Photoselective vaporization of the prostate with the 180-W XPS-Greenlight laser: Five-year experience of safety, efficiency, and functional outcomes

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Abstract

Introduction: Transurethral resection of the prostate (TURP) is still considered the gold standard surgical treatment for symptomatic benign prostatic hyperplasia (BPH). However, photoselective vaporization of the prostate (PVP) has gained widespread global acceptance in national guidelines as a safe and effective alternative option. Nevertheless, further evidence is required to assess the durability of Greenlight PVP. Herein, we report our five years of PVP experience with the Greenlight 180W XPS laser system.

Methods: A retrospective analysis was conducted on a prospectively gathered database of 370 consecutively included patients who underwent PVP using Greenlight XPS-180 W laser system (Boston Scientific, Boston, MA, U.S.) performed by a single experienced laser surgeon between 2011 and 2016. Preoperative characteristics, intervention parameters, postoperative functional, uroflowmetry outcomes, and complications were collected. Outcomes are reported over a period of five years.

Results: Mean age was 68 years, with a mean prostate volume of 78.8 cc (95% confidence interval [CI] 70.9–78.7]). The mean followup was 59.4 months (55.4–63.5). Mean energy, operative time, and energy/cc were 270.2 kJ (255.2–285.2), 62.7 minutes (59.6–65.7), and 3.7 kJ/cc (3.6–3.9), respectively. Compared to preoperative values, International Prostate Symptom Score (IPSS), maximum flow rate (Qmax), and post-void residual (PVR) parameters were significantly improved and sustained over the five postoperative years. Of note, only 66 patients (out of 370) had a complete five-year followup. Prostate-specific antigen (PSA) reached nadir at one year, with a drop of 67% from the mean preoperative value of 6.2 ng/mL. Mean IPSS nadir was reached at three years, with a drop of 80.4% (-21.1 points). Similarly, mean quality of life (QoL) score dropped by 82.8% after three years (preoperative mean of 4.7). With respect to mean Qmax, there was an increase by 72.7% (+14.7 mL/s) at one year, reaching the value of 19.9 mL/s. Moreover, mean PVR was 32.8 mL at four years compared to 345 mL preoperatively. At five years followup, PSA, IPSS, QoL, and PVR dropped by 59.7% (3.7 ng/mL), 75.2% (19.7 points), 78.72% (3.7 points), and 84.4% (291.3 mL), respectively. Qmax increased by 12.9 mL/s. Clavien complication rates were low, with bladder neck stenosis observed in seven (1.6%) men. During the five-year followup, only four patients (1%) required BPH surgical re-intervention.

Conclusions: This is the first long-term reporting of Greenlight XPS-180W laser system. In experienced hands, the observed outcomes appear to demonstrate that Greenlight XPS-180 W laser system is safe, efficacious, and durable for the treatment of bladder outlet obstruction (BOO) secondary to BPH.

Introduction

Benign prostatic hyperplasia (BPH) is a common condition diagnosed in men with increasing incidence after the age of 50.[1,2] Clinically, it manifests itself by progressive development of lower urinary tract symptoms (LUTS) that include voiding and storage disturbances.[1,2] The severity of BPH and the patient's degree of bothersome can be assessed by self-administered questionnaires, such as the International Prostate Symptom Score (IPSS).[1] Medical treatment should be offered to patients with moderate to severe symptoms (IPSS 8–35). According to the American and other international guidelines, surgery should be suggested as an option to patients having one or more of the following: urinary symptoms refractory to maximal medical therapy, gross hematuria, recurrent infections, bladder stones, or deterioration of kidney function.[1-3] Transurethral resection of the prostate (TURP) remains the gold standard treatment for LUTS secondary to BPH.[1] However, this intervention is associated with safety issues, particularly in patients taking anticoagulation therapy and those with larger prostates (>80 cc).[4,5]

Over the past decades, Greenlight (GL) 532 nm laser photo selective vaporization of the prostate (PVP) has gained widespread acceptance as a safe and effective alternative to TURP.[3,6] This technology is based on a 532 nm length laser that vaporizes the highly vascularized transitional prostatic zone by selectively heating the hemoglobin.[7,8] In the year 2000, the first laser 80W KTP laser was commercialized. It was succeeded in 2006 by the 120W HPS system and most recently, in 2011, by the 180 W Light XPS (XPS GL). Studies demonstrated that PVP was as safe and efficient as TURP, with significant shorter catheterization and hospitalization times.[6,9,10] However, durability outcomes have been questioned for the initial 80 W and 120 W generation systems.[9] Despite the 180 W XPS improved efficiency and short-term benefits, long-term data assessing BPH treatment durability is lacking. As such, we report the efficacy and safety of the 180 W XPS system over a five-year experience and followup.

Methods

Patient characteristics

In this single institutional retrospective study, we prospectively collected data for 370 men who underwent 180 W XPS GL (Boston Scientific, Boston, MA, U.S.) for BPH between 2011 and 2016. Patients with prostate cancer (n=16) and those treated with the HPS GL (n=38) were excluded from the analyses. Indications for treatment were based on the American Urological Association (AUA) BPH clinical guidelines.[1] Institutional review board approval was obtained for the study.

Surgical procedures

All men were treated with the 180 W XPS GL as previously reported. The surgeries were performed by a single experienced surgeon at our institution. The approach and technical procedure about the GL 180W XPS surgery is well-described.[11,12]

Study design

All patients had prostate-specific antigen (PSA), IPSS, quality of life (QoL), post-void residual (PVR), maximum flow rate (Qmax), and transrectal ultrasound (TRUS) prostate volume assessment before surgery. Men were followed up at three, six, 12, 24, 36, 48, and 60 months. The outcomes of the patients were documented at each visit. The results were compared to preoperative values. Patients identify as "drop-out" were scheduled for a five-year visit.

Complications were also prospectively described in this study. They included overactive bladder (OAB) symptoms, stress urinary incontinence (SUI), dysuria, urinary tract infection (UTI), urinary retention, hematuria, urethral strictures, and erectile dysfunction (ED) (Erection Hardness Score [EHS] and Sexual Health Inventory for Men [SHIM]). These complications were categorized according to the Clavien-Dindo classification.[13]

Statistical analyses

Means and standard deviations (SD) were reported for continuous variables, and proportions were used for nominal variables. Categories were compared using the Chi-square test and Fisher exact test for continuous variables. A p value <0.05 was considered statistically significant. All analyses were performed using the SPSS software.

Results

After exclusion, the study included 370 men who underwent PVP using the GL 180 W XPS. Patients were followed up for a period of five years (mean 59.4 months; confidence interval [CI] 55.4–63.5]; median: 56.3 months). However, only 66 patients (out of 370) had a complete five-year followup. The functional outcomes are comparable between the 66 patients and all other patients during the followup period. The mean age of the patients was 68 years. Moreover, the mean prostate was 78.8 cc (70.9–78.7). Mean operative time of the surgical procedures was 62.7 minutes (59.6–65.7), with a mean total energy expenditure of 270.2 kJ (255.2–285.2) per surgery. Thus, the average energy density utilization was 3.7 kJ/cc (3.6–3.9) in the entire cohort.

Of note, seven (1.9%) of the patients were on anticoagulation therapy at the time of surgery, knowing that 135 men (36.5%) stopped anticoagulation days before surgery. Patients' perioperative characteristics are summarized in Tables 1 and 2.

Functional outcomes were reported preoperatively and at three, six, 12, 24, 36, 48, and 60 months (Tables 3 and 4). Retrospectively, preoperatively, the mean values for the IPSS, QoL, Qmax, and PVR were 26.2, 4.7, 5.5 mL/s, and 345 mL, respectively. After five years, the values recorded were 6.5, 1, 18.4 mL/s, and 53.7 mL, respectively. All functional outcomes significantly improved compared to baseline and appear to be maintained over the followup period. With respect to the PSA, the average preoperative value was 6.2 ng/mL compared to 2.5 ng/mL after five years (Fig. 1).

Clavien-Dindo categorized adverse events are listed in Table 5. At three months, 63 (18.8%) patients had treatment for irritative voiding symptoms with possible pre-existing OAB. This incidence dropped to 16 (8.46%) at one year and 0 at five years, suggesting improvement of irritative voiding parameters after resolution of BOO postoperatively. On the other hand, five (1.5%) patients had signs of bladder underactivity at three months. With respect to dysuria, 14 (4.7%) patients complained of burning sensation three months after

Table 1. Baseline characteristics

	Number of patients	Mean	Confidence interval
Age (years)	370	67.8	66.9–68.7
BMI (kg/m^2)	370	26.8	26.4–27.2
Prostate volume (cc)	370	78.8	70.9–78.7
Median lobe (preop ultrasound or cystoscopy)	138 (37.3%)		
Duration on α-adrenergic blockers (years)	370	2.01	1.8–2.2
Duration on 5-alpha reductase inhibitors (years)	241	1.8	1.5–2.1
Retention with urethral catheter at time of surgery	170 (45.9%)		
Anticoagulation stopped before surgery and resumed immediately thereafter	135 (36.5%) Aspirin: 94 Clopidogrel: 5 Aspirin + clopidogrel: 12 Coumadin switched to low molecular weight heparin: 15 Dabigatran etexilate: 6 Aspirin + dabigatran etexilate: 3		
Continued anticoagulation at time of surgery	7 (1.9 %) Aspirin: 3 Aspirin + clopidogrel: 3 Coumadin switched to low molecular weight heparin: 1		

BMI: body mass index.

Table 2. Operative parameters

	Number of patients	Mean	Confidence interval
Duration of surgery (min)	370	62.7	59.6–65.7
Total energy used (kJ)	370	270.2	255.2–285.2
Energy per g (kJ/cc)	370	3.7	3.6–3.9
Number of fibers used	370	1.12	1.09–1.16
Pathological specimen weight of retrieved tissue removed (g)	370	3.9	3.3–4.5
Hospital stay (days)	370	0.7	0.5–0.8
Foley catherization (days)	370	1.1	1.0–1.2
Conversion to TURP	10 (2.7%)		

TURP: transurethral resection of the prostate.

the surgery compared to 0 patients after four years. Eight (2.4%) patients had urinary infections within three months postoperatively requiring antibiotic treatment. Concerning bladder neck contracture (BNC), cystoscopy confirmed its diagnosis in two patients within six months and in five (2.6%) patients at one year. Only two men (0.5%) were reported to have clinically worsening erectile dysfunction at six months. Most important with respect to treatment durability, only four (1.1%) men required BPH retreatment: one at one year, one at two years, and two at four years. Mean procedure prostate volume and kJ/cc treatment were 87.3 cc and 3.9 kJ/cc, respectively, in these patients.

Discussion

In 2011, Bachmann et al were the first to report promising results on the efficiency and safety of the 180 W XPS GL treatment for LUTS.[14] As its predecessors, the 180 W is a 532 nm lithium triporate laser, but it is equipped with a MoXy liquid-cooled fiber.[7,15] This innovative technology was created to enhance the efficiency, durability, and safety of GL prostatectomy for patients with BPH. This technique can be offered in the long-run to patients with large prostates rather than having them undergo open prostatectomy.[15] Indeed, the 180 W GL safety has been upgraded by an infra-based feedback mechanism at the fiber-tip, along with a new pulsed coagulation device.[7] Such features would allow the rapid control of bleeding intraoperatively. Furthermore, the increased output power allows improvement in the rate of vaporization and, therefore, a faster operative time.[7,16] Since

Table 3. Outcomes of 180 XPS Greenlight

Outcomes	Preoperative	Months							p
		3	6	12	24	36	48	60	
PSA (ng/mL)	6.2 4.5–8.1	NA	2.3 1.9–2.6	2.0 1.8–2.3	2.6 2.3–2.9	2.4 1.7–3.1	2.8 1.4–4.0	2.5 0.3–4.0	<0.001
IPSS	26.2 25.6–26.8	7.7 7.2–8.2	6.1 5.7–6.5	5.8 5.3–6.3	5.4 4.9–5.9	5.1 4.54–5.70	6.2 5.0–7.4	6.5 4.0–8.9	<0.001
QoL	4.7 4.6–4.8	1.3 1.2–1.4	1.02 0.9–1.1	0.9 0.8–1.1	0.9 0.9–1.5	0.8 0.6–0.9	0.9 0.7–1.2	1.0 0.9–1.48	<0.001
Qmax (mL/s)	5.5 5.3–5.9	19.9 19.5–20.5	20.2 19.5–20.6	19.9 19.2–20.4	19.8 19.1–20.5	19.5 17.8–19.8	19.3 17.7–20.8	18.4 16.5–20.4	<0.001
PVR (mL)	345 320–370	45.1 36.2–54.5	38.9 31.1–46.8	44.3 33.5–55.1	44.2 29.9–55.5	40.4 21.2–59.7	32.8 12.6– 52.9	53.7 36.1–71.4	<0.001

IPSS: International Prostate Symptom Score; PSA: prostate-specific antigen; PVR: post-void residual; Qmax: maximum flow rate; QoL: quality of life.

Table 4. Outcomes of 180 XPS Greenlight of the 66 patients with complete 5-year followup

Outcomes	Preoperative	Months							p
		3	6	12	24	36	48	60	
PSA (ng/mL)	11.9 8.4–15.0	NA	3.2 1.5–4.9	2.5 1.4–3.7	2.7 1.5–3.9	2.8 1.7–3.8	2.7 1.6–3.8	2.5 0.3–4.0	<0.001
IPSS	25.3 23.5–26.8	7.9 6.8–9.1	6.0 5.1–6.9	5.1 4.3–7.8	4.9 4.3–5.5	4.9 4.3–5.6	5.4 4.5–6.4	6.5 4.0–8.9	<0.001
QoL	4.5 4.2–4.8	1.3 1.0–1.6	0.9 0.7–1.2	0.9 0.7–1.2	0.8 0.6–1.0	0.8 0.6–1.0	0.9 0.7–1.1	1.0 0.9–1.48	<0.001
Qmax (mL/s)	4.5 4.2–4.8	20.3 19.4–21.2	20.5 19.4–21.6	20.3 19.0–21.6	20.8 19.8–21.8	18.8 17.7–19.9	16.8 15.6–18.1	18.4 16.5–20.4	<0.001
PVR (mL)	293.1 229.9–356.2	20.9 11.2– 30.6	26.6 12.9–20.3	23.8 12.6–34.9	23.2 10.6–35.7	43.7 15.1–72.3	55.5 31.0–79.9	53.7 36.1–71.4	<0.001

IPSS: International Prostate Symptom Score; PSA: prostate-specific antigen; PVR: post-void residual; Qmax: maximum flow rate; QoL: quality of life.

its introduction to the urological armamentarium, several studies reported its superiority to monopolar TURP, with shorter hospitalization, shorter catheterization time, and faster time to clinical stability.[16,17]

More recent studies have demonstrated excellent outcome of 180 W XPS GL PVP over a period of two years.[6] The current study is unique, as it is the first study, to the best of our knowledge, to report five-year durability outcomes. To note, only 66 patients (out of 370) had a complete five-year followup. In addition, it is important to mention that the patients treated had an average prostate size of 78.8 cc measured by TRUS preoperatively, which is significantly larger than in the Goliath trial (48.6 cc). All functional outcomes demonstrated and sustained significant improvement even after a period of five years.

As mentioned previously, the Goliath study is the only prospective, randomized clinical trial comparing 180 W XPS and TURP with an exclusion of any patient in urinary retention.[6] At two years, they reported an IPSS score of 6.9, which suggests a drop of 14.3 points (67.5%) form baseline (21.2 points). In our study, the preoperative IPSS was 26.2 points, with 46% of patients in urinary retention at the time of surgery. After initial rapid decline in IPSS postoperatively at three months (mean 7.7 points), future decline to nadir was observed at three years (mean IPSS of 5.1 points). This suggests the immediate relief of obstructive urinary symptoms with a delayed recovery in bladder storage symptoms. At five-year followup, the IPSS was 6.5, a 75.2% (19.7 points) drop from baseline. Similarly, the reported QoL score was 1. This significant improvement was similar to the 71.1% drop (1.3 from 4.6) observed at two years in the GOLIATH study.[6]

With regards to urodynamic parameters, we observed that Qmax reached its maximal value at one year, with an increase of 14.4 mL/s from 5.5 mL/s at baseline. At five years, the Qmax was 18.4 mL/s. Such results are comparable to the Altay et al study, which included 68 patients with prostates larger than 80 mL and demonstrated a significant improvement at one year, with a Qmax of 16 mL/s compared to 7.6 mL/s preoperatively.[15] Furthermore, Bachmann et al reported an increase of 12.6 mL/s at six months, with a preoperative Qmax of 8.4 mL/s.[14] When treated with TURP, the mean Qmax before the operation was 7.1 mL/s and reached 20.0 mL/s after five years.[18] This increase of 12.9 mL/s is comparable with the increase after five years of surgery with the 180 W XPS.

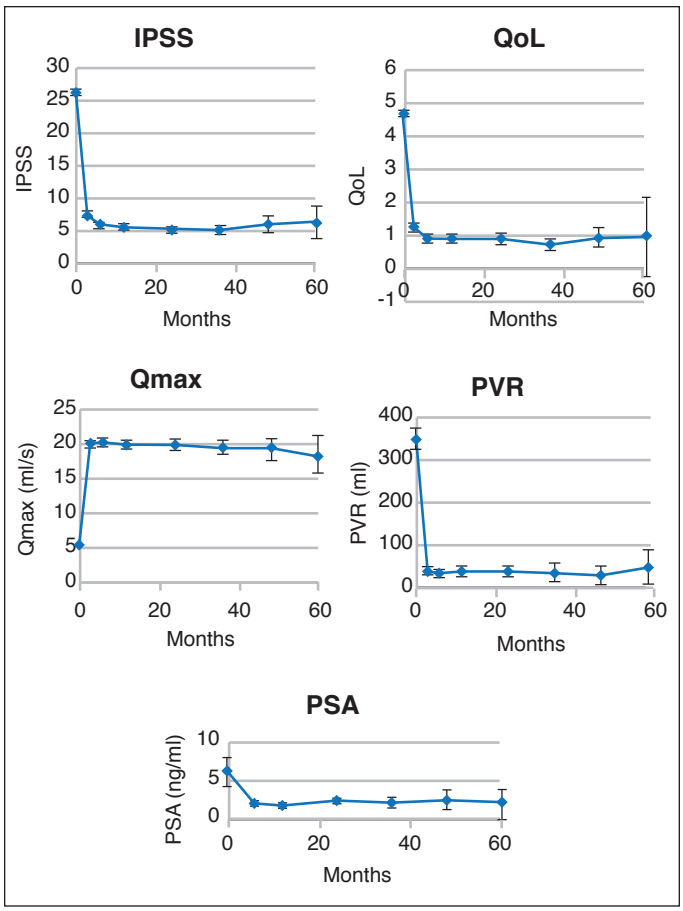

Fig. 1. Functional outcomes. IPSS: International Prostate Symptom Score; PSA: prostate-specific antigen; PVR: post-void residual; Qmax: maximum flow rate; QoL: quality of life.

Table 5. Complications of 180W XPS Greenlight

		Months						
		3	6	12	24	36	48	60
	Number of patients	336	221	189	144	89	42	66
	Number of eligible patients	343	246	200	144	89	45	69
Clavien-Dindo grade								
Minor: I/II								
	OAB (%)	63 (18.8)	29 (13.1)	16 (8.46)	10 (6.9)	7 (7.9)	4 (9.5)	0
	SUI (%)	17 (5.1)	4 (1.8)	6 (3.17)	2 (1.4)	2 (2.2)	2 (4.8)	0
	Dysuria (%)	14 (4.6)	4 (1.8)	3 (1.6)	1 (0.7)	4 (4.5)	0	0
	UTI (%)	8 (2.4)	3 (1.4)	2 (1.1)	0	0	0	0
	Bladder underactivity/retention (%)	5 (1.5)	3 (1.4)	1 (0.5)	4 (2.8)	1 (1.1)	0	0
	Hematuria (%)	6 (1.8)	2 (0.9)	1 0.5)	4 (2.8)	2 (2.2)	0	0
Major: IIIa/IIIb								
	Urethral stricture (%)	0	1 (0.5)	2 (1.1)	0	0	0	0
	Bladder neck contracture (%)	1 (0.3)	1 (0.5)	5 (2.6)	0	0	0	0
	BPH recurrence requiring repeat BPO surgery (%)	0	0	1 (0.5)	1 (0.7)	0	2 (4.8)	0

BPH: bengign prostatic hyperplasia; BPO: benign prostatic obstruction; OAB: overactive bladder; SUI: stress urinay incontinence; UTI: urinary tract infection.

PVR is another parameter used to evaluate functional outcome following benign prostatic obstruction (BPO) surgery. Several components play a role in determining the value of the post-void residue. Such components include the duration of BOO and its effect on the detrusor muscle. Other factors, like prostatic regrowth, urethral strictures, the usage of anticholinergic medications, and age-related detrusor contractibility, influence bladder emptying.[1] In our study, the average PVR at five years was 53.7 mL compared to 345 mL preoperatively. The PVR nadir was reached at four years, with a value of 32.8 mL (90.5% drop). The review of the literature made by Castellan et al revealed that after a three- and six-month followup, the PVR decreased significantly.[17] Tasci et al showed that the PVR, after TURP, improved by 116.6 mL after five years. The mean PVR was 142 at baseline and 25.4 mL at five years.[18]

Moreover, PSA reduction has been established in the holmium laser enucleation of the prostate (HoLEP) literature as a surrogate marker for BPH adenoma removal and, thus, is

Table 6. Literature review of other modalities

Parameter	80W (Guo et al)		120W (Cho et al)		TURP (Tasci et al)		HoLEP (Elmansy et al)	
Number of patients	120		85		3589		949	
	Preoperative	60 months	Preoperative	36 months	Preoperative	120 months	Preoperative	120 months
Mean prostatic volume (cc)	52.3 33–72.6	NA	50 33–67	NA	62.4 50.4–74.4	NA	81	NA
Energy delivery (kJ/cc)	225.8 129.6–332	NA	92.35 16.5–168.2	NA	NA	NA	96.0	NA
OR time (min)	72.7 49.9–95.5	NA	60.3 28.7–92.5	NA	42 30.3–53.3	NA	NA	NA
PSA (ng/ml)	3.5 0.1–7.1	2.2 0.3–4.1	4 0.8–7.2	NA	3.9 3–4.8	2.3 0.4–4.2	4.3	0.69
IPSS	19.4 13.1–25.7	6.6 4.7–8.5	21.7 13.8–29.6	13.4 11–15.8	26 23–29	6.9 2.8– 11	19 0–35	3.6 0–12
QoL	3.7 2–5.4	1.3 0–3.1	4.2 3.0–5.4	2.3 1.6–3	4 3–5	1.8 1.3– 2.3	3.8 0–6	0.7 0–3
Qmax (ml/s)	8.3 2.3–14.3	6.8 2.6–11	8.7 5.6–11.8	13.9 12–14	7.1 4.7–9.5	20 11.5–28.5	8 1.3–20	26.9 6.6–44.5
PVR (ml)	119.5 35.7–203.3	34.5 0–114.5	93.5 2.3–184.7	35.3 15–55	142 131–153	25.4 17.3– 33.5	311 102–500	20.7 0–654
BPH retreatment (%)		10.2		NA		4.4		0.7
Mean followup (months)		12		36		42*		62

BPH: bengign prostatic hyperplasia; IPSS: International Prostate Symptom Score; OR: operating room; PSA: prostate-specific antigen; PVR: post-void residual; Qmax: maximum flow rate; QoL: quality of life.

another useful parameter to assess the success and durability of BPO surgery.[19] In the present study, with 3.7 kJ/cc, the PSA decreased from 6.2 ng/mL to 2.5 ng/mL after five years with a 59.3% drop. In comparison to the Goliath study, the PSA drop for the TURP group was around 57.7% from a preoperative value of 2.6 ng/mL.[6] BPH surgical retreatments was only 1% in our observed cohort.

As per international BPH guidelines, TURP is still the gold standard for surgical management of LUTS secondary to BPH for patients with prostate size <80 cc because of its efficacy and global access. Unfortunately, bleeding and long-term durability are the Achilles heel to this procedure. Reich et al evaluated the outcomes of 10 654 men who underwent TURP and demonstrated that morbidity and mortality increase with the increase in preoperative prostatic size.[5,20]

HoLEP is another well-established laser minimally invasive endo-surgical option for the management of BPH. HoLEP has been demonstrated as a size-independent procedure with incredible long-term durable outcomes.[21] Table 6 compares outcomes for GL 80 W, 120 W, TURP, and HoLEP.[18,22-24]

Complications are part of any surgical procedure. The most commonly reported complication in our study was clinical symptoms of OAB, observed in 63 patients (18.8%) three months after the surgery. One year postoperatively, only 16 patients were still medically treated for OAB, suggesting BOO relief improvement in detrusor hyperactivity. After five years of followup, there were no complications reported. BNC has been observed in 1–12% of patients after PVP or TURP, and as high as in 0.5–17.5% after radical prostatectomies.[25] In our study, a total of seven men (1.9%) developed BNC during followup. Mean prostatic volume in such patients was 72 cc. Most were diagnosed within six months. The other five patients were diagnosed one year postoperatively. During our five-year experience, four (1.1%) patients needed bladder neck resection: one after one year, one at two years, and two at four years**.** Comparatively, the rate of retreatment after TURP was estimated to be 7.6%.[6] In the literature, many studies didn't experience BNC, but those studies only had data for 30 days postoperative.[26] Therefore, BNC is probably a late surgical complication.

Despite its merits, our study has certain limitations that need to be mentioned. Results are obtained from a retrospective analysis of a prospectively maintained database of a single surgeon in a single institution. This is reflected in the loss at follow up at four and five years, with only 42 (88.7% drop) and 66 (82.2 %), respectively. However, the percentage of the patients participating in the study out of the number of eligible patients is 93% and 96% at four and five years, respectively. Despite these limitations, we believe our results indicate that 180 W XPS GL PVP in experienced hands delivering volume-appropriate energy (≥ 3–4 kJ/cc) is a safe, efficient, and durable procedure.[27] This article can be the backbone for counselling men more accurately and precisely before choosing the surgical procedure for small- to medium-sized BPH.

Conclusion

Greenlight PVP can be considered a safe and durable procedure for patients with BPH needing surgical treatment. This study has shown the effectiveness of this procedure that can be maintained for a period of at least five years.

Competing interests: Dr. Misrai has attended advisory boards and received speaker honoraria from for Boston Scientific. Dr. Elterman has attended advisory boards, is a speaker for, and has received grant funding from Allergan, Astellas, Boston Scientifc, Ferring, Medtronic, and Pfizer; and has participated in clinical trials supported by Astellas and Medtronic. Dr. Zorn has received honoraria as a procter/Greenlight lecturer for Boston Scientific; and has participated in clinical trials supported by Procept Biorobotics. The remaining authors report no competing personal or financial interests related to this work.

This paper has been peer-reviewed.

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