Lasers in Medical Science (2019) 34:1637–1643
https://doi.org/10.1007/s10103-019-02760-1

ORIGINAL ARTICLE

Thulium vapoenucleation of the prostate (ThuVEP) for prostates larger than 85 ml: long-term durability of the procedure

Benedikt Becker[1] · Ann Kathrin Orywal[1] · Andreas J. Gross[1] · Christopher Netsch[1]

Received: 12 April 2018 / Accepted: 26 February 2019 / Published online: 5 March 2019
© Springer-Verlag London Ltd., part of Springer Nature 2019

Abstract

The purpose of this prospective study of 90 consecutive patients is to assess the long-term durability of ThuVEP in patients with benign prostatic hyperplasia (BPH) and prostate volumes ≥ 85 ml. Ninety patients with prostates ≥ 85 ml underwent ThuVEP between 2008 and 2010 at our institution. Patient demographics and short-term and long-term follow-up were evaluated. Maximum urinary flow rate (Qmax), post-void residual urine (PVR), international prostate symptom score (IPSS), quality of life (QoL), complications, and PSA were assessed at follow-up. Median age at surgery was 71 (66–75.25) years. Thirty-seven (41.1%) of the patients were in urinary retention at the time of surgery. Prostate volume was 100 (88–122) ml. Median follow-up was 36.5 (16–60) months. At 12-month follow-up, IPSS, QoL, Qmax, and PVR had improved significantly compared with preoperative assessment and continued to do so during follow-up ($p < 0.001$). At 4-year postoperative, median Qmax (19.1 vs. 7.75 ml/s), PVR (31.9 vs. 150 ml), IPSS (4.5 vs. 24), and QoL (1 vs. 5) differed significantly from baseline ($p \leq 0.027$). PSA decreased from 7.4 (4.14–14) to 0.70 (0.36–1.64) μg/l ($p < 0.001$) at 48-month follow-up, corresponding to a PSA reduction of 86.48% (79.85–95.25%). Urinary tract infections occurred in 2 (2.2%) patients. Urethral stricture and bladder neck contracture developed in 1 (1.1%) patient each. One patient (1.1%) had recurrent adenoma of the prostate and was treated with thulium vaporesection of the prostate. ThuVEP is a durable modern alternative to open prostatectomy for patients with substantially enlarged prostates due to BPH. The incidence of complications with ThuVEP during long-term follow-up was low.

Keywords BPO · Vapoenucleation · ThuVEP · Laser surgery · Tm:YAG · Long-term follow-up

Introduction

Although associated with considerable perioperative morbidity such as severe bleeding, secondary wound healing, prolonged catheterization, or hospital stay, open prostatectomy (OP) has been the standard treatment of substantially enlarged prostates due to benign prostatic hyperplasia (BPH) over decades [1]. However, minimally invasive procedures have been developed to decrease the perioperative morbidity and to achieve a comparable outcome as in OP [2]. Holmium laser enucleation of the prostate (HoLEP) has been proven to be a minimally invasive, size-independent method with excellent long-term results [3–9]. Alternative procedures mimicking the HoLEP technique have been described during the past 10 years utilizing different types of energy sources [10].

As one of these modern procedures, thulium vapoenucleation of the prostate (ThuVEP) has been shown to be a size-independent procedure for the surgical treatment of BPH with low perioperative morbidity and good long-term results [11–14]. HoLEP or endoscopic enucleation of the prostate (EEP) has been recommended by the current guidelines of the European Association of Urology (EAU) in men with substantially enlarged prostates (> 80 ml) as the first choice [15]. However, long-term results for EEP procedures other than HoLEP in men with substantially enlarged prostates are sparse, i.e., plasmakinetic enucleation of the prostate (PkEP) [16] and bipolar enucleation of the prostate (BipolEP) [17]. The aim of this study was therefore to present the long-term results of ThuVEP in men with substantially enlarged BPH (> 85 ml) to verify the long-term durability of the procedure.

✉ Benedikt Becker
ben.becker@asklepios.com

[1] Department of Urology, Asklepios Hospital Barmbek, Rübenkamp 220, 22291 Hamburg, Germany

Methods

All patients were treated after obtaining informed consent, following institutional review board approval. Between January 2008 and January 2010, 90 consecutive patients presenting with prostates ≥ 85 ml underwent ThuVEP combined with mechanical morcellation at our department. Inclusion criteria were maximum urinary flow (Qmax) < 15 ml/s and International Prostate Symptom Score (IPSS) > 7 points. Exclusion criteria were previous urethral/prostatic surgery, prostate cancer or urethral strictures, and/or urodynamically diagnosed neurogenic bladder. Furthermore, all men on anticoagulation or aspirin were excluded in this study because of the large prostate volume. Preoperative assessment included a physical examination with digital rectal examination, transrectal ultrasound and biopsy whenever indicated, uroflowmetry, measurement of post-void residual urine (PVR), IPSS, quality of life (QoL), PSA assay, urine analysis, and urine culture.

The procedures were carried out by two surgeons who had performed more than 200 ThuVEP procedures each. A 26F continuous-flow laser resectoscope (R. Wolf, Knittlingen, Germany) in combination with a mechanical tissue morcellator (R. Wolf, Piranha™, Knittlingen, Germany) was used. ThuVEP was carried out using a 2.013-nm continuous wave 120-W Tm:YAG laser at 90 W (RevoLix®, Lisa Laser, Katlenburg, Germany). Laser energy was delivered through a 550-μm optical core, bare-ended, re-usable laser fiber (RigiFib™, Lisa Laser, Katlenburg, Germany). The technique of ThuVEP has been previously reported in detail [11, 13]. All interventions were carried out using normal saline as irrigation fluid with the patient under spinal or general anesthesia. At the end of surgery, a 22F three-way Foley catheter was inserted for continuous bladder irrigation, which was finished the next morning based on standard department protocol. Routinely, the catheter was removed on the second postoperative day. All patients received a perioperative antibiotic treatment with a second-generation cephalosporine regularly or an antibiotic regimen according to an antibiogram until removal of the indwelling catheter. Patients were discharged after the removal of the catheter and after being able to void adequately as measured by Qmax and PVR.

Blood loss was estimated by comparing the serum hemoglobin value before and after surgery at postoperative day 1. Patients were reassessed at 12-, 24-, 36-, and 48-month follow-up after ThuVEP by means of physical examination, urine analysis, IPSS, QoL, Qmax, and PVR. The complications were assessed perioperatively and at each follow-up visit. PSA was measured at 48-month follow-up.

Statistical analysis was performed using SPSS 22 (IBM Corp, Armonk, NY, USA). Improvement in the assessed parameters was calculated using the paired *t* test. Patient data were expressed as median (interquartile range). A p value < 0.05 was considered statistically significant.

Results

Table 1 shows the baseline characteristics of the 90 patients who underwent ThuVEP. The perioperative results were reported previously in detail [13]. Table 2 shows the follow-up data of all patients who underwent ThuVEP with prostates larger than 85 ml. Median follow-up was 36.5 (16–60)

Table 1 Baseline characteristics and perioperative data

Parameter	
Baseline characteristics	
Age (years)	71 (66–75.3)
No. of pts. ≥ 80 years (%)	12 (13.3)
No. alpha-blocker therapy (n)	45 (50)
No. 5-α-reductase inhibitor therapy (n)	19 (21.1)
No. history of urinary retention (n)	49 (54.4)
No. preoperative urinary retention (n)	37 (41.1)
PSA (ng/ml)	7.4 (4.4–14)
Prostate volume (ml)	100 (88–122)
ASA score	2 (2–3)
No. of associated conditions	
Hypertension (%)	54 (60)
Ischemic heart disease (%)	16 (17.8)
Diabetes mellitus (%)	13 (14.4)
Chronic renal failure (%)	4 (4.4)
Cardiac pacemaker (%)	2 (2.2)
Inguinal hernia (%)	17 (18.9)
Bladder diverticulum (%)	2 (2.2)
Bladder tumor (%)	3 (3.3)
Bladder stones (%)	1 (1.1)
Upper tract urolithiasis (%)	5 (5.6)
Perioperative data	
Laser energy (kJ)	206.58 (170.84–282.57)
Total operation time (min)	95 (70–120)
Enucleation time (min)	53.5 (35.25–80)
Morcellation time (min)	22 (15–35)
Resected weight (g)	66 (52–86)
Percentage resected tissue^{+} (%)	65.9 (51–79.56)
Hemoglobin decrease (g/dl)	1.5 (0.78–2.5)
Catheter time (days)	2 (2–2)
No. PVR ≥ 100 ml (*n*)	
- Preop	71 (78.9)
- At discharge	4 (4.4)

Data as *n* (%) or median (interquartile range (IQR)); $^{+}$ Resected weight/preoperative prostate volume; *PVR*, post-voiding residual urine

months. At 12-month follow-up, IPSS, QoL, Qmax, and PVR had improved significantly compared with preoperative assessment and continued to do so during follow-up ($p < 0.001$) (Table 2). At 4-year postoperative, median Qmax (19.1 vs. 7.75 ml/s), PVR (31.9 vs. 150 ml), IPSS (4.5 vs. 24), and QoL (1 vs. 5) differed significantly from baseline ($p \leq 0.027$) (Table 2). PSA decreased from 7.4 (4.14–14) to 0.70 (0.36–1.64) μg/l ($p < 0.001$), corresponding to a PSA reduction of 86.48% (79.85–95.25%) at 48-month follow-up.

During 48-month follow-up, urinary tract infections (UTI) occurred in 2 (2.2%) patients. A urethral stricture and a bladder neck contracture developed in 1 (1.1%) patient each. One patient (1.1%) required oral medication with alpha blockers due to obstructive symptoms; however, this patient already received a vaporesection of the prostate as a secondary treatment (Table 4). After 4 years of follow-up, no patient developed an embolism or other cardiac events due to desobstruction of the prostate.

Discussion

Our current study demonstrates that ThuVEP appears to be a durable minimally invasive alternative to OP for patients with enlarged prostates due to BPH with a median prostate volume of 100 ml with a low complication rate during long-term follow-up.

Despite the considerable perioperative morbidity of OP, this procedure has been the standard treatment of substantially enlarged prostates due to BPH over decades due to the low reintervention rate during long-term follow-up by a complete dissection of the prostate adenoma from the prostatic pseudocapsule [1, 6, 18]. Although more minimally invasive alternative procedures to OP have been developed [2, 9], only EEP procedures such as HoLEP [2–4, 6–9], PkEP [16], or BipolEP [17] have been proven to be size-independent procedures with excellent long-term outcomes by combining the advantages of OP (complete dissection of the prostate adenoma from the prostatic pseudocapsule) with those of the transurethral approach (direct sealing of bleeding vessels). To note, long-term results for photoselective vaporization of the prostate (PVP) utilizing the 180-W XPS laser, laparoscopic simple prostatectomy, or robotic-assisted simple prostatectomy in substantially enlarged prostates have not been published so far. ThuVEP has been shown to be a size-independent procedure for the surgical treatment of BPH with low perioperative morbidity, a shallow learning curve, and promising long-term results [11–14, 19]. Long-term results of ThuVEP in men with large-volume prostates ≥ 85 ml have not been published so far.

Pearce et al. and Netsch et al. evaluated 25 and 84 patients with a prostate volume of > 75 ml, respectively. However, functional outcome parameters were only assessed after 12 months without long-term follow-up [20, 21]. The largest study of patients receiving ThuVEP with a prostate volume > 80 ml was published in 2013. In this series, the early postoperative outcome of 266 patients undergoing ThuVEP was presented without follow-up examinations [14]. The only study with a long-term follow-up was presented in 2016 by Yang et al. in a randomized trial including ThuLEP and PKRP with 39 patients completing the 5-year follow-up with regard to the ThuLEP group. The functional outcome is comparable to our series; however, the initial mean prostate volume at surgery was significantly lower than in our series with 72.4 ± 21.2 (45.7–94.7) ml [22].

However, there is no clear definition of "long-term" in the BPH literature. The definition of "long-term" ranges in the literature from 12 up to 60 months of follow-up [4, 7, 23]. We defined "long-term results" arbitrarily as those with a follow-up greater than 48 months and compared our results with those studies of HoLEP, BipolEP, bipolar transurethral resection of the prostate (B-TURP), PkEP, and OP series with prostate volumes greater than 80 ml and a follow-up longer than 48 months [3, 4, 6–8, 16–18] (Table 3).

Our current results confirm the durable effect of the ThuVEP procedure. A significant improvement of Qmax, PVR, IPSS, and QoL could be shown at each follow-up until

Table 2 Descriptive analysis of outcomes after thulium vapoenucleation of the prostate (ThuVEP)

Follow-up	No. pts	Qmax (ml/s)	PVR (ml)	IPSS	QoL	PSA	PSA reduction
Preop	90*	7.75 (3.93–12.3)*	150 (80–265)*	24 (20–29)	5 (3–5.25)	7.4 (4.4–14)	–
12 months	64	20.15 (16.38–28)	15.75 (0–50)	4 (1–7)	1 (0–1)	–	–
p value**		< 0.001	< 0.001	< 0.001	< 0.001		
24 months	42	19.8 (16.35–24.05)	19.31 (10.3–53.2)	4 (1–6.75)	1 (0–1)	–	–
p value**		≤ 0.012	< 0.001	< 0.001	< 0.001		
36 months	36	18.9 (15.75–23.65)	27 (14.1–60)	4 (1–7)	1 (0–1)	–	–
p value**		≤ 0.012	< 0.001	< 0.001	< 0.001		
48 months	29	19.1 (16.02–23.7)	31.9 (15.03–63.01)	4.5 (1–7)	1 (0–1)	0.70 (0.36–1.64)	86.48 (79.85–95.25)
p value**		≤ 0.027	≤ 0.001	< 0.001	< 0.001	< 0.001	

Data as median (interquartile range (IQR)); *IPSS*, International Prostate Symptom Score; *QoL*, quality of life; *Qmax*, maximum urinary flow rate; *PVR*, post-voiding residual urine; *NA*, not analyzed; *Except those in urinary retention; **Preoperative vs. follow-up data

Table 3 Long-term results following ThuVEP, OP, and HoLEP in series with a follow-up ≥48 months

Author							Perioperative data					At last follow-up						
	Intervention	Year	LOE	No. pts	Follow-up (months)	Pts. rate[f]	Preop prostate, wt (gm)	Enucleation time (min)	Resected tissue (gm)	Transfusion rate	Revision[a]	Urethral stricture	BNC	Re-OP for recurrent BPH	Qmax (ml/s)	PVR (ml)	IPSS	Qol
Netsch/Bach	ThuVEP	2015	4	90	48	32.2	100[b]	53.3[b]	66[b]	2.2	1.1	1.1	1.1	1.1	19.1[b]	31.9[b]	4.5[b]	1[b]
Elzayat	HoLEP	2005	4	552	48	11.2	83.7	86	52.1	2	1.3	1.8	1.3	0.3	19	44	5.4	1.2
Elzayat	HoLEP	2006	4	225	36	13.7	126.4	95.8	86.5	1.3	0.4	1.8	0.4	0	28.5	46.1	3.5	0.7
Kuntz	HoLEP	2008	1b	60	48	75	114.6	NA	83.9	0	5	3.3	1.7	0	27.7	8.6	3	NA
Elmansy	HoLEP	2011	4	949	48	65.6	81	NA	NA	0.4	NA	1.6	0.8	0.7	23.7	36	4.6	1
Zhu	PkEP	2013	1b	40	60	77.5	113.8	94	64.2	0	0	2.5	0	0	26.45	4	3.32	1
Zhu	B-TURP	2013	1b	40	60	75	109.7	89	50.6	2.5	0	2.5	2.5	5	22.07	7	4.9	1
Varkarakis	OP	2004	4	232	41.8[d]	65.1	104.5	NA	NA	6.3	4.3[c]	1.3	2.2	2.6	23.7	11.9	1.6	0.6
Madersbacher	OP	2005	4	2452	96	NA	NA	NA	NA	NA	NA	9.5[e]	9.5[e]	9.5e[f]	NA	NA	NA	NA
Kuntz	OP	2008	1b	60	48	60	113	NA	96.4	13.3	5	1.7	3.3	0	25	6.5	3	–

Data given as *n* (%) or mean unless otherwise stated. *ThuVEP*, thulium vapoenucleation of the prostate; *OP*, open prostatectomy; *HoLEP*, holmium laser enucleation of the prostate; *PkEP*, plasmakinetic enucleation of the prostate; *B-TURP*, bipolar transurethral resection of the prostate; *LOE*, level of evidence; *BNC*, bladder neck contracture; *BPH*, benign prostatic hyperplasia; *Qmax*, maximum urinary flow rate; *PVR*, post-voiding residual urine; *IPSS*, international prostate symptom score; *QoL*, quality of life. [a] Initial surgical revision (bleeding + reintervention for residual prostatic tissue). [b] Median. [c] Wound complications (seroma, abscess, prolonged drainage). [d] Mean follow-up. [e] Secondary endoscopic intervention (TURP, urethrotomy, bladder neck incision). [f] Follow-up rate at last follow-up mark

the last follow-up consultation after 48 months. These results are well comparable with HoLEP [3, 4, 6–8], PkEP [16], BipolEP [17], OP [6, 17], and B-TURP [16] series in patients with substantially enlarged prostates, respectively (Table 3). As in OP or other EEP procedures, complete dissection of the prostatic adenoma from the pseudocapsule is achieved with ThuVEP leading to a median PSA reduction of 86.48% at 48-month follow-up. This PSA reduction is well comparable with HoLEP [4, 7, 24], OP [17], and BipolEP [17] series in patients with enlarged prostates. Only one patient was retreated for recurrent prostatic tissue during 48-month follow-up in this study, which supports the completeness of enucleation by ThuVEP.

With regard to the learning curve, the most important aspect of laser enucleation is finding the correct layer between the prostate capsule and the adenomatous tissue. Netsch et al. compared three surgeons with different levels of experience with regard to ThuVEP [19]. The authors stated that approximately 8–16 cases are necessary to feel safe during enucleation with the thulium laser with comparable enucleation and morcellation efficiency of the surgeons. After 12 months of follow-up, functional parameters and prostate volume had improved significantly in each surgeon without differences in the complication rate. It seems that the learning curve of ThuVEP is not as steep as that of HoLEP. This is most likely caused by the smooth cutting abilities of the thulium laser with its continuous wave laser, which makes it easier to find the correct plane and allows the surgeon to correct the layer of enucleation while switching to vaporesection or pure vaporization of the adenomatous tissue [25]. However, despite the physical characteristics of the laser, it is necessary to perform ThuVEP with a mentor-based approach to keep the learning curve as low as possible [19].

The main difference between ThuVEP and HoLEP is the energy source used for enucleation. The thulium laser works as a continuous wave laser with a wavelength of 2.1 μm with a recommended power output setting of 90 W [25]. The holmium laser works in a pulsed mode with energy settings between 90 and 120 W [4]. The surgical principle in all laser enucleation techniques remains identical. In a randomized study by Becker et al., it was shown the HoLEP and ThuVEP lead to comparable postoperative results with a significant improvement in functional parameters without differences between both procedures [26]. Hence, there is no need no switch from HoLEP to ThuVEP or vice versa. The aspect of why a physician would choose ThuVEP over HoLEP is probably the faster learning curve of the procedure.

Low perioperative complication rates, short catheterization times, and a short hospital stay after ThuVEP have been published before [13], well comparable with other transurethral EEP procedures like HoLEP [2–4, 6–9], PkEP [16], or BipolEP [17] and significantly lower compared with OP [1, 6, 17] and TURP [27]. In addition, the incidence of late complications after ThuVEP in this series is also in line with a series of HoLEP, PkEP, B-TURP, BipolEP, and OP, respectively (Table 4). One patient received surgical therapy during follow-up because of a urethral stricture, a bladder neck contracture, and a bladder neck sclerosis, respectively.

Table 4 Detailed analysis of Clavien grade 1 to 3b complications

Complication	Treatment	Total (%)
Clavien grade 1 complications		
Urinary retention after catheter removal	Bedside recatheterization	2 (2.2)
Clot retention without surgical revision	Bladder irrigation (prolonged) and tamponade evacuation through catheter	6 (6.7)
Extraperitoneal fluid collection	Oral diuretics, prolonged catheterization	7 (7.7)
Superficial bladder injury due to morcellation	No special therapy	1 (2.2)
Capsular perforation	No special therapy	2 (2.2)
Bladder neck false passage	Prolonged catheterization	3 (3.3)
Clavien grade 2 complications		
Postoperative Hematuria	Blood transfusion	2 (2.2)
UTI	Antibiotics	12 (13.3)
Clavien grade 3b complications		
Hemorrhage/clot retention	Cystoscopy with clot evacuation, coagulation of prostate fossa	1 (1.1)
Late complications (48-month follow-up)		
Urinary retention	Bedside recatheterization	2 (2.2)
Epididymitis	Antibiotics	2 (1.6)
Regrowth of prostatic tissue	Vaporesection (thulium laser)	1 (1.1)
Urethral stricture	Internal urethrotomy	1 (1.1)
Bladder neck sclerosis	Bladder neck incision	2 (1.1)

Table 5 Causes of patient drop-out during follow-up

	Total (%)
Living abroad	9 (10)
Died during follow-up (myocardial infarction, apoplexy, brain tumor)	7 (7.8)
Dementia	2 (2.2)
Appointment not possible due to other medical reasons	4 (4.4)
Did not want to participate follow-up assessments	16 (17.7)
Person unavailable (now living abroad)	16 (17.7)
Muscle-invasive bladder cancer (radical cystectomy)	1 (1.1)
Prostate cancer (postop histology or diagnosed during follow-up)	6 (6.7)
Patients finally available at 48-month follow-up	29 (32.2)

We, here, present the largest study regarding ThuVEP therapy due to BPH in large-volume prostates; however, the current study reveals few limitations. This study was performed at a single center with a non-randomized study design. Furthermore, due to a relatively high rate of lost to follow-up, we had a smaller sample size at 48-month follow-up. However, the follow-up rate of 32.2% at the 48-month mark in this study is similar to other case series (7.4–65.6%) for larger prostates at long-term follow-up (Table 3). In particular, Elzayat et al. published a retrospective case series of 552 patients with a mean prostate volume of 83.7 ml treated with HoLEP [3]. Only 62 of 552 patients (11.2%) were available at the 48-month follow-up mark. Krambeck and colleagues followed 1065 patients after HoLEP. At 5-year follow-up and longer, IPSS and QoL (Qmax, PVR not analyzed) were available only in 79 of 1065 patients (7.4%) [7]. In addition, Ruszat et al. had a follow-up rate of 17.6% (88 of 500 patients) 4 years after PVP [28]. Therefore, the decreasing follow-up rate is not an uncommon problem in case series regarding surgical therapies of BPH.

Different reasons for the low follow-up rate of series regarding surgical BPH treatment have to be mentioned: first, the age of the patients at surgery receiving treatment due to BPH is around 70 years. These patients will be getting older and linked to a higher rate of comorbidities. A certain amount of the patients might be living in a nursing home, unable to attend follow-up visits, or die due to reasons unrelated to BPH surgery. Second, patients are referred from other cities or states for the treatment of large-volume prostates by EEP in our ThuVEP series as stated before in HoLEP series [3, 4, 12]. Third, in patients treated for benign diseases with significant symptom improvement after treatment (i.e., good micturition), it might be more likely that these patients deny long-term follow-up visits (Table 5).

However, despite the low follow-up rate at 48-month, our outcomes of ThuVEP in large-volume prostates seem robust, since the PSA decrease of 86.48% is very high at 48-month follow-up. The reintervention rate in our series was related to the complete study population of 90 patients. However, even when relating this rate just to the follow-up group of 29 patients at 48-month follow-up, the reintervention rates for regrowth of prostatic adenoma, bladder neck contractures, and urethral strictures are 3.4% each and still well comparable with the HoLEP, PkEP, B-TURP, BipolEP, and OP literature for the treatment of substantially enlarged prostates due to BPH (Table 4).

Conclusions

ThuVEP appears to be a durable alternative to OP for patients with substantially enlarged prostates due to BPH. The incidence of complications with ThuVEP during long-term follow-up was low.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

1. Gratzke C, Schlenker B, Seitz M et al (2007) Complications and early postoperative outcome after open prostatectomy in patients with benign prostatic enlargement: results of a prospective multicenter study. J Urol 177:1419–1422. https://doi.org/10.1016/j.juro.2006.11.062

2. Ahyai SA, Gilling P, Kaplan SA et al (2010) Meta-analysis of functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic enlargement. Eur Urol 58:384–397. https://doi.org/10.1016/j.eururo.2010.06.005
3. Elzayat EA, Habib EI, Elhilali MM (2005) Holmium laser enucleation of the prostate: a size-independent new "gold standard". Urology 66:108–113. https://doi.org/10.1016/j.urology.2005.06.006
4. Elzayat EA, Elhilali MM (2006) Holmium laser enucleation of the prostate (HoLEP): the endourologic alternative to open prostatectomy. Eur Urol 49:87–91. https://doi.org/10.1016/j.eururo.2005.08.015
5. Fraundorfer MR, Gilling PJ (1998) Holmium:YAG laser enucleation of the prostate combined with mechanical morcellation: preliminary results. Eur Urol 33:69–72
6. Kuntz RM, Lehrich K, Ahyai SA (2008) Holmium laser enucleation of the prostate versus open prostatectomy for prostates greater than 100 grams: 5-year follow-up results of a randomised clinical trial. Eur Urol 53:160–166. https://doi.org/10.1016/j.eururo.2007.08.036
7. Krambeck AE, Handa SE, Lingeman JE (2013) Experience with more than 1,000 holmium laser prostate enucleations for benign prostatic hyperplasia. J Urol 189:S141–S145. https://doi.org/10.1016/j.juro.2012.11.027
8. Elmansy HM, Kotb A, Elhilali MM (2011) Holmium laser enucleation of the prostate: long-term durability of clinical outcomes and complication rates during 10 years of followup. J Urol 186:1972–1976. https://doi.org/10.1016/j.juro.2011.06.065
9. Cornu J-N, Ahyai S, Bachmann A et al (2015) A systematic review and meta-analysis of functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic obstruction: an update. Eur Urol 67:1066–1096. https://doi.org/10.1016/j.eururo.2014.06.017
10. Gilling PJ (2013) Laser enucleation is increasingly becoming the standard of care for treatment of benign prostatic hyperplasia of all sizes. Eur Urol 63:868–869; discussion 870-871. https://doi.org/10.1016/j.eururo.2013.01.001
11. Bach T, Wendt-Nordahl G, Michel MS et al (2009) Feasibility and efficacy of thulium:YAG laser enucleation (VapoEnucleation) of the prostate. World J Urol 27:541–545. https://doi.org/10.1007/s00345-008-0370-0
12. Netsch C, Engbert A, Bach T, Gross AJ (2014) Long-term outcome following thulium VapoEnucleation of the prostate. World J Urol 32:1551–1558. https://doi.org/10.1007/s00345-014-1260-2
13. Bach T, Netsch C, Pohlmann L et al (2011) Thulium:YAG vapoenucleation in large volume prostates. J Urol 186:2323–2327. https://doi.org/10.1016/j.juro.2011.07.073
14. Gross AJ, Netsch C, Knipper S et al (2013) Complications and early postoperative outcome in 1080 patients after thulium vapoenucleation of the prostate: results at a single institution. Eur Urol 63:859–867. https://doi.org/10.1016/j.eururo.2012.11.048
15. Gravas S, Bach T, Bachmann A, et al (2016) Guidelines on the management of non-neurogenic male lower urinary tract symptoms (LUTS), including benign prostatic obstruction (BPO). Eur Urol 67(6):1099-1109. https://doi.org/10.1016/j.eururo.2014.12.038
16. Zhu L, Chen S, Yang S et al (2013) Electrosurgical enucleation versus bipolar transurethral resection for prostates larger than 70 ml: a prospective, randomized trial with 5-year followup. J Urol 189:1427–1431. https://doi.org/10.1016/j.juro.2012.10.117
17. Chen S, Zhu L, Cai J et al (2014) Plasmakinetic enucleation of the prostate compared with open prostatectomy for prostates larger than 100 grams: a randomized noninferiority controlled trial with long-term results at 6 years. Eur Urol 66:284–291. https://doi.org/10.1016/j.eururo.2014.01.010
18. Madersbacher S, Lackner J, Brössner C et al (2005) Reoperation, myocardial infarction and mortality after transurethral and open prostatectomy: a nation-wide, long-term analysis of 23,123 cases. Eur Urol 47:499–504. https://doi.org/10.1016/j.eururo.2004.12.010
19. Netsch C, Bach T, Herrmann TRW et al (2013) Evaluation of the learning curve for thulium VapoEnucleation of the prostate (ThuVEP) using a mentor-based approach. World J Urol 31:1231–1238. https://doi.org/10.1007/s00345-012-0894-1
20. Pearce SM, Pariser JJ, Malik RD et al (2016) Outcomes following thulium vapoenucleation of large prostates. Int Braz J Urol Off J Braz Soc Urol 42:757–765
21. Netsch C, Bach T, Herrmann TRW, Gross AJ (2012) Thulium:YAG VapoEnucleation of the prostate in large glands: a prospective comparison using 70- and 120-W 2-μm lasers. Asian J Androl 14:325–329. https://doi.org/10.1038/aja.2011.167
22. Yang Z, Liu T, Wang X (2016) Comparison of thulium laser enucleation and plasmakinetic resection of the prostate in a randomized prospective trial with 5-year follow-up. Lasers Med Sci 31:1797–1802. https://doi.org/10.1007/s10103-016-2052-2
23. Kuo RL, Kim SC, Lingeman JE et al (2003) Holmium laser enucleation of prostate (HoLEP): the Methodist Hospital experience with greater than 75 gram enucleations. J Urol 170:149–152. https://doi.org/10.1097/01.ju.0000070686.56806.a1
24. Tinmouth WW, Habib E, Kim SC et al (2005) Change in serum prostate specific antigen concentration after holmium laser enucleation of the prostate: a marker for completeness of adenoma resection? J Endourol 19:550–554. https://doi.org/10.1089/end.2005.19.550
25. Netsch C, Bach T, Herrmann TRW, Gross AJ (2015) Update on the current evidence for tm:YAG vapoenucleation of the prostate 2014. World J Urol 33:517–524. https://doi.org/10.1007/s00345-014-1417-z
26. Becker B, Herrmann TRW, Gross AJ, Netsch C (2018) Thulium vapoenucleation of the prostate versus holmium laser enucleation of the prostate for the treatment of large volume prostates: preliminary 6-month safety and efficacy results of a prospective randomized trial. World J Urol. https://doi.org/10.1007/s00345-018-2321-8
27. Reich O, Gratzke C, Bachmann A et al (2008) Morbidity, mortality and early outcome of transurethral resection of the prostate: a prospective multicenter evaluation of 10,654 patients. J Urol 180:246–249. https://doi.org/10.1016/j.juro.2008.03.058
28. Ruszat R, Seitz M, Wyler SF et al (2008) GreenLight laser vaporization of the prostate: single-center experience and long-term results after 500 procedures. Eur Urol 54:893–901. https://doi.org/10.1016/j.eururo.2008.04.053