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Platinum Priority – Benign Prostatic Obstruction

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Complications and Early Postoperative Outcome in 1080 Patients After Thulium Vapoenucleation of the Prostate: Results at a Single Institution

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Abstract

Background: Thulium vapoenucleation of the prostate (ThuVEP) has been introduced as a minimally invasive treatment for benign prostatic obstruction (BPO).
Objective: To analyze immediate outcomes and the institutional learning curve of ThuVEP, and to report its standardized complication rates, using the modified Clavien classification system (CCS) to grade perioperative complication rates.
Design, settings, and participants: A prospective evaluation of 1080 patients undergoing ThuVEP from January 2007 until May 2012 at our institution.
Intervention: ThuVEP was performed using the 2-μm, continuous-wave, thulium: yttrium-aluminum-garnet laser.
Outcome measurements and statistical analysis: Preoperative status, surgical details, and immediate outcome were recorded for each patient. Perioperative complications were classified according to the modified CCS.
Results and limitations: Median prostate size was 51 ml (interquartile range [IQR]: 36–78.7). Median operation time was 56 min (IQR: 40–80), and median enucleation time was 32.5 min (IQR: 22-50). Median catheterization time was 2 d (IQR: 2–2); median length of hospital stay was 4 d (IQR: 3–5). Median resected tissue weight was 30 g (IQR: 16.00–51.25). Incidental carcinoma of the prostate was detected in 59 (5.5%) patients. Median maximum urinary flow rate (8.9 vs 18.4 ml/s) and postvoid residual urine volume (120 vs 20 ml) changed significantly ($p < 0.001$). Minor complications occurred in 24.6% of the patients (Clavien 1: 20.8%; Clavien 2: 3.8%). Early reinterventions were necessary in 6.6% of the patients (Clavien 3a: 0.6%; Clavien 3b: 6%). One Clavien 4 complication occurred (0.09%). The overall complication rates decreased significantly over time due to decreasing Clavien 1, 2, and 3b events. The major limitations of the study are the prospective, unicentric study design, the lack of a control group, and that only short-term data were documented on morbidity and efficacy of the ThuVEP procedure.
Conclusions: ThuVEP is a safe and effective procedure for the treatment of symptomatic BPO, with low perioperative morbidity.
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1. Introduction

Transurethral resection of the prostate (TURP) and open prostatectomy (OP) are considered the gold standards for the treatment of benign prostatic obstruction (BPO) [1,2], although they are associated with considerable perioperative morbidity, such as severe bleeding, the risk of fluid volume absorption, and prolonged recovery [3–8]. Minimally invasive procedures like photoselective vaporization of the prostate (PVP) [9–12] or holmium laser enucleation of the prostate (HoLEP) [13–20] have been developed to decrease morbidity and to achieve comparable surgical outcome as TURP or OP.

Thulium vapoenucleation of the prostate (ThuVEP) has been introduced as a size-independent, minimally invasive treatment of BPO using an approach comparable to HoLEP [21–23]. The modified Clavien classification system (CCS) has been successfully adopted to TURP as a straightforward, standardized platform allowing for sound comparisons among different technologies [24,25]. We report standardized, perioperative complication rates using the modified CCS and early postoperative outcome in a large, prospective series of patients undergoing ThuVEP for treatment of BPO.

2. Methods

In this prospective analysis, 1080 patients with symptomatic BPO were treated with ThuVEP between January 2007 and May 2012 at our institution. Inclusion criteria were maximum urinary flow rate (Q_{max}) <15 ml/s and International Prostate Symptom Score (IPSS) ≥7; patients with Q_{max} ≥15 ml/s, IPSS <7, urodynamically diagnosed neurogenic bladder, prostate cancer (PCa), and previous urethral surgery were excluded. Preoperative assessment included a physical examination with digital rectal examination, prostate volume measurement by transrectal ultrasound (TRUS), measurement of postvoid residual urine (PVR) by abdominal ultrasonography, uroflowmetry, IPSS, quality of life (QoL), prostate-specific antigen (PSA) assay, blood analysis, urinalysis, and urine culture.

A total of 1080 ThuVEP procedures were performed by a total of 11 surgeons. One surgeon (A.J.G.) performed 473 (43.8%) ThuVEP procedures, five surgeons performed between 52 and 204 procedures each (total procedures among these surgeons: 520; 48.1%), and the remaining five surgeons performed a total of 87 procedures (8.1%), respectively. A 2-μm continuous-wave thulium:yttrium-aluminum-garnet (Tm:YAG) laser (RevoLix; LISA Laser products, Katlenburg, Germany) was used as the energy source at 70, 90, 120, or 200 W. Laser energy was delivered through a 550- or 800-μm, optical core, bare-ended, reusable laser fiber. The procedure was performed using a 26F continuous-flow laser resectoscope combined with a mechanical tissue morcellator. During all interventions, normal saline was used as irrigation fluid. The technique of ThuVEP has been previously reported in detail [21,23]. At the end of surgery, a 22F three-way Foley catheter was inserted for continuous bladder irrigation with normal saline. Bladder irrigation was terminated on the first postoperative day based on department protocol. The catheter was removed on the second postoperative day after ThuVEP regardless of preoperative prostate size.

Blood loss was estimated by comparing the hemoglobin value 1 d before surgery with the corresponding value on the first postoperative day. Enucleated tissue was histopathologically analyzed in all patients. Patients were discharged after removal of the catheter and after being able to void adequately as measured by PVR and Q_{max}.

Basic pre- and postoperative patient data were prospectively recorded using an SPSS spreadsheet (IBM Corp, Armonk, NY, USA), with undersigned consent for scientific use of data. All medical and surgical complications (except dysuria, transient urge/stress incontinence, and retrograde ejaculation) during the perioperative period (up to the end of the first month after surgery) were noted and classified according to the modified CCS [24,25] by two residents not involved in the surgical procedures (J.H., S.K.). Any disagreement regarding the classification according to the modified CCS was resolved by discussion, and final decision was based on consensus.

Overall immediate morbidity was defined in terms of surgical revision (secondary apical resection, reintervention for bleeding), recatheterization, significant urinary tract infection (UTI) with signs of bacteremia, or bleeding requiring blood transfusions. Mortality was defined as death occurring within the first month after surgery.

To assess the impact of the institutional learning curve on complication rates, patients were divided into five consecutive subgroups of 216 patients each. Patient data were expressed as median (interquartile range [IQR]). According to prostate size by TRUS, patients were classified into three groups: prostate <40 g (group A), 40–79 g (group B), and ≥80 g (group C). Differences between the groups were assessed using the Kruskal-Wallis test; improvement in the assessed parameters in each group was calculated using the paired *t* test. Categorical variables were compared using the chi-square test. Statistical analysis was performed using the calculating program SPSS v.11.5.1 for Windows. A two-sided p value <0.05 was considered statistically significant.

3. Results

Table 1 lists the baseline characteristics of all patients. Median age at surgery was 71 yr (IQR: 66–76 yr). More than one-fifth of patients (n = 233; 21.6%) presented with urinary retention with an indwelling catheter. The median prostate sizes were 30 g (IQR: 25–34 g), 54 g (IQR: 45–64 g), and 100 g (IQR: 89–120 g) for groups A, B, and C, respectively, and differed significantly among the groups ($p < 0.001$).

Table 2 lists perioperative data. Laser energy; operative, enucleation, and morcellation time; morcellation, enucleation, and operation efficiency; resected tissue weight; percentage of resected tissue; and hemoglobin decrease differed significantly among groups A, B, and C ($p < 0.001$). There were no differences among the groups regarding catheterization time (2 d [IQR: 2–2 d]) and hospital stay (4 d [IQR: 3–5 d]).

At discharge, Q_{max} increased from a median 8.9 ml/s (IQR: 6.2–12.5) to 18.4 ml/s (IQR: 14.15–24.5) and PVR decreased from a median 120 ml (IQR: 62–200) to 20 ml (IQR: 0–40) compared with baseline ($p < 0.001$) (Table 1). Only 5.6% of the patients had a PVR >100 ml compared with the baseline of 61.1%. Incidental PCa was detected on histologic examination in 59 (5.5%) patients.

Tables 3–6 list detailed information on all complications and treatment modalities. The overall immediate morbidity rate was 16.9% (Table 3). The most frequent complications were acute urinary retention (AUR) (9%), surgical revision (4.7%), significant UTI (1.5%), and bleeding requiring blood transfusions (1.7%). There were no differences regarding the occurrence of overall morbidity, AUR, surgical revision, significant UTI, and the transfusion rate among groups A, B, and C. Using the CCS, minor complications requiring no or

Table 1 – Baseline characteristics of 1080 patients who underwent thulium vapoenucleation of the prostate stratified by prostate size*

	<40 ml (Group A) (*n* = 305)	40–79 ml (Group B) (*n* = 509)	≥80 ml (Group C) (*n* = 266)	Overall (*n* = 1080)
Age, yr	70 (65–76)	71 (66–76)	71 (66–75)	71 (66–76)
Patients aged ≥80 yr	41 (13.4)	62 (12.2)	26 (9.8)	129 (11.9)
Duration of LUTS, yr	4 (2–6)	4 (2–7)	5 (2–7)	4 (2–7)
Alpha-blocker therapy	224 (73.4)	343 (67.4)	181 (68)	748 (69.3)
5-α-reductase inhibitor therapy	78 (25.6)	109 (21.4)	58 (21.8)	245 (22.7)
History of urinary retention	84 (27.5)	174 (34.2)	128 (48.1)	386 (35.7)
Preoperative urinary retention	54 (17.7)	104 (20.4)	75 (28.2)	233 (21.6)
Episodes of urinary retention, median (IQR)**	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)
PSA, ng/ml, median (IQR)	1.53 (0.8–2.62)	3.7 (2.25–6.62)	6.3 (3.56–11.15)	3.34 (1.69–6.54)†
Prostate volume, ml, median (IQR)	30 (25–34)	54 (45–64)	100 (89–120)	51 (36–78.7) c
IPSS, median (IQR)	21 (15–25)	21 (17–26)	21 (16–26)	21 (16–26)
QoL, median (IQR)	4 (4–5)	5 (4–5)	4 (4–5)	4 (4–5)
Q_{max}, ml/s, median (IQR)				
– Preoperative††	8.6 (5.6–12.28)	9.45 (6.45–12.2)	8.5 (6.2–12)	8.9 (6.2–12.5)
– At discharge	18.2 (14.15– 25)	17.8 (13.8–25)	19.4 (15.3–23)	18.4 (14.15–24.5)
p value (preoperative vs discharge)	<0.001	<0.001	<0.001	<0.001
PVR, ml, median (IQR)				
– Preoperative††	112 (70–200)	117.5 (62–173.75)	120 (52–220)	120 (62–200)
– At discharge	20 (0–40)	20 (0–40)	20 (0–40)	20 (0–40)
p value (preoperative vs discharge)	<0.001	<0.001	<0.001	<0.001
PVR ≥100 ml				
– Preop	189 (62)	299 (58.7)	172 (64.7)	660 (61.1)
– At discharge	28 (9.2)	24 (4.7)	9 (3.4)	61 (5.6)
ASA score, median (IQR)	2 (2–3)	2 (2–3)	2 (2–3)	2 (2–3)
Pressure flow evaluation	2 (0.7)	32 (6.3)	17 (6.4)	51 (4.7)
Associated conditions				
Hypertension	190 (62.3)	282 (55.4)	157 (59)	629 (58.2)
Ischemic heart disease	72 (23.6)	88 (17.3)	43 (16.2)	161 (18.8)
Diabetes mellitus	58 (19)	81 (15.9)	41 (15.4)	180 (16.7)
Chronic renal failure	14 (4.6)	31 (6.1)	13 (4.9)	58 (5.4)
Cardiac pacemaker	6 (2)	19 (3.7)	4 (1.5)	29 (2.7)
Inguinal hernia	57 (18.7)	88 (17.3)	36 (13.5)	181 (16.8)
Bladder diverticulum	23 (7.5)	32 (6.3)	11 (4.1)	66 (6.1)
Bladder tumor history	8 (2.6)	11 (2.2)	4 (1.5)	23 (2.1)
Bladder stones	9 (3)	21 (4.1)	2 (0.8)	32 (3)‡
Upper tract urolithiasis	16 (5.2)	24 (4.7)	10 (3.8)	50 (4.6)
Prostate surgery history	15 (4.9)	13 (2.6)	2 (0.8)	30 (2.8)§
Surgery under anticoagulant therapy	17 (5.6)	24 (4.7)	12 (4.5)	53 (4.9)
Antiplatelet medication (aspirin/clopidogrel)	99 (32.5)/15 (4.9)	144 (28.3)/11 (2.2)	68 (25.6)/6 (2.3)	310/32 (28.7/3)
Warfarin therapy	31 (10.2)	43 (8.4)	11 (4.1)	85 (7.9)

LUTS = lower urinary tract symptoms; IQR = interquartile range; PSA = prostate-specific antigen; IPSS = International Prostate Symptom Score; QoL = quality of life; Q_{max} = maximum urinary flow rate; PVR = postvoid residual urine; ASA = American Society of Anesthesiologists.
Data given as no. (%) unless otherwise indicated.
* Two patients (group A, C) with intraoperative malfunction of the thulium:yttrium-aluminum-garnet laser device were excluded from immediate outcome analysis (Q_{max}, PVR).
** In patients with preoperative urinary retention.
† $p < 0.001$ (A vs B vs C).
†† Except those in urinary retention.
‡ Treated with holmium-laser endoscopic lithotripsy prior to the ThuVEP procedure.
§ Transurethral resection of the prostate in 26 patients; open prostatectomy in 4 patients.

noninterventional treatment occurred in 262 (24.6%) of 1080 patients (Clavien 1: 20.8%; Clavien 2: 3.4%) (Tables 4 and 5). Major complications requiring reinterventions within 4 wk were necessary in 6.6% of patients (Clavien 3a: 0.6%; Clavien 3b: 6%). One patient had an acute myocardial infarction (Clavien 4a: 0.09%). The mortality rate was zero (Clavien 5). According to the CCS, there were no differences in the occurrence of overall complications (30.9%) among the groups (Table 6). After discharge, UTI (1.5%), AUR (2.8%), and/or clot retention requiring manual/continuous bladder irrigation (3.1%) developed in 16, 30, and 34 patients, respectively. Forty-four of these patients (4.1%) needed to be admitted, while the other patients could be treated as outpatients. These patients were all managed conservatively.

The overall complication rates decreased significantly over time, reflecting the institutional learning curve of the procedure (41.7% within the first 216 cases vs 19.4% within the last 216 cases; $p < 0.001$). This change results from decreasing Clavien 1 (25% within the first 216 cases vs 15.7% within the last 216 cases; $p < 0.02$), Clavien 2 (4.6% within the first 216 cases vs 0% within the last 216 cases; $p < 0.0011$) and Clavien 3b (Fig. 1) events. The changes in Clavien 3a (1% vs 0%) and 4a were less relevant (0% vs 0.5%).

Table 2 – Perioperative data of 1080 patients who underwent thulium vapoenucleation of the prostate stratified by prostate size*

	≤40 ml (Group A) (*n* = 305)	40–79 ml (Group B) (*n* = 509)	≥80 ml (Group C) (*n* = 266)	Overall (*n* = 1080)
Laser energy, kJ	90.73 (70.9–119.18)	124.6 (94.35–160.04)	181.15 (133.9–251.65)	123 (87.93–175.33)+
Operation time†, min	40 (29.25–59.75)	55 (40–75)	75 (57–115)	56 (40–80)+
Enucleation time††, min	23 (17–35)	33 (24–50)	48 (32.75–70.75)	32.5 (22–50)+
Morcellation time, min	10 (5; 12.25)	11 (8–18)	20 (12.75–30)	11 (8–20)+
Morcellation efficiency**, g/min	1.67 (1.08–2.6)	2.8 (2–4)	3.62 (2.5–5.06)	2.6 (1.7–4)+
Enucleation efficiency***, g/min	0.62 (0.33–1)	1 (0.58–1.57)	1.45 (1.05–2)	1 (0.57–1.56)+
Operation efficiency****, g/min	0.33 (0.21–0.49)	0.58 (0.36–0.85)	0.85 (0.58–1.12)	0.55 (0.33–0.87)+
Resected weight, g	14 (10–20)	32 (20–45)	65 (50–89.5)	30 (16–51.25)+
Percentage resected tissue‡, %	45.45 (33.33–66.67)	58.24 (40.89–78.59)	63.45 (49.13–78.85)	56.76 (40–76.67)+
Hemoglobin decrease, g/dl	1 (0.4–1.5)	1 (0.4–1.8)	1.4 (0.8–2.2)	1.1 (0.5–1.8)+
Catheterization time, d	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–2)
Hospitalization, d	4 (3–5)	4 (3–5)	4 (3–5)	4 (3–5)

Data given as median (IQR).
* Two patients (group A, C) with intraoperative malfunction of the thulium:yttrium-aluminum-garnet laser device (conversion to transurethral resection of the prostate) were excluded from perioperative data analysis.
+ $p < 0.001$ (A vs B vs C).
† Measured from insertion until removal of the resectoscope.
†† Measured from insertion of the laser fiber until removal.
** Resected weight/morcellation time.
*** Resected weight/enucleation time.
**** Resected weight/operation time.
‡ Resected weight/preoperative prostate volume.

Table 3 – Influence of prostate size on morbidity and mortality in 1080 patients who underwent thulium vapoenucleation of the prostate

Prostate volume, ml	AUR	Reoperation*	UTI**	Transfusion	Morbidity	Mortality
<40 (Group A; *n* = 305)	36 (11.8)	12 (3.9)	3 (1)	3 (1)	54 (17.7)	0 (0)
40–79 (Group B; *n* = 509)	41 (8.1)	25 (4.9)	8 (1.6)	8 (1.6)	82 (16.1)	0 (0)
≥80 (Group C; *n* = 266)	20 (7.5)	14 (5.3)	5 (1.9)	7 (2.6)	46 (17.3)	0 (0)
Overall (*n* = 1080)	97 (9)	51 (4.7)*	16 (1.5)	18 (1.7)	182 (16.9)	0 (0)

AUR = acute urinary retention; UTI = urinary tract infection.
Data given as no. (%).
* Secondary apical resection (*n* = 29), coagulation of prostate fossa (*n* = 22 hemorrhage/clot retention).
** Significant UTI with signs of bacteremia.

We observed a decrease in transfusion rates (3.2% vs 0%; $p < 0.007$), AUR (9.3% vs 4.2%; $p < 0.034$), and overall morbidity (24.5% vs 13%; $p < 0.0017$), but not with respect to UTI over time.

4. Discussion

ThuVEP has been introduced as a size-independent, minimally invasive treatment of BPO using an approach

Table 4 – Detailed analysis of Clavien grade 1 complications stratified by prostate size

Complication*	Treatment	<40 ml Group A (*n* = 305)	40–79 ml Group B (*n* = 509)	≥80 ml Group C (*n* = 266)	Overall (*n* = 1080)
Urinary retention after catheter removal	Bedside recatheterization	36 (3.3)	41 (3.8)	20 (7.5)	97 (9)
Clot retention without surgical revision	Bladder irrigation (prolonged) and tamponade evacuation through catheter	8 (2.6)	18 (3.5)	12 (4.5)	38 (3.5)
Extraperitoneal fluid collection	Oral diuretics, prolonged catheterization	1 (0.3)	7 (1.3)	8 (3)	16 (1.5)
Superficial bladder injury due to morcellation	No special therapy	4 (1.3)	9 (0.6)	2 (0.8)	15 (1.4)
Malfunction of the Tm:YAG laser device	Conversion to TURP	1 (0.3)	0 (0)	1 (0.4)	2 (0.2)
Capsular perforation	No special therapy	6 (2)	13 (2.6)	4 (1.5)	23 (2.1)
Ureteric orifice injury	Prolonged catherization	3 (1)	4 (0.8)	1 (0.4)	8 (0.7)
Bladder neck false passage	Prolonged catheterization	2 (0.8)	4 (0.9)	4 (1.9)	10 (0.9)
Low UTI (positive urine culture plus LUTS)	Oral antibiotics	13 (4.3)	36 (7.1)	26 (9.8)	75 (6.9)

TURP = transurethral resection of the prostate; Tm:YAG = thulium:yttrium-aluminum-garnet; UTI = urinary tract infection; LUTS = lower urinary tract symptoms.
Data given as no. (%).
* Complications (*n* = 284) in 225 of 1080 patients (20.8%).

Table 5 – Detailed analysis of Clavien grade 2–4a complications stratified by prostate size

Complication	Treatment	<40 ml Group A (*n* = 305)	40–79 ml Group B (*n* = 509)	≥80 ml Group C (*n* = 266)	Overall (*n* = 1080)
Clavien grade 2 complications (*n* = 37; 3.4%)					
Phlebothrombosis of the leg	Anticoagulants	0	2 (0.4)	1 (0.4)	3 (0.3)
Postoperative hematuria	Transfusion	3 (1)	8 (1.6)	7 (2.6)	18 (1.7)
UTI with signs of bacteremia (temperature >38.5 °C)	Parenteral antibiotics	3 (1)	8 (1.6)	5 (1.9)	16 (1.5)
Clavien grade 3a complications (*n* = 6; 0.6%)					
Hydronephrosis due to ureteric orifice injury	Ureteral stent (double-J stent)	1 (0.3)	4 (0.8)	1 (0.4)	6 (0.6)
Clavien grade 3b complications (*n* = 69 complications [6.4%] in 65 patients [6.0%])					
Incomplete morcellation (blade malfunction)	Secondary morcellation	1 (0.3)	1 (0.2)	0 (0)	2 (0.2)
Incomplete morcellation (hemorrhage)	Secondary morcellation	6 (2)	7 (1.4)	3 (1.1)	16 (1.5)
Residual prostate tissue	Secondary apical resection	8 (2.6)	12 (2.4)	9 (3.4)	29 (2.7)
Hemorrhage/clot retention	Cystoscopy with clot evacuation, coagulation of prostate fossa	4 (1.3)	13 (2.6)	5 (1.9)	22 (2)
Clavien grade 4a complications (*n* = 1; 0.09%)					
Myocardial infarction	Admission to intensive care unit	0 (0)	0 (0)	1 (0.4)	1 (0.09)

UTI = urinary tract infection.
Data given as no. (%).

Table 6 – Detailed analysis of Clavien grade 1–4a complications stratified by prostate size

Complication, Clavien grade, no.	<40 ml Group A (*n* = 305)	40–79 ml Group B (*n* = 509)	≥80 ml Group C (*n* = 266)	Overall (*n* = 1080) (%)
1	60	108	57	225 (20.8)*
2	6	18	13	37 (3.4)
3a	1	4	1	6 (0.6)
3b	19	29	17	65 (6)**
4a	–	–	1	1 (0.09)
Total	86	163	89	334 (30.9)***

* 284 complications in 225 patients.
** 69 complications in 65 patients.
*** 397 complications in 334 patients.

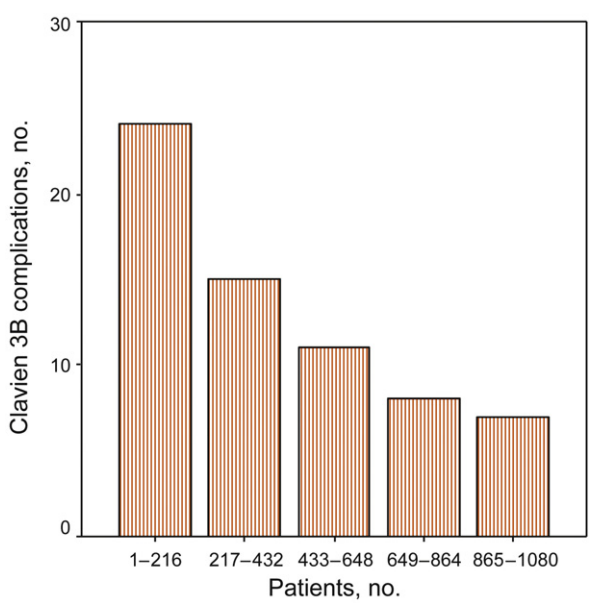

Fig. 1 – A significant decrease in Clavien 3b complications between the first and the last 216 patients (11.1% vs 3.3%; $p \leq 0.0012$) shows the institutional learning curve.

comparable to HoLEP [21–23]. There have only been few, large, contemporary series reported that analyzed the perioperative morbidity of minimally invasive procedures like ThuVEP [22], HoLEP [13–20], and PVP [9–12], as well as TURP [3,8] and OP [4–8] for the treatment of BPO. However, there is a lack of standardized reporting of the complication rates (Table 7) [3–20,22,26,27]. To create a reference for ThuVEP, our aim was to analyze in a large, prospective study the immediate outcomes and the institutional learning curve of ThuVEP, and to report standardized complication rates for ThuVEP using the modified CCS [24], which has been successfully applied to TURP [25].

In this study, the immediate improvement of obstructive voiding after ThuVEP proved to be satisfactory. PVR and Q_{max} improved significantly at discharge and were comparable with HoLEP [13–20], PVP [9], TURP [3], and OP [4,6]. Hospital stay and catheterization times in our study were relatively longer compared with HoLEP [13–17,19], but shorter than in TURP [3] or OP [4–7] (Table 7). This might be due to the specifics of the German diagnosis-related groups health system; that is, reimbursement is by case-based lump sums, requiring a minimum of two overnight hospital

Table 7 – Incidence of perioperative complications after thulium vapoenucleation of the prostate, and those reported after open prostatectomy, holmium laser enucleation, photoselective vaporization, and transurethral resection of the prostate in series with >200 patients

Citation	–	[7]	[5]	[6]	[8]	[4]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[9]	[10]	[11]	[12]	[8]	[3]
Year of publication	2012	2002	2004	2004	2005	2007	2005	2006	2006	2008	2008[a]	2008[a]	2010	2011	2008	2008[a]	2008	2009	2004	2008
Intervention	ThuVEP	OP	OP	OP	OP	OP	HoLEP	HoLEP	HoLEP	HoLEP	HoLEP	HoLEP	HoLEP	HoLEP	PVP	PVP	PVP	PVP	TURP	TURP
Study design	P	R	R	R	R	P	R	R	P	P	R	R	R	R	P	P	NA	R	R	P
Single/multicenter study	S	M	S	S	M	M	S	S	S	S	S	S	S	S	M	M	M	S	M	M
Surgeons	11	NA	1	NA	NA	NA	1[b]	1[b]	1	2	1[b]	1	1[c]	1	7	7	NA	1	NA	NA
Patients	1080	1804	232	201	2452	902	552	225	280	330	507	354	1065	949	500	269	305	321	20671	9197
Preoperative prostate weight, g	51[d]	75	104.5	90.3	NA	96.3	83.7	126.4	54.6	62	52–97–170[a]	38–76–134[a]	NA	81	56.1	56–65–69[a]	NA	54.7	NA	NA
Resected weight, g	30[d]	NA	NA	70.3	NA	84.8	52.1	86.5	29.8	40	45–85–140[a]	19–41–83[a]	76	NA	NA	NA	NA	NA	NA	28.4
Operative time, min	56[d]	NA	NA	85.3	NA	81	NA	NA	61.3	74.8	NA	NA	NA	96	66.4	74–73–69[a]	NA	NA	NA	52.4
Q_{max} increase, ml/s	14.3[n]	NA	NA	16	NA	13[n]	13.8	18.8	10.4[e]	13	9.1	9.8[e]	17.4[f]	16.6	NA	NA	NA	NA	NA	NA
Recatheterization	9[i]	3.3	1.7[e]	NA	NA	NA	1.4[e]	NA	3.9	5.2	NA	3.7[e]	NA	NA	11[i]	10[i]	4.6[j]	NA	NA	5.8[i]
Reoperation	6.6[g,i]	1.1	3.9[e]	3.5	4.8[e]	3.7[i]	3.4[h,e]	4.4	3.6	6.7	1	0.84[e]	1.3[e]	NA	0.6[i]	0.7[i]	1[j]	10.2[k]	5.8[e]	5.6[i]
UTI	8.4[i]	8.6	2.6[e]	12.9	NA	5.1[i]	1.1[e]	1.7	3.9	NA	0.2	3.7[e]	0.1[l]	NA	6.8[i]	7.1[i]	4.3[j]	NA	NA	3.6[i]
Transfusions	1.7	8.2	6.8	18.9	NA	7.5	2	1.3	1.8	0	0.4	1.4	NA	0.4	0.4	0.7	1	NA	NA	2.9
Morbidity	16.9[i]	NA	NA	NA	NA	17.3[i]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11.1[i]
Mortality	0	0.06	0	0	0.9	0.2	0	0	0	0	NA	0	NA	NA	0	0	NA	NA	0.7	0.1
Catheterization time, days	2[d]	5.5	5	6.1	NA	NA	1.4	1.3	34.9[m]	23[m]	22–16–15.3[m,a]	24–32–43[m,a]	19.1	NA	1.8	1.5–1.7–2.4[a]	NA	NA	NA	NA
Hospital stay, days	4[d]	6.9	6	11.5	NA	11.9	1.5	1.2	39.1[m]	48[m]	29–27–25[m,a]	NA	32[m]	NA	3.7	3–4–5[a]	NA	NA	NA	8
12-mo follow-up	–	–	65.1	–	100	–	54.7	46.7	55.7	96.4	NA	57.6	29.4	81.2	60.4	45.7	4.2[j]	76.6[k]	100	–

ThuVEP = thulium vapoenucleation of the prostate; OP = open prostatectomy; HoLEP = holmium laser enucleation of the prostate; PVP = photoselective vaporization of the prostate; TURP = transurethral resection of the prostate; P = prospective study; R = retrospective study; NA = not analyzed; S = single center; M = multicentre; Q_{max} = maximum urinary flow rate; UTI = urinary tract infection.

Data given as no. (%) or mean.

[a] Analysis according to prostate size in three subgroups.

[b] Performed or supervised by one surgeon.

[c] One surgeon had performed 850 HoLEP procedures (80%).

[d] Median.

[e] 1-yr follow-up.

[f] Measured in only 40 patients.

[g] Secondary morcellation ($n = 18$), secondary apical resection ($n = 29$), hemorrhage/clot retention ($n = 22$), ureteral stenting ($n = 6$).

[h] Cystostomy incision ($n = 8$), morcellation postponed ($n = 2$), cystoscopy cauterization of bleeding points ($n = 3$), reoperation of residual adenoma ($n = 2$), readmission for cystoscopy bladder irrigation ($n = 4$).

[i] Within 30 d.

[j] Median follow-up 4.2 mo.

[k] At 5-yr follow-up.

[l] Sepsis.

[m] Hours.

[n] At discharge.

stays for full reimbursement. In addition, the policy of keeping the patient in the hospital until able to void adequately was used. Hospital stay might certainly be decreased by discharge before catheter removal. Regarding hospital stay, differences in national health systems should be taken into account when comparing studies of surgical treatments of BPO (Table 7).

Prostate volume was ≥80 g in 266 of the patients in our series, with a median prostate volume of 100 g; there were no differences in the occurrence of complications when compared with smaller prostates. Bach et al. showed a significant PSA (88%) and prostate volume (81%) decrease 12 mo after ThuVEP [23], which confirms complete removal of the prostatic adenoma, comparable with HoLEP [13,14,17,20]. This leads to the conclusion that ThuVEP is a size-independent procedure for patients with symptomatic BPO.

This large, prospective, single-institution, ThuVEP series showed a low incidence of perioperative complications in 1080 patients, comparable with other minimally invasive procedures such as HoLEP [13–20], PVP [9–12], and lower than in TURP [3] or OP [4–8]. The analysis showed no difference in the transfusion rate and no statistically significant differences in any other complications with regard to prostate size. Morbidity and mortality rates in TURP are closely related to prostate size [3]. Transurethral incision of the prostate (TUIP) offers low perioperative morbidity in small prostates (<30 g) compared to TURP. The retreatment rates of TUIP, however, were significantly higher in TUIP compared to TURP [28].

In contrast, the perioperative complication rates in small (group A) to midsized prostates (group B) in this ThuVEP series were even lower than in TURP (transfusion rate, risk of transurethral resection syndrome, surgical revision, UTI, mortality rate) [3]. The overall complications were rare and consisted mainly of AUR (9%), significant UTI (1.5%), secondary apical resection (2.7%), reintervention for bleeding (2%), and blood transfusions (1.7%), comparable with HoLEP [13–20,29], PVP [9–12,29], and lower than in TURP [3] or OP [4–8] (Table 7). Notably, ThuVEP was performed in 53 patients under ongoing oral anticoagulant therapy, which highlights the safety of the Tm:YAG device [21–23].

Only two, large, prospective, multicenter studies have analyzed the morbidity of OP (17.3%) [4] and TURP (11.1%) [3], while morbidity has not been reported in large HoLEP [13–20] or PVP [9–12] series so far. The morbidity rate in this ThuVEP series (16.9%) was comparable with OP and TURP (11.1–17.3%) series when using the same criteria [3,4,25]. Of note, AUR requiring recatheterization accounted for 9% of the morbidity rate in this series. On the other hand, the mortality rate in this series was zero, as in HoLEP [13–16,18] and PVP [9,10], while mortality rates up to 0.9% and 0.7% in OP and TURP have been reported [3,4]. The comparability of the perioperative morbidity of surgical procedures for BPO is hindered, however, due to non-standardized reporting of the occurrence of complications (Table 7). The use of the modified CCS for standardized reporting of complications has been proposed [26]; it has not been applied to large TURP, OP, PVP, ThuVEP, or HoLEP series so far.

Using the modified CCS in the current study, complications were 24.6% (Clavien 1–2) and 6.7% (Clavien 3–5). Minor complications requiring no or noninterventional treatment dominated. These complication rates were rather high when compared with a TURP series using the modified CCS (Clavien 1–2: 19.7%; Clavien 3–5: 2.5%) [25], which might be due to the elaborate presentation of complications in this series, including those of having no clinical consequence, like malfunction of the Tm:YAG device. There was a significant decrease in overall complication rates over time (41.7% vs 19.4%), mainly because of a decrease in Clavien 1 (25% vs 15.7%), 2 (4.6% vs 0%), and 3b (11.1% vs 3.3%) complications. In particular, we observed a significant decrease in transfusion (3.2% vs 0%), AUR (9.3% vs 4.2%), and overall morbidity rates (24.54% vs 13%). The complication rates in this ThuVEP series are therefore influenced by the institutional learning curve (ie, establishing a new surgical procedure) and the individual learning curves of the surgeons. However, we have shown that the use of a mentor-based approach combines short, individual learning curves of the ThuVEP procedure with low perioperative morbidity [30].

The disadvantages of the modified CCS have been already discussed [27]. Complications with different morbidities may be classified similarly and some complications may be performed under local or general anesthesia. For example, stenting for hydronephrosis may be classified as Clavien 3a or 3b. In addition, Clavien 3b in this series may include interventions of different severity such as incomplete morcellation, apical resection, or cauterization of bleeding vessels. Prospective recording of complications over a long period of time may also lead to a bias mainly concerning Clavien 1 + 2 events. Minor events classified as complications at the end may have been considered normal at the beginning [27].

The main limitations of our results lie within the prospective, unicentric study design, the lack of control group (eg, patients who had undergone a TURP procedure), and the possible bias when reporting our own complication rates. There are only few, large, prospective, multicentric studies for OP [4], TURP [3], and PVP [9–11], while two prospective, unicentric series for HoLEP [15,16] exist. In addition, the largest HoLEP series [13–20] are from four institutions (Table 7) reporting more or less single-surgeon experience, whereas the ThuVEP procedures were performed by 11 surgeons in this series. Prospective, multicenter studies may be more appropriate to assess the surgical outcome and complication rates of minimally invasive procedures for BPO. However, an elaborate analysis of complications according to the modified CCS might complicate data acquisition and patient enrolment to this type of study.

5. Conclusions

We report the largest prospective series of patients undergoing ThuVEP. Using the modified CCS, minor complications

(24.6%; Clavien 1–2) requiring no or noninterventional treatment dominated. The immediate outcome and our complication rates are comparable to those published in large series on HoLEP and PVP, and lower than in TURP and OP, indicating that ThuVEP is a minimally invasive, size-independent, safe, and efficacious procedure for the treatment of BPO. The major limitations of the study are the prospective, unicentric study design, the lack of control group, and documenting only short-term data on morbidity and efficacy of the ThuVEP procedure. Further, prospective, large, multicenter studies are needed to evaluate the standardized CCS on HoLEP, PVP, TURP, and OP to facilitate better comparability of ThuVEP to these respective procedures.

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Study concept and design: Netsch.
Acquisition of data: Netsch, Knipper, Hölzel.
Analysis and interpretation of data: Netsch, Gross.
Drafting of the manuscript: Netsch.
Critical revision of the manuscript for important intellectual content: Netsch, Gross, Bach.
Statistical analysis: Netsch.
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