001$) (Figure 2). In the ANCOVA model, lower BOOI at 6 months was independently associated with lower IPSS at 6 months (β per 10-point decrease = −2.2, 95% CI [−3.6, −0.9]; $p = 0.001$), after adjustment for baseline IPSS. Consistently, ΔIPSS correlated modestly with ΔBOOI ($\rho = -0.34$; $p = 0.008$). Patients achieving urodynamic success (BOOI < 20 at follow-up) showed significantly greater symptom improvement compared to non-responders (ΔIPSS = −22.0 vs. −18.0; $p = 0.03$).

The mean operative time was 66.0 ± 7.7 min. The urinary catheter was removed after a mean of 1.9 ± 0.4 days, and the mean hospital stay was 2.6 ± 0.4 days. No intraoperative complications occurred, and no patient required blood transfusion or re-intervention for hemostasis control. Trial without a catheter was successful in all patients, and no re-catheterization for BPO was needed during the first 12 months.

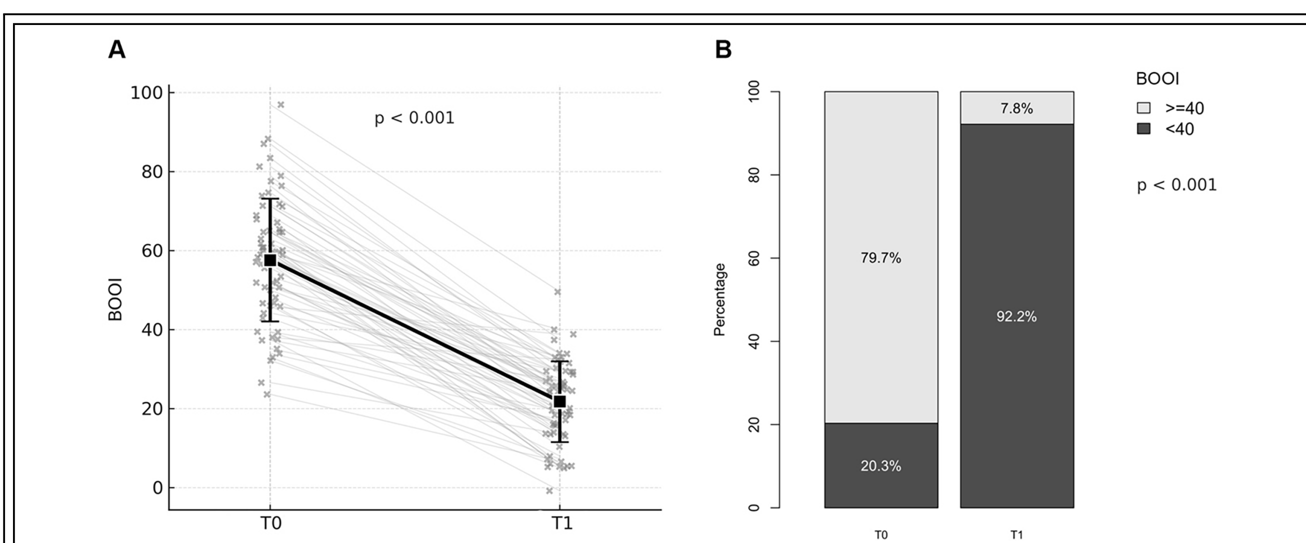

FIGURE 1. BOOI changes between baseline (T0) and 6 months (T1) after Thulium laser vaporization (ThuVAP) (n = 64). (**A**) Paired dot plot (mean ± SD) showing the change in BOOI from baseline to 6 months postoperatively (55.9 ± 17.2 vs. 21.3 ± 11.2; $p < 0.001$; paired *t*-test). (**B**) Stacked bars showing the proportion of obstructed patients (BOOI ≥ 40) at baseline and 6 months postoperatively (79.7% vs. 7.8%; $p < 0.001$; McNemar's test). Abbreviations: BOOI, Bladder Outlet Obstruction Index; SD, Standard Deviation.

TABLE 2. **Urodynamic parameter changes between baseline (T0) and 6 months (T1) after thulium laser vaporization (ThuVAP)**

Parameter	T0	T1	*p*-value
Cystometry			
FDU (mL), Mean (SD)	95.4 (33)	117.3 (30.3)	<0.001
NDU (mL), Mean (SD)	175.8 (45.3)	185.9 (47.4)	<0.001
SDU (mL), Mean (SD)	297.2 (75.5)	312.3 (69)	<0.001
MCC (mL), Mean (SD)	340 (83.4)	375 (73.4)	<0.001
LBC, n (%)	12 (18.8)	2 (3.1)	<0.001
IDC, n (%)	14 (21.9)	7 (10.9)	0.07
Detrusor pressure at IDC (cmH_2O), Mean (SD)	12.6 (24.7)	5.6 (16.3)	0.02
Pressure flow study			
P_{det} at opening (cmH_2O), Mean (SD)	73.2 (21.3)	35.2 (9.4)	<0.001
$P_{det}Q_{max}$ (cmH_2O), Mean (SD)	72 (14.8)	26.4 (6.5)	<0.001
$P_{det,\ max}$ (cmH_2O), Mean (SD)	37.1 (29.8)	21.1 (16.4)	<0.001
Q_{max} (mL/s), Mean (SD)	7.9 (1.8)	20.8 (4.5)	<0.001
tQ_{max} (s), Mean (SD)	32.4 (38.7)	20.8 (16.4)	0.09
VT (s), Mean (SD)	70 (60)	45.8 (14.5)	0.22
PVR (mL), Mean (SD)	121 (43)	22 (25)	<0.001
PVR ≥ 100 mL, n (%)	50 (78.1)	0 (0.0)	<0.001
BVE, %	64.4	94.1	<0.001
BOOI, Mean (SD)	55.9 (17.2)	21.3 (11.2)	><0.001
BOOI > 40, n (%)	51 (79.7)	5 (7.8)	<0.001
BCI, Mean (SD)	114.2 (15.2)	140 (33.3)	<0.001
BCI > 150, n (%)	2 (3.1)	21 (32.8)	<0.001
Schäfer nomogram grade, Mean (SD)	3.6 (0.7)	0.31 (0.46)	<0.001

Note. Continuous variables are compared using paired *t*-tests, and categorical variables using McNemar's test. Bold *p*-values indicate statistical significance ($p < 0.05$). Abbreviations: BCI, bladder contractility index; BOOI, bladder outlet obstruction index; BVE, bladder voiding efficiency; FDU, first desire to urinate; IDC, involuntary detrusor contractions; LBC, low bladder compliance (≤20 mL/cmH_2O); MCC, maximum cystometric capacity; NDU, normal desire to urinate; P_{det} at opening, detrusor pressure at opening of flow; $P_{det,\ max}$, maximum detrusor pressure during voiding; $P_{det}Q_{max}$, detrusor pressure at maximum flow; PVR, post-void residual; Q_{max}, maximum flow rate (during pressure–flow study); SD, standard deviation; SDU, strong desire to urinate; tQ_{max}, time to maximum flow; VT, voiding time.

TABLE 3. **Changes in free uroflowmetry parameters during follow-up**

Parameters	Baseline	3 months	*p*-value[a]	6 months	*p*-value[b]	12 months	*p*-value[c]
Q_{max}, (mL/s), Mean (SD)	8.0 (3.3)	21 (4.1)	<0.001	24.5 (3.2)	0.003	23.4 (5.2)	0.87
PVR, (mL), Mean (SD)	93.1 (36.8)	9.4 (9.1)	<0.001	6.1 (3.2)	<0.001	6.1 (4.8)	0.08
Elevated PVR*, n (%)	51 (79.6)	5 (7.8)	<0.001	3 (4.6)	0.05	3 (4.6)	0.9

Note. Continuous variables are compared using paired *t*-tests. Bold *p*-values indicate statistical significance ($p < 0.05$). * >20% of the bladder volume at voiding; [a] baseline vs. 3 months; [b] 3 months vs. 6 months; [c] 6 months vs. 12 months. Abbreviations: PVR, post-void residual; Q_{max}, maximum flow rate; SD, standard deviation.

According to the Clavien-Dindo classification, all postoperative adverse events were grade I–II. Transient dysuria was reported in 19 patients (29.7%), UTI in 3 patients (4.7%), and clot retention in 2 patients (3.1%), all were managed conservatively. Mild, transient urinary incontinence (0–1 pad/day) was observed in 5 patients (7.8%) and resolved spontaneously within three months in all cases (Table 4).

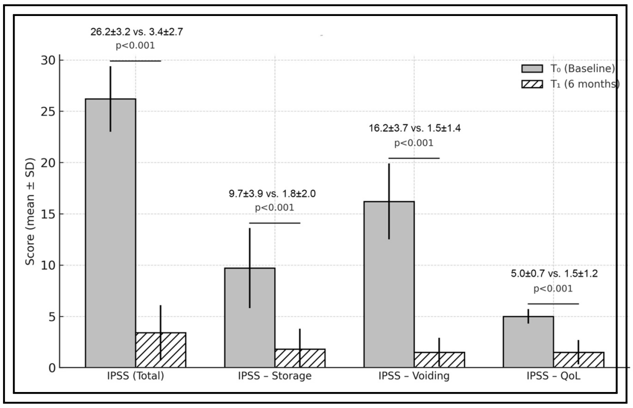

FIGURE 2. Changes in IPSS scores between baseline (T0) and 6 months (T1) after ThuVAP (n = 64). Bar plot (mean ± SD) showing changes in total IPSS total, storage, voiding, and quality-of-life scores from baseline to 6 months postoperatively. The storage subscore comprises questions 2, 4, and 7; the voiding subscore comprises questions 1, 3, 5, and 6; the total IPSS is the sum of questions 1–7. All comparisons were significant ($p < 0.001$, paired *t*-test). Abbreviations: IPSS, International Prostate Symptom Score; QoL, quality of life; SD, standard deviation.

At 6 months, retrograde ejaculation was present in 38 patients (59.4%), while erectile function according to the 5-item version of the International Index of Erectile Function (IIEF-5) showed no significant change (17.8 ± 6.4 vs. 18.5 ± 5.6; $p = 0.30$).

Between 6 and 12 months, two patients received antimuscarinic therapy for persistent storage symptoms, and one patient with persistent obstruction resumed alpha-blocker therapy. At 12 months, no cases of urinary incontinence, urethral stricture, or bladder neck contracture were identified, and no surgical re-interventions were required for persistent or recurrent BPO.

Discussion

Main findings and available evidence

In this prospective study, ThuVAP demonstrated substantial urodynamic de-obstruction at six months. The mean BOOI decreased from 55.9 ± 13.4 to 21.3 ± 10.4, reducing the proportion of patients classified as obstructed from 79.7% to 7.8%. Pressure–flow analyses revealed a marked decline in detrusor pressure at maximum flow ($P_{det}Q_{max}$: 58.1 ± 24.2 to 32.5 ± 14.1 cmH_2O), accompanied by a significant increase in maximum urinary flow (Q_{max}: 10.3 ± 4.3 to 17.7 ± 7.0 mL/s). Moreover, detrusor overactivity resolved in nearly three-quarters of affected patients, and the prevalence of low bladder compliance decreased from 18.8% to 3.1%. Importantly, lower postoperative BOOI values were independently associated with greater symptom relief, underscoring the clinical relevance of urodynamic de-obstruction. Collectively, these results indicate that ThuVAP produces consistent and meaningful improvements across obstruction, voiding, and storage domains. Direct comparisons with the literature are difficult, as few ThuVAP studies have reported paired urodynamic outcomes. A large retrospective 200-W ThuVAP series provided baseline pressure–flow data but no postoperative urodynamic follow-up, instead focusing on clinical parameters such as IPSS, Q_{max}, and PVR.[24] Similarly, a prospective ThuVAP cohort reported early improvements in these same clinical outcomes, but did not include pressure–flow testing after surgery.[25]

Against this backdrop, contextualization with established procedures is essential. Conventional TURP remains the reference standard for prostates between 30 and 80 mL, with EAU 2024 guidelines recommending monopolar or bipolar TURP as the first-line intervention when medical therapy fails.[26] Randomized controlled trials and meta-analyses consistently confirm robust and durable improvements in IPSS, Q_{max}, and PVR following TURP.[27]

TABLE 4. **Postoperative complications according to the Clavien-Dindo classification**

Complication	CD grade	n (%)	Management
Dysuria	I	19 (29.7)	Oral NSAIDs, reassurance
Urinary tract infection	II	3 (4.7)	Antibiotics
Clot retention	II	2 (3.1)	Bladder irrigation
Urinary incontinence	I	5 (7.8)	0-1 pads; resolved ≤3 months

Note. Abbreviations: CD: Clavien-Dindo; NSAIDs: Non-Steroidal Anti-Inflammatory Drugs.

Holmium laser enucleation of the prostate (HoLEP) has been extensively benchmarked against TURP in the same prostate volume range. Comparative studies demonstrate equivalent efficacy in both functional and urodynamic outcomes, with HoLEP offering advantages in transfusion requirements, catheterization duration, and hospital stay, albeit at the expense of longer operative times.[28–30]

Minimally invasive surgical therapies (MIST) such as Aquablation and Rezūm have also been evaluated in men with prostates <80 mL. The WATER randomized trial[31] reported non-inferior IPSS and Q_{max} outcomes for Aquablation compared with TURP at five years, with a clear advantage in ejaculatory function preservation, though perioperative morbidity was slightly higher. More recently, a multicenter randomized study comparing TURP, Aquablation, and Rezūm in prostates 30–80 mL found broadly similar improvements in LUTS, albeit with somewhat slower functional gains and lower flow improvements in the MIST arms.[32,33]

Within this context, our findings suggest that ThuVAP achieves functional outcomes directionally comparable to TURP and HoLEP, particularly with respect to BOOI reduction and IPSS improvement. It also offers the intrinsic advantages of laser technology, including excellent hemostasis and a favorable perioperative safety profile. Unlike MIST procedures, however, ThuVAP did not preserve ejaculatory function in the majority of patients, underscoring trade-offs that should be carefully considered in treatment selection. Photoselective vaporization (PVP) provides an additional indirect comparator. In an 80-W KTP PVP series with paired urodynamic testing, BOOI decreased from 49.8 to 9.8, $P_{det}Q_{max}$ from 68.7 to 40.6 cmH_2O, and the proportion of obstructed patients from 64% to 4% at six months.[34] Another prospective PVP study documented significant relief of outlet obstruction, with detrusor overactivity decreasing from 47.4% to 26.9%, while detrusor contractility remained largely unchanged.[35] Overall, our results align with these findings, reinforcing the physiological plausibility of a de-obstructive effect with ThuVAP, and highlight the need for dedicated prospective studies with standardized urodynamic endpoints.

Strengths and limitations

This study represents, to our knowledge, the first prospective clinical trial to comprehensively assess paired pre- and postoperative urodynamic parameters after ThuVAP. Strengths include its prospective design, prespecified primary endpoint (BOOI) supported by an a priori power calculation, and a predefined secondary objective linking de-obstruction to symptom relief. Standardized urodynamic testing was performed by a single experienced functional urologist (RB), ensuring methodological consistency, while narrow inclusion and exclusion criteria and consistent laser parameters further enhanced internal validity.

Nevertheless, important limitations must be acknowledged. The absence of a comparator arm precludes direct conclusions relative to TURP, HoLEP, or MIST. The single-center design and strict eligibility criteria limit generalizability to broader BPH populations. While the study was sufficiently powered for its primary endpoint, the relatively modest sample size limited subgroup analyses and may have underestimated rare adverse events. Urodynamic follow-up was restricted to six months, and clinical follow-up to twelve months, preventing evaluation of late complications, long-term durability, and reoperation rates. Moreover, sexual outcomes were assessed only using the IIEF-5 and reporting of retrograde ejaculation, without the application of more comprehensive validated instruments such as the full IIEF or MSHQ-EjD. Finally, patient-reported outcomes were unblinded and may be subject to expectation bias, though the magnitude and consistency of improvement support the validity of the observed effects.

The restriction to prostates <80 mL introduces a notable selection bias, as this is precisely the group in which TURP remains the gold standard supported by randomized evidence and guideline recommendations. Therefore, our results should not be interpreted as demonstrating superiority over TURP, but rather as supporting ThuVAP as an effective alternative in carefully selected patients. In larger prostates, HoLEP or other enucleation techniques may offer superior long-term outcomes, highlighting the need for stratified comparative trials.

Finally, our adoption of PVR thresholds (>100 mL or >20% of bladder volume) as indicators of clinically significant incomplete emptying is supported by the literature. ICS guidance[36] identifies PVR >100 mL as a widely accepted cut-off associated with impaired emptying and increased risk of lower urinary tract dysfunction, while Rubilotta et al.[37] demonstrated that residual urine exceeding 20% of bladder volume correlates with impaired contractility and worse symptom severity. In our cohort, both absolute and relative PVR values improved markedly, with nearly all patients falling below clinically meaningful thresholds postoperatively. These results further substantiate the physiological plausibility of ThuVAP's de-obstructive effect and the utility of standardized PVR criteria in assessing surgical efficacy.

Future perspectives

Future studies should build on current evidence by conducting multicenter, randomized comparative trials to directly benchmark ThuVAP against gold-standard procedures and other laser techniques, using harmonized urodynamic endpoints and patient-reported outcomes. Larger sample sizes are required to enable reliable subgroup and multivariate analyses, particularly in relation to baseline obstruction severity, detrusor contractility, prostate volume, age, and the presence of a median lobe. Longer follow-up is essential to confirm the durability of functional improvements and to provide more reliable estimates of medical retreatment and reoperation rates. Broader eligibility criteria—including patients with larger prostates, prior procedures, or relevant comorbidities—would enhance external validity and generalizability. Finally, systematic assessment of sexual and ejaculatory function with validated outcome tools, together with economic and learning-curve evaluations, would help define the role of ThuVAP in contemporary BPO management.

Conclusions

ThuVAP produced substantial and clinically meaningful relief of bladder outlet obstruction, with BOOI shifting from obstructive to lower ranges at 6 months. Improvements were consistent across pressure–flow parameters, voiding efficiency, and symptom burden, and lower BOOI was independently associated with greater IPSS improvement, reinforcing the clinical relevance of urodynamic de-obstruction. Larger multicenter randomized trials with extended follow-up are warranted to validate these results, establish long-term durability, explore subgroup responses, and better define the role of ThuVAP in contemporary BPO management. Until then, our data should be considered exploratory, and ThuVAP cannot yet be considered a standard of care.

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Author Contributions

The authors confirm contribution to the paper as follows: conceptualization, Simone Tammaro, Raffaele Balsamo; methodology, Simone Tammaro, Celeste Manfredi; software, Claudia Collà Ruvolo, Biagio Barone, Gianluigi Califano; validation, Francesco Di Fiore; Francesco Paolo Calace; formal analysis, Celeste Manfredi, Simone Tammaro, Claudia Collà Ruvolo; investigation, Lorenzo Spirito; resources, Felice Crocetto, Davide Arcaniolo; data curation, Lorenzo Spirito, Pasquale Reccia; writing—original draft preparation, Simone Tammaro, Raffaele Balsamo; writing—review and editing, Simone Tammaro, Celeste Manfredi, Gianluigi Califano; visualization, Claudia Collà Ruvolo, Francesco Di Fiore; supervision, Davide Arcaniolo, Ferdinando Fusco, Marco De Sio; project administration, Raffaele Balsamo. All authors reviewed the results and approved the final version of the manuscript.

Availability of Data and Materials

The data that support the findings of this study are available from the Corresponding Author, [CM], upon reasonable request.

Ethics Approval

This study was conducted in accordance with the Declaration of Helsinki on ethical principles for medical research involving human subjects. The study protocol was approved by the University of Campania Luigi Vanvitelli-A.O.R.N. dei Colli Ethics Committee (approval number 11566/2022).

Informed Consent

All patients provided written informed consent for the inclusion of their data in the database and the use of these data in scientific research.

Conflicts of Interest

The authors declare no conflicts of interest to report regarding the present study.

Abbreviations

ThuVAP	Thulium Laser Vaporization of the Prostate
BOOI	Bladder Outlet Obstruction Index
Qmax	Maximum Flow Rate
PVR	Post-Void Residual volume
BVE	Bladder Voiding Efficiency
IPSS	International Prostate Symptom Score
BPO	Benign Prostatic Obstruction
BPH	Benign Prostatic Hyperplasia
LUTS	Lower Urinary Tract Symptoms
BD	Bladder Dysfunction
DO	Detrusor Overactivity
DU	Detrusor Underactivity
TURP	Transurethral Resection of the Prostate
ThuVARP	Thulium Laser Vaporesection
ThuLEP	Thulium Laser Enucleation of the Prostate
ICS	International Continence Society
PCa	Prostate Cancer
UTIs	Urinary Tract Infections
DRE	Digital Rectal Examination
PSA	Prostate-Specific Antigen
TRUS	Transrectal Ultrasonography
BCI	Bladder Contractility Index
FDU	First Desire to Urinate
NDU	Normal Desire to Urinate
SDU	Strong Desire to Urinate
MCC	Maximum Cystometric Capacity
LBC	Low Bladder Compliance
IDC	Involuntary Detrusor Contractions
$P_{det}Q_{max}$	Detrusor Pressure at Maximum Flow
P_{det}at opening	Detrusor Pressure at Opening of Flow
P_{det}, max	Maximum Detrusor Pressure
tQ_{max}	Time to Maximum Flow
VT	Voiding Time
CD	Clavien-Dindo
IIEF-5	International Index of Erectile Function-5 items
5-ARI	5-α Reductase Inhibitor
BMI	Body Mass Index
PVP	Photoselective Vaporization of the Prostate
nel contesto PVP	Potassium Titanyl Phosphate (KTP) laser

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