Endoscopic Vaporesection of the Prostate Using the Continuous-Wave 2-μm Thulium Laser: Outcome and Demonstration of the Surgical Technique

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Abstract

Background: The potential of a new continuous-wave (CW) 70-W, 2.013-μm thulium-doped yttrium aluminium garnet (Tm:YAG) laser for the endoscopic treatment of benign prostatic hyperplasia (BPH) is investigated.

Objective: The simultaneous combination of vaporisation and resection of prostatic tissue in a retrograde fashion is the main characteristic of this new laser technique. We provide a DVD that shows the main steps of this procedure.

Design, setting, and participants: We retrospectively evaluated 56 nonconsecutive patients who were treated by thulium laser vaporesection of the prostate in our institution between 2005 and 2007.

Surgical procedure: Vaporesection of the prostate is performed by moving the fibre semicircumferentially from the verumontanum towards the bladder neck, thereby undermining tissue and cutting chips.

Measurements: Blood loss, postvoiding residual urine (PVRU), maximum flow rate ($Q_{\text{max}}$), and the International Prostate Symptom Score (IPSS) were measured as well as prostate volume and prostate-specific antigen (PSA). The duration of the procedure, need for postoperative irrigation, duration of catheterisation, and hospital stay were recorded.

Results and limitations: The median procedure time was 60 min, postoperative irrigation was necessary in 19 out of 56 patients, and the median duration of catheterisation was 23 hr. At the day of discharge, the mean haemoglobin value decreased by 0.2 mg/dl ($p = 0.13$), the average $Q_{\text{max}}$ improved from 8.1 to 19.3 ml/s ($p < 0.001$), and the PVRU decreased from 152 ml to 57 ml ($p < 0.05$). The blood transfusion rate was 3.6%, and two patients needed a recatheterisation postoperatively (3.6%). After a median follow-up of 9 mo, the IPSS improved from 19.8 at baseline to 8.6 ($p < 0.001$). Four patients had a repeat transurethral resection of the prostate (TURP) during the learning curve, but this was not necessary in any of the later patients. One patient developed a urethral stricture, and another developed a bladder neck contracture.

Conclusions: The thulium laser seems to be a suitable tool for the endoscopic treatment of BPH.

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1. Introduction

The majority of men >60 yr of age are affected by benign prostate hyperplasia (BPH) [1], and according to the European Association of Urology (EAU) guidelines, transurethral resection of the prostate (TURP) and suprapubic prostatectomy are still considered the gold standard for surgical treatment of the lower urinary tract symptoms (LUTS) caused by BPH [2,3]. Over the past decade, different laser systems for transurethral ablation, vaporisation, or enucleation of the prostate have been successfully introduced [4].

Every new laser technology comes with certain advantages, but each also has natural limitations resulting from its individual laser physics. Despite a growing commercial market and increasing patient demand for supposedly modern laser surgery rather than electroresection of the prostate, none of the presently available laser systems has attained unchallenged supremacy so far.

Presently, among the most commonly used lasers in transurethral prostate surgery are variations of the neodymium-doped yttrium aluminium garnet (Nd:YAG) laser [5], the holmium-doped YAG (Ho:YAG) laser [6], and the potassium titanyl phosphate laser (KTP, or “green-light” laser) [7] as well as the high-performance (HPS) version of the KTP laser [4]. These lasers substantially differ in their function, application technique, and tissue absorption as a result of the power, wavelength, type of energy emission (continuous wave versus pulsed wave), and type of ion the laser uses [8]. Which laser system should be used will doubtless depend on various factors, such as the short- and long-term functional outcome, safety of the procedure, complication rate, length of the operation, duration of catheterisation and hospitalisation, and simplicity and cost-effectiveness of the procedure.

We investigated the potential of the new continuous-wave (CW) thulium-doped YAG laser (Tm:YAG; RevoLix, LISA laser products OHG, Katlenburg-Lindau, Germany) for endoscopic treatment of BPH using the vaporesection technique, which consists of a combination of tissue ablation and cutting chips of prostate tissue in a retrograde fashion. The data of 56 patients are presented in this work. Furthermore, we demonstrate the surgical technique and the potential of this procedure in the attached DVD.

2. Methods

The 70-W CW Tm:YAG laser emits a wavelength of 2.013 μm and is highly absorbed by water, which is ubiquitous in any tissue (Fig. 1). Therefore, it is well suited for tissue ablation, while tissue damage is restricted to <1 mm beneath the cut. We used the Tm:YAG laser in combination with a conventional 24F resectoscope using a 12.5° angulate optic (Karl Storz GmbH, Tuttingen, Germany). Intermittent irrigation with physiologic saline solution ensured good visibility. An additional trocar cystostomy for a continuous-flow setup was not necessary. The laser beam was delivered though the laser insert containing a reusable 440-μm core diameter bare-ended quartz fibre, which was in direct contact with the tissue, with slight pressure, at an angle of 30–90°.

The first 56 patients who were treated by thulium laser vaporesection in our institution are reported in this retrospective case-control study. Two endourologically experienced surgeons performed the operations between April 2005 and October 2007. Only patients who provided oral and written informed consent to be treated by this investigative laser surgery technique with unknown long-term results were included in this study; however, the majority of patients with bladder outlet obstruction (BOO) resulting from BPH were treated by classic TURP.

Fig. 1 – Wavelength and water absorption coefficient of the 2.013-μm Tm:YAG laser compared with the Ho:YAG, Nd:YAG, and CO2 lasers (courtesy of LISA laser products, Germany).

Tm:YAG = thulium-doped yttrium aluminium garnet; Ho:YAG = holmium-doped yttrium aluminium garnet; Nd:YAG = neodymium-doped yttrium aluminium garnet.

Inclusion criteria consisted of a symptomatic BPH with a maximum flow rate (Q_{max}) <15 ml/s and an International Prostate Symptom Score (IPSS) >7. We also included patients with elevated prostate-specific antigen (PSA) levels, a transrectal adenomas volume exceeding 100 ml, and prior urinary retention with the presence of an indwelling catheter. No age limit was set. Patients with a neurogenic bladder and any urethral, bladder neck, or prostatic surgery were excluded. Patients <75 yr with an abnormal finding on digital rectal examination (DRE) and/or PSA levels >4 ng/ml were subjected to a preoperative prostate biopsy. Oral anticoagulant medication was interrupted preoperatively. Before treatment, the patients provided a complete medical history and underwent a physical examination, including DRE, transrectal ultrasound (TRUS) of the prostate, urine analysis, PSA measurement, blood chemistry studies, and postvoiding residual urine (PVR) as well as Q_{max} measurements. We used the postoperative
The term vaporesecion describes the simultaneous vaporisation and resection of prostate tissue. Gas bubbles indicate high vaporisation activity. The surgeon can control the degree of vaporisation by the speed of the laser beam movement through the tissue as well as by applying the laser beam more tangentially to the tissue. As demonstrated in the video, the cutting of tissue can be accomplished almost completely without bleeding.

The surgical technique is similar to other resection procedures. After an initial incision at 5 o’clock and 7 o’clock at the bladder neck, the vaporesection of the median lobe is initiated. The fibre is moved semicircumferentially from the verumontanum so that the external sphincter can be preserved in the best way. Vaporesection of the lateral lobes is continued until the proximity of the surgical prostatic capsule is reached. Because of the good haemostatic properties of the thulium laser, even heavy arterial bleeding can be handled easily. The use of normal saline for irrigation excludes the risk of a transurethral resection (TUR) syndrome.

At the end of the procedure, the resected tissue chips are removed, and a 20F triple-lumen catheter is inserted into the prostate; PCa = prostate cancer.

It is important to cut small pieces that do not exceed the size of the inner sheath diameter so that the pieces of tissue can be washed out without morcellation at the end of the procedure. After resecting the middle lobe of the prostate, the lateral lobes are removed in a retrograde fashion beginning at the verumontanum so that the external sphincter can be preserved in the best way. Vaporesection of the lateral lobes is continued until the proximity of the surgical prostatic capsule is reached. Because of the good haemostatic properties of the thulium laser, even heavy arterial bleeding can be handled easily. The use of normal saline for irrigation excludes the risk of a transurethral resection (TUR) syndrome.

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the bladder. The balloon is inflated within the bladder according to the estimated sum of resected plus vaporised adenoma tissue.

3. Results

A total of 56 patients suffering from BPH were treated by Tm:YAG laser vaporesection in our department between April 2005 and October 2007. Baseline characteristics and perioperative results are summarised in Table 1. Postoperative and follow-up data are summarised in Table 2.

3.1. Histopathology

A maximum incision depth of 3 mm was obtained using the maximum power of 70 W and a cutting velocity of about 2 mm/s. The resected tissue chips were small enough to be retrieved without morcellation. Although the tissue is carbonised when cut, the very thin coagulation rim of necrotic tissue did not interfere with an adequate histologic analysis (Fig. 2). An experienced pathologist of the institution evaluated all resected material. Histologically, the incision was surrounded by a 150-μm-thick layer of coagulated and vacuolised tissue, which is again surrounded by a denatured layer of approximately 800-μm thickness. The tissue damage next to the incision at the surface of the hematoxylin-eosin–stained sections was therefore <1 mm.

In three patients aged 87, 70, and 84 yr, respectively, with PSA values of 33.0, 9.4, and 1.6 ng/ml, respectively, an incidental prostate cancer (PCa) was detected (5.3% detection rate); in one patient, an incidental urothelial carcinoma pTa G1 was diagnosed.

3.2. Blood loss

The haemostatic properties of the laser are obvious at first sight and evident from our data and the video. Two out of three of our patients did not need continuous irrigation postoperatively. The average decrease in haemoglobin between the day of admission and the day of discharge was 0.2 mg/dl (p = 0.133). Two of 56 patients received intraoperatively a blood transfusion; however, both of these patients had a preoperative haemoglobin value <10.0 mg/dl resulting from an underlying haemato-ma-oncologic condition, and the postoperative haemoglobin values remained stable >10 mg/dl in both of these patients.

3.3. Functional results

In most patients, the Q_{max} immediately after catheter removal was excellent and improved from 8.1 ml/s ± 4.4 (2.6–15.0) to 19.3 ml/s ± 7.9 (6.3–56.6) (p < 0.001), respectively, to 21.9 ± 7.9 (6.3–56.6) (p < 0.001), respectively, for the 39 patients who were not in urinary retention preoperatively. For the remaining 17 patients who were in urinary retention preoperatively, the Q_{max} after catheter removal was 13.9 ml/s ± 7.8 (6.3–24.8).

No sloughing of necrotic tissue was reported. The mean improvement of the IPSS score was 11.2 points after a median follow-up of 9 mo. The average PSA decreased from 5.7 ng/ml ± 7.5 (0.3–35.8) to 2.5 ng/ml ± 2.9 (0.3–12.4) in 28 patients after a median follow-up of 9 mo (p = 0.016).

3.4. Complications

No intraoperative complications occurred. Postoperatively, two patients needed a temporary reinserion of a catheter; however, both of these patients had a history of urinary retention prior to surgery. Because of insufficient tissue removal, 4 patients needed a repeat TURP during the learning curve (first 20 patients), but this was not necessary in any of the last 36 patients. One patient developed a urethral stricture after 3 mo; another patient developed a bladder neck contracture 5 mo post-operatively.

4. Discussion

TURP may still be considered the gold standard surgical BPH therapy, but it is also associated with an overall immediate morbidity of 11.1% [9,10]. In a large multicentre prospective study, the most sig-
significant complications of TURP were a blood transfusion rate of 2.0–9.5%, failure to void (5.8%), surgical revision (5.6%), and TUR syndrome (1.4%) [9]. An increasingly ageing population leads to a patient group for TURP with rising comorbidities and a higher risk of bleeding, necessitating new surgical treatments that meet this challenge.

As a possible answer to these developments, various laser systems are being promoted as alternatives to TURP. At the same time, minimally invasive techniques like transurethral needle ablation (TUNA) or transurethral microwave thermotherapy (TUMT) may be attractive because of low perioperative complication rates [11,12], but there is clear evidence that the outcomes are more sustainable for truly ablative and thus deobstructing procedures [13].

Laser surgery in general, and the use of the Tm:YAG laser for the endoscopic treatment of BPH in particular, constitutes a truly ablative procedure that has the advantage of less blood loss even for patients receiving anticoagulants. Because of saline irrigation, there is no risk of a TUR syndrome. The thulium laser works with a standard domestic 16-A power supply and without external water cooling. When compared to the quite popular KTP laser, the main advantage of the thulium laser is the retrieval of tissue for histology and a higher cost-effectiveness resulting from lower acquisition costs and the repeated use of the laser fibres.

Although holmium enucleation of the prostate (HoLEP) carries the risk of superficial bladder mucosal injuries and ureteral ostia injuries [14], these complications seem better avoidable with the thulium laser, because the vaporesection technique does not require tissue morcellation within the bladder at the end of the procedure. At the same time, thulium vaporesection is a user-friendly TURP-like technique requiring less expertise and a shorter learning curve than HoLEP [15]. The limitation of thulium laser vaporesection is a longer operation time compared to electroresection and a loss of 50–66 % of tissue for histologic evaluation because of vaporisation [8,17]. Furthermore, large prostatic adenomas (>100 ml) may be more conveniently transurethrally operated by the HoLEP method, although there is one small study showing that the thulium laser may also be an effective energy source for enucleating the prostate quite comparably to HoLEP [16].

The re-TURP rate of 7.1 % in our series is higher than generally reported for other laser systems [13,17] or TURP (5.6%) [9]. We explain this high percentage by a statistical overemphasising of the learning curve in this small series of 56 patients because no reoperation was necessary in the last 36 patients.

<p>| Table 3 – Summary of the pros and cons for thulium laser vaporesection, holmium enucleation of the prostate, and potassium-titanyl-phosphate laser vaporisation based on a comparison of our own data and current literature |
|---------------------------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th><strong>Thulium laser</strong> vaporesection</th>
<th><strong>HoLEP</strong></th>
<th><strong>KTP laser</strong> vaporisation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acquisition costs</strong></td>
<td>~100 000€</td>
<td>~120 000€</td>
</tr>
<tr>
<td><strong>Costs per patient (fibre costs)</strong></td>
<td>Reusable fibre, ~20€</td>
<td>Reusable fibre, ~20€</td>
</tr>
<tr>
<td><strong>Learning curve</strong></td>
<td>Short, TURP-like technique</td>
<td>Rather longer than for TURP</td>
</tr>
<tr>
<td><strong>Speed of tissue ablation (g/min)</strong></td>
<td>0.3–0.9</td>
<td>0.2–0.5</td>
</tr>
<tr>
<td><strong>Tissue ablation</strong></td>
<td>56–70%</td>
<td>30–85%</td>
</tr>
<tr>
<td><strong>Ideal adenoma size</strong></td>
<td>Small to medium</td>
<td>Size independent</td>
</tr>
<tr>
<td><strong>Histologic evaluation</strong></td>
<td>33–50% of tissue suitable for evaluation</td>
<td>90–95% of tissue retrieval for histology</td>
</tr>
<tr>
<td><strong>Versatility</strong></td>
<td>Very smooth precision cutting of various tissues, multimodal tool</td>
<td>Usable for laser lithotripsy, multimodal tool</td>
</tr>
<tr>
<td><strong>Intraoperative complications</strong></td>
<td>No significant complications reported</td>
<td>Bladder injuries after morcellation reported</td>
</tr>
<tr>
<td><strong>Postoperative decrease in haemoglobin</strong></td>
<td>14–6.6%</td>
<td>8.9–9.6%</td>
</tr>
<tr>
<td><strong>Postoperative decrease of PSA after 6–9 mo</strong></td>
<td>56%</td>
<td>80–85%</td>
</tr>
</tbody>
</table>

HoLEP = holmium enucleation of the prostate; KTP = potassium-titanyl-phosphate; PSA = prostate-specific antigen; TURP = transurethral resection of the prostate.
A summary of the pros and cons for thulium laser vaporesection, HoLEP, and KTP laser vaporisation based on a comparison of our own data and current literature [4,8,17,20,22–27] is presented in Table 3.

On the Austrian market, the acquisition costs for the thulium laser equipment are about 100 000€, and the fibres cost about 450€ each. In contrast to some other laser systems, however, the bare-ended quartz fibres of the thulium laser can be reused many times, which leads to almost negligible running costs. Furthermore, some lasers such as the KTP laser are BPH lasers only, whereas others such as the holmium or thulium laser have a variety of additional indications. The thulium laser in particular can also be used for other applications requiring precision cutting, such as bladder-neck contractures, urethral and ureteral strictures, and possibly lithotripsy [18] and laparoscopic partial nephrectomy (LPN), as demonstrated in animal studies [19].

With rising health care expenses throughout Europe, the cost-effectiveness and versatility of a tool is an important factor when it comes to making decisions about the routine implementation of new technology. Thus, vaporesection using the thulium laser represents a safe and effective alternative surgical approach for the treatment of BPH with a low morbidity, a mean catheterisation time of <2 d, and, therefore, a short hospital stay. Furthermore, the postoperative voiding parameters are very satisfying, with a 150% increase in Q_max and an improvement of 11.2 points on the IPSS after a median follow-up of 9 mo. Our findings are well in line with the results of a prospective randomised study reporting a series with 52 thulium laser resections in China that was recently published by this journal [20]. The authors compared the thulium laser vaporesection with standard TURP for symptomatic BPH in a total of 100 consecutive patients with a follow up of 12 mo, and they also reported minimal blood loss, 1–3 d of catheterisation, with significantly improved IPSS scores and Q_max as well as a comparably low complication rate in both groups [20].

As already mentioned, functional outcomes seem to be more sustainable for truly ablative procedures [13]. The ablative effect of the thulium laser vaporesection can be documented either by TRUS measurement of pre- and postoperative prostate volume (Fig. 3 and Fig. 4) or by a pronounced decrease in the tissue marker PSA, which we used as a surrogate parameter for prostate tissue volume reduction (Table 3). The comparison of prostate volume reduction with the resected tissue weight indicates a resection to vaporisation ratio between 1:1 and 1:2, which is in line with the observations of others [8,20,21]. A high tissue vaporisation rate is achieved by moving the laser fibre rather fast and directing it tangentially to the tissue surface [5,8,21].

Although these initial results are promising, further prospective investigations and preferably multicentre, large-scale studies including the measurement of postoperative prostate volume and PSA are needed to assess long-term outcomes and to make comparisons to currently available technologies possible.
5. Conclusions

This initial study shows that the 2-μm Tm:YAG laser is a tool that seems to be suited to the endoscopic treatment of small and medium-sized BPH. The vaporesection technique is user-friendly, has a low complication rate, offers excellent haemostasis, provides tissue for histologic analysis, and has promising functional results. Prospective, randomised, comparative studies with long-term results are needed to underline these data.

Author contributions: Roman Szlauer had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Schmeller, Götschl.

Acquisition of data: Schmeller, Szlauer, Razmaria.

Analysis and interpretation of data: Szlauer, Razmaria, Paras.

Drafting of the manuscript: Szlauer.

Critical revision of the manuscript for important intellectual content: Schmeller, Szlauer, Razmaria, Paras.

Statistical analysis: Szlauer, Schmeller, Razmaria, Paras.

Obtaining funding: None.

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Supervision: Schmeller.

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Appendix A. Supplementary data


References


