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ORIGINAL ARTICLE

Transurethral vaporesection of prostate: diode laser or thulium laser?

Xinji Tan[1,2] · Xiaobo Zhang[1,2,3,4] · Dongjie Li[1] · Xiong Chen[1] · Yuanqing Dai[2] · Jie Gu[1,2] · Mingquan Chen[1,2] · Sheng Hu[1,2] · Yao Bai[1,2,4] · Yu Ning[5]

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Abstract
This study compared the safety and effectiveness of the diode laser and thulium laser during prostate transurethral vaporesection for treating benign prostate hyperplasia (BPH). We retrospectively analyzed 205 patients with BPH who underwent a diode laser or thulium laser technique for prostate transurethral vaporesection from June 2016 to June 2017 and who were followed up for 3 months. Baseline characteristics of the patients, perioperative data, postoperative outcomes, and complications were compared. We also assessed the International Prostate Symptom Score (IPSS), quality of life (QoL), maximum flow rate (Q_{max}), average flow rate (AFR), and postvoid residual volume (PVR) at 1 and 3 months postoperatively to evaluate the functional improvement of each group. There were no significant differences between the diode laser and thulium laser groups related to age, prostate volume, operative time, postoperative hospital stays, hospitalization costs, or perioperative data. The catheterization time was 3.5 ± 0.8 days for the diode laser group and 4.7 ± 1.8 days for the thulium laser group ($p < 0.05$). Each group had dramatic improvements in IPSS, QoL, Q_{max}, AFR, and PVR compared with the preoperative values ($p < 0.05$), although there were no significant differences between the two groups. Use of both diode laser and thulium laser contributes to safe, effective transurethral vaporesection in patients with symptomatic BPH. Diode laser, however, is better than thulium laser for prostate transurethral vaporesection because of its shorter catheterization time. The choice of surgical approach is more important than the choice of laser types during clinical decision making for transurethral laser prostatectomy.

Keywords Benign prostate hyperplasia · Transurethral vaporesection of prostate · Laser surgery · Diode laser · Thulium laser

Introduction

As our society increasingly becomes an aging population, the prevalence of benign prostate hyperplasia (BPH) increases [1, 2]. Currently, transurethral resection of the prostate (TURP) is considered the "gold standard" for BPH surgical management [3]. However, because of its associated bleeding, TUR syndrome, urethral stricture, bladder neck contracture, and the high rate of other complications, the application of TURP has become restricted.

With the development of laser technology in recent years, increasingly more laser types are appearing in BPH treatment areas, including neodymium, thulium, Holmium:YAG, green, and diode laser [4]. Thulium laser and diode laser are new laser types that have attracted widespread attention because of their good ablation and hemostasis results. No studies have compared them, however, which prompted us to conduct a retrospective analysis of the safety and effectiveness of the diode laser and thulium laser during transurethral

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✉ Xiaobo Zhang
xiaobozxb@163.com

1 Xiangya International Medical Center, Xiangya Hospital, Central South University, Changsha 41008, Hunan, China

2 The Department of Geriatric Urology, Xiangya Hospital, Central South University, Changsha, Hunan, China

3 Urolithiasis Institute of Central South University, Xiangya Hospital, Central South University, Changsha, Hunan, China

4 The Department of Urology, Xiangya Hospital, Central South University, Changsha, Hunan, China

5 The Department of Anesthesiology, Xiangya Hospital, Central South University, Changsha, Hunan, China

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vaporesection from June 2016 to June 2017. The study was designed to provide a reference for clinical decision making about these two laser types.

Methods and materials

Patients

We retrospectively reviewed the patients treated by prostate transurethral vaporesection in Xiangya Hospital from June 2016 to June 2017. Surgery was performed when patients had experienced recurrent or refractory urinary retention, overflow incontinence, recurrent urinary tract infection (UTI), bladder stones or diverticula, treatment-resistant macroscopic hematuria due to BPH, dilatation of the upper urinary tract due to bladder outlet obstruction, or when the patients had not obtained adequate relief from lower urinary tract symptoms (LUTS) or postvoid residual volume (PVR) using conservative or medical treatment [5].

The patient's age, body mass index (BMI), American Society of Anesthesiologists classification, PSA, prostatic volume, renal function, history of catheterization or bladder stones, International Prostate Symptom Score (IPSS), quality of life (QoL), PVR, maximum flow rate (Q_{max}), and average flow rate (AFR) were recorded before surgery. The perioperative hemoglobin and electrolyte levels, operation time, catheterization time, postoperative hospital stay, hospitalization costs, postoperative histopathology diagnosis, and complications were recorded during the perioperative period. All patients had been followed up at 1 and 3 months after surgery. Surgical effectiveness was evaluated by the IPSS, QoL, Q_{max}, AFR, and PVR. The Clavien–Dindo classification was used to classify complications.

Surgical management

All patients underwent preoperative assessment and preparation, and all procedures were performed by the same experienced surgeon. The surgical approach in both groups was transurethral vaporesection.

The continuous-wave thulium laser (wavelength 1940 nm) was performed by Vela® XL (Boston Scientific, Ratingen, Germany). The continuous-wave diode laser group (proportional combinational wavelengths of 980 and 1470 nm, matching at 3:1) was performed by Biolitec® HPD (Biolitec, Jena, Germany). Both two lasers were operated at a power of 120 W to vaporize tissue and 60 W to accomplish hemostasis. The energy was delivered via 550 μm end-firing laser fiber (LISA Laser Products, Katlenburg-Lindau, Germany) for thulium laser and via 600 μm end-firing laser fiber (Biolitec) for diode laser (Table 1). The laser irradiation was in contact with prostate tissue for vaporesection and at a distance of 3 mm for hemostasis [6].

All patients received general anesthesia and were operated on lithotomy position. The laser fiber was used combine with a 23 Fr continuous-flow laser cystoscope (Storz Medical, Tuttlingen, Germany). At the beginning, the distal resection border was marked as laser incisions at 5 and 7 o'clock lithotomy positions close to the verumontanum. Then, the median lobe, lateral lobes, and the apical portion were resected in sequence until the prostatic surgical capsule was reached. The prostatic tissue was vaporized or resected into pieces, with the tissue chips small enough to go through the resectoscope sheath without further morcellation. The resected tissue chips were pushed into the bladder and evacuated together when the operation was completed [7, 8]. At the end of the operation, a 20-Fr, three-way silicone urethral catheter was placed and maintained with continuous saline irrigation until resolution of macroscopic hematuria. Both the operation and postoperative bladder irrigation used 0.9% normal saline. All resected prostatic tissue chips underwent histopathological diagnosis after surgery.

Statistical analysis

Results are reported as means ± standard deviation (SD). Student's t test was used to verify the homogeneity and differences of two variables between groups. The variance analysis was used to compare multiple variables between groups. The χ^2 test was used to verify the differences in categorical data between groups. Statistical Package for the Social Science (SPSS Inc., Chicago, IL, USA) version 18.0 software was used for data analysis. Values of $p < 0.05$ were considered to indicate statistical significance.

Results

In all, 205 patients underwent prostate transurethral vaporesection: 80 patients in the diode laser group and 125 in the thulium laser group. There were no significant differences in the population or patients' characteristics of the two groups (Table 2).

There were no significant differences in the operative time, postoperative hospital stays, hospitalization cost, or complications between the two groups. The catheterization time in the diode laser and thulium laser groups were 3.5 ± 0.8 and 4.7 ± 1.8 days, respectively ($p = 0.007$). None of the resected prostate tissues contained cancer cells according to the postoperative histopathology evaluation. The serum Na^+ concentration of diode laser and thulium laser groups in preoperatively (143.6 ± 2.3 vs. 142.2 ± 1.6 mmol/L, $p = 0.02$) and postoperatively (146.7 ± 2.2 vs. 143.4 ± 2.8 mmol/L, $p = 0.002$), respectively, were significantly different. Further analysis, however,

Table 1 Characteristics of diode laser and thulium laser in this study

Characteristic	Diode laser	Thulium laser
Wavelength	1470 nm + 980 nm	1940 nm
Treatment mode	CW	CW
Fiber type	End-firing	End-firing
Fiber diameter	550 µm	600 µm
Cystoscope OD	23 Fr	23 Fr
Work power		
Vaporize	120 W (30 W/1470 nm + 90 W/980 nm)	120 W
Hemostasis	80 (20 W/1470 nm + 60 W/980 nm)	80 W

OD outside diameter, *CW* continuous wave

showed that there was no statistical difference between the two groups regarding the preoperative to postoperative serum Na^+ changes (Table 3).

At the 1- and 3-months postoperative follow-up visits, the IPSS, QoL, Q_{max}, AFR, and PVR in each group had dramatically improved compared with their preoperative assessments ($p < 0.05$) (Fig. 1), but there were no significant differences between the two groups (Table 4).

Discussion

At present, TURP is the "gold standard" surgical treatment of BPH [9]. Because of its favorable vaporization, coagulation, and non-conductive properties, however, laser has become one of the most important techniques in transurethral BPH surgery.

Diode laser is generated by a semiconductor, commonly using wavelengths of 940, 980, and 1470 nm. The 980-nm diode laser produces the maximum combined absorption rate in water and hemoglobin, with a penetration depth of about 0.5 mm [10]. The 1470-nm diode laser has a similar property with 980 nm diode laser, and it has the penetration deep of 2–3 mm [11]. Thulium laser's wavelength is closer to the maximum absorption wavelength of water than that of the diode laser, and when it operates at a wavelength of 2013 nm its penetration depth is about 0.25 mm [12]. Both diode and thulium laser are highly effective, causing less bleeding during the operation, and are associated with a rapid postoperative recovery and fewer complications. These laser techniques can be safely used in patients with a hemorrhagic tendency and are widely used in the surgical treatment of BPH [13–19].

In this study, diode laser had a shorter catheterization time than thulium laser (3.5 ± 0.8 vs. 4.7 ± 1.8 days, $p = 0.007$), but there is no significant difference in pre-postoperative hemoglobin change (− 4.7 ± 11.5 vs. − 4.9 ± 8.4 g/L, $p = 0.94$). Thus, although the amount of bleeding during operations was no different for the two laser types, there was more postoperative bleeding in the thulium laser group than in the diode laser group. This difference may due to the different thermally denatured depth of the two laser types. An operative area's scab falling off caused by movement of the urethral catheter could induce postoperative bleeding. Diode laser's penetration depth in prostate tissue is deeper than that of thulium laser and can generate more stable encrustation, which may mean less postoperative bleeding and a shorter catheterization time.

Lee et al. [15] compared benefits and drawbacks among green laser (PVP), thulium laser (ThuLEP), and diode laser (DiLVP) during BPH treatment. The operation times of the three laser types were significantly different (106.9 ± 39.9 vs. 97.8 ± 39.0 vs. 98.6 ± 31.4 min, respectively, $p < 0.05$). Wang et al. [20] reported a network meta-analysis based on 27 articles reporting on all kinds of laser. It shows that the order for operative time was TURP > TmLRP > DiLEP. For catheterization, the time was DiLEP > TmLRP > PVP. Unfortunately, none of comparisons in either study used the same surgical approach. In addition, Wang et al. study is only a statistical analysis, not a direct clinical trial. In our study, all patients underwent laser vaporesection, with the results showing that

Table 2 Baseline characteristics of patients

	Diode laser	Thulium laser	*p* value
Patients (no.)	80	125	
Age (years)	69.4 ± 8.4	70.6 ± 8.4	0.49
BMI	20.8 ± 2.9	22.8 ± 3.6	0.06
ASA grade (no.)			0.63
II	34 (42.5%)	49 (39.2%)	
III	46 (57.5%)	76 (60.8%)	
Catheterization (no.)	12 (15%)	15 (12%)	0.53
Bladder stone (no.)	10 (12.5%)	23 (18.4%)	0.26
Prostate volume (mL)	43.9 ± 23.2	59.2 ± 35.8	0.16
Cr (µmol/L)	94.8 ± 35.9	89.8 ± 32.5	0.66
BUN (mmol/L)	7.8 ± 4.1	6.2 ± 1.8	0.10

Cr serum creatinine, *BUN* serum urea, *ASA grade* The grade in American Society of Anesthesiologists classification

* Statistically significant

Table 3 Preoperative, intraoperative, and postoperative outcomes of diode laser and thulium laser

	Diode laser	Thulium laser	*p* value
Patients (no.)	80	125	
Operation time (min)	69.4 ± 15.3	73.8 ± 37.8	0.60
Postoperative hospital stays (days)	4.9 ± 1.0	5.6 ± 1.8	0.12
Postoperative catheterization time (days)	3.5 ± 0.8	4.7 ± 1.8	0.007*
Hospitalization costs (¥)	23,351.9 ± 2391.1	23,440.7 ± 2699.8	0.83
Hemoglobin (g/L)			
Pre-	129.6 ± 21.1	134.5 ± 16.6	0.42
Post-	122.0 ± 20.8	127.9 ± 12.2	0.32
Δ	−4.7 ± 11.5	−4.9 ± 8.4	0.94
Serum Na^+ (mmol/L)			
Pre-	143.6 ± 2.3	142.2 ± 1.6	0.02*
Post-	146.7 ± 2.2	143.4 ± 2.8	0.002*
Δ	3.3 ± 3.6	1.1 ± 2.6	0.08
Complications (no.)			0.90
Non-	53 (66.3%)	82 (65.6%)	
I	18 (22.5%)	26 (20.8%)	
II	6 (7.5%)	13 (10.4%)	
III	3 (3.7%)	4 (3.2%)	
IV	0	0	
V	0	0	
Prostate cancer (no.)	0	0	N/A

Pre- preoperative, *Post-* postoperative; *Δ* the change between postoperative and preoperative

* Statistically significant

there was no significant difference in operative time between diode laser and thulium laser (69.4 ± 15.3 vs. 73.8 ± 37.8 min, respectively, $p = 0.60$). Generally, the operation time depends on the laser type, the surgical approach, and the surgical

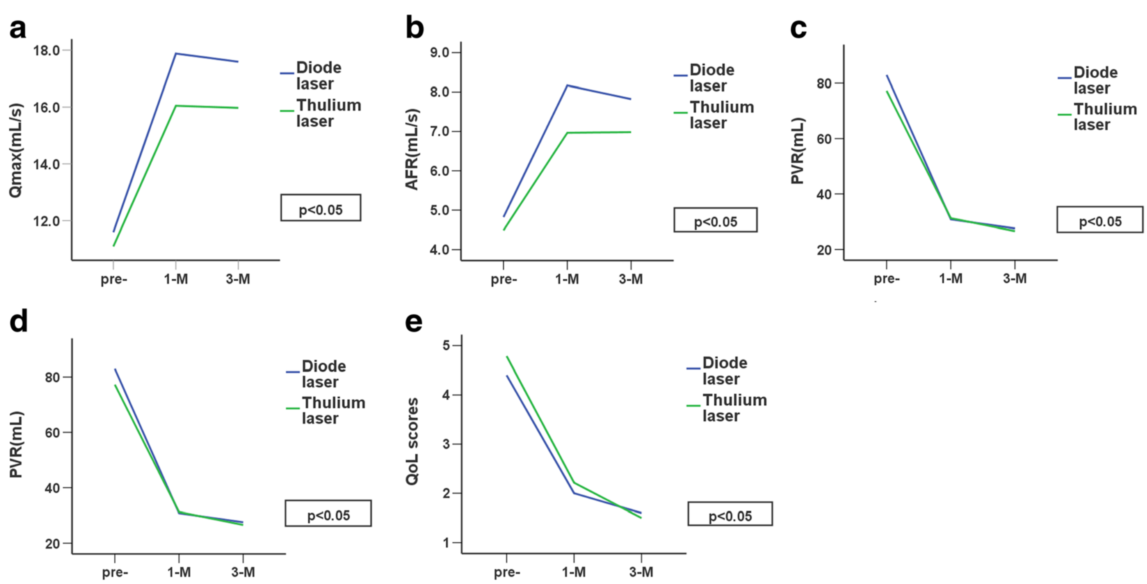

Fig. 1 Both diode laser and thulium laser groups have dramatically improved the International Prostate Symptom Score (IPSS), quality of life (QoL), maximum flow rate (Q_{max}), average flow rate (AFR), and postvoid residual volume (PVR) between the preoperative assessment and that at either the 1-month postoperative follow-up ($p < 0.05$) or the 3-month postoperative follow-up ($p < 0.05$). **a** Q_{max}. **b** AFR. **c** PVR. **d** IPSS. **e** QoL

Table 4 Clinical outcomes at baseline, and at 1 and 3 months of follow-up

Parameter	Date	Diode laser	Thulium laser	*p* value
Q_{max}	Preoperative	11.6 ± 7.0	11.1 ± 5.6	0.84
	1-month	17.4 ± 4.8	16.4 ± 3.8	0.48
	3-month	17.2 ± 4.1	16.4 ± 3.5	0.49
AFR	Preoperative	4.8 ± 3.3	4.5 ± 1.7	0.73
	1-month	8.1 ± 2.6	7.6 ± 2.3	0.53
	3-month	7.9 ± 2.4	7.4 ± 2.0	0.42
PVR	Preoperative	82.9 ± 45.5	77.2 ± 36.9	0.66
	1-month	30.8 ± 10.3	31.2 ± 14.6	0.91
	3-month	27.6 ± 16.8	26.6 ± 12.7	0.83
IPSS scores	Preoperative	21.4 ± 6.0	19.5 ± 6.7	0.57
	1-month	7.3 ± 2.2	7.1 ± 1.5	0.82
	3-month	4.2 ± 0.9	3.8 ± 1.0	0.17
QoL scores	Preoperative	4.4 ± 0.9	4.8 ± 1.0	0.45
	1-month	2.2 ± 0.7	2.4 ± 0.8	0.36
	3-month	1.6 ± 0.5	1.6 ± 0.6	0.66

IPSS International Prostate Symptom Score, *QoL* quality of life, Q_{max} maximum flow rate, *AFR* average flow rate, *PVR* postvoid residual volume

[*] Statistically significant

proficiency of the surgeon. However, we found that when patients undergoing the same surgical approach by the same surgeon, that two types of laser do not obviously influence the operation time.

In our research, most patients with grade I of the Clavien–Dindo classification had postoperative urinary catheter-related symptoms that remained unrelieved until the catheter was removed or nonsteroidal anti-inflammatory drugs were administered. Grade II patients had UTI or LUTS during the follow-up. In the diode laser group, two (2.5%) patients had UTI and four (5%) had LUTS, whereas in the thulium laser group five (4%) had UTI and eight (6.4%) patients had LUTS. There were no significant differences in UTI ($p = 0.56$) nor LUTS ($p = 0.68$) between two groups. All of the UTI were cured with specific antibiotic therapy. Most of the LUTS disappeared after administration of α-blockers and/or antimuscarinic drugs. At the 3-month follow-up, both groups had one (1.3 vs. 0.8%, $p = 0.75$) patient each complaining of LUTS, although it had been dramatically alleviated compared to their preoperative status. Grade III patients had postoperative dysuria. Most of them had urethrostenosis diagnosed by urography or urethrocystoscopy and improved after urethral dilatation. In two (one patient in each group, 1.3 vs. 0.8%, $p = 0.75$) patients, no urethral stricture or bladder neck contracture was revealed by urography or urethrocystoscopy. Because of the patients' medical histories and urodynamic examinations, we believed that the dysuria might have been due to detrusor underactivity caused by long-term urinary retention.

Irritative events may occur early after a laser procedure but generally not after more than 2–4 weeks. In addition, some patients experienced dysuria or urge incontinence, but these symptoms tended to subside within 6–12 months [13, 16]. Laser was able to immediately ablate prostatic tissues, but deeper coagulated tissues might escape vaporization, which could lead to residual necrotic tissue [21]. Kim et al. [13] showed that, in addition to scar healing of the surgical area, bladder neck stricture is also significantly associated with small prostates, which can cause postoperative dysuria. It occurs because of excessive widening of a small prostate during the operation, thereby damaging normal tissue.

Transurethral laser prostatectomy has a better hemostatic effect than TURP, but the missing tissue caused by ablation should also be a concern. The laser vaporesection we used retains more tissue for postoperative histopathological examination than laser vaporization. Nevertheless, compared with laser enucleation or TURP, it still vaporizes a small area of tissue. Nafie et al. [22] claimed that prostate cancer was diagnosed by histopathological examination in about 5–10% of BPH patients after transurethral prostatectomy, although most of these cancers are thought to be clinically insignificant. No prostate cancer was found in our study, nor has histopathological examination produced a high rate of malignancies in our previous clinical experience. Most prostate cancers are present in peripheral zones, and transurethral prostatectomy is executed in the transitional zone [7]. In addition, only a small amount of tissue is vaporized. Finally, prostate cancer is strictly excluded before BPH surgery. Therefore, in our opinion, transurethral laser vaporesection is as safe as TURP in postoperative prostate cancer detection, although further study may be needed to confirm it. To avoid the small risk of not identifying a clinically significant prostate cancer, excluding patients with suspected prostate cancer and choosing a suitable surgical approach, carefully and preoperatively, is extremely important.

As our research has shown, there is no difference in hospitalization costs between the diode laser group and the thulium laser group (23,351.9 ± 2391.1 vs. 23,440.7 ± 2699.8 ¥, $p = 0.83$), although the catheterization time is shorter in the diode laser group by approximately 1–2 days. That may because the cost of such event is low in China because of the short time difference and the small amount of medication used. We, however, failed to collect the cost information for outpatients who required further therapy after hospital discharge. Considering that only a few patients had complications that required treatment, and the lack of differences in complications between the two groups, we concluded that there was no difference in total cost between the two laser groups. Conversely, TURP was more cost-effective than transurethral laser prostatectomy [23], but it also had longer catheterization and hospital times and more severe complications, such as transfusion and transurethral resection syndrome (TURS) [8, 14, 24, 25].

Overall, we think that diode laser is better than thulium laser for transurethral prostatectomy because of the less post-operative bleeding. But the difference between two lasers was realistic limited, especially compared with the variation of different surgical approach. As for clinical decisions about the type of transurethral laser prostatectomy to perform, we believe that it is more important to choose the suitable surgical approach for patients and surgeons, rather than the laser type, because it may allow greater variations in effectiveness, safety, and treatment cost.

We failed to use the IIEF-5 questionnaire during the follow-up. Because the patients in our center are elderly (ages 58–87 years), and almost none participate in coital activity, they could not finish the questionnaire. Most elderly Chinese men are sexually conservative, thinking that the loss of libido and erectile function are natural consequences of aging. Hence, these elders do not consult with a doctor about this embarrassing situation, although it is sometimes morbid and could be treated [26].

Our research was not performed within the framework of a randomized controlled trial. Considering other drawbacks of this study, a further large, extended-duration follow-up in a randomized controlled trial is needed.

Conclusion

Our study compared the differences in safety and effectiveness between diode laser and thulium laser usage in transurethral vaporesection of the prostate. The results showed that both diode laser and thulium laser can effectively relieve LUTS. There were no significant differences in short-term effectiveness, complications, or treatment costs between the two laser techniques. Diode laser is better than thulium laser for prostate transurethral vaporesection because of its shorter catheterization time. In our opinion, the choice of surgical approach is more important than the choice of laser type when making clinical decisions about transurethral laser prostatectomy.

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Compliance with ethical standards

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

Ethical approval For this type of study, formal consent is not required.

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