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TOPIC PAPER

Thulium:YAG 2 μm cw laser prostatectomy: where do we stand?

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Abstract
Introduction Tm:YAG 2 μm cw laser prostatectomy was introduced in the treatment of benign ptostatic obstruction (BPO). Since then numerous studies have been published proving efficacy during follow-up. However, different surgical techniques were introduced with different names for similar techniques that complicate comparison. This reviews aim was to compare published data and break down surgical techniques to core points. The authors define validate appellations for different surgical techniques and propose further use of these names to ensure homogenous nomenclature.
Materials and methods All publications on Thulium:YAG prostatectomy have been included in this review. Articles were reviewed and associated due to the nature of the surgical approach. A systematic review of published data was performed.
Results Sixteen peer-reviewed publications dealing with Tm:YAG laser prostatectomy were printed since 2005. Four different surgical principles are described, including vaporization, resection and enucleation. Follow-up, up to 24 months, showed durable functional results.
Conclusion Efficacy of Tm:YAG prostatectomy was shown. Surgical techniques include "Tm:YAG Vaporization of the prostate (ThuVAP)", "Tm:YAG VapoResection of the prostate (ThuVaRP)" and "Tm:YAG VapoEnucleation of the prostate (ThuVEP)". The almost blunt enucleation is introduced as "Tm:YAG laser enucleation of the prostate (ThuLEP)". The authors recommend the use of this neologism in the future. Further, large-scale prospective studies are needed to prove long-term durability. To initiate and canalize these upcoming studies, the Urothulium Study Group© was founded, combining international experts on Thulium:YAG laser prostatectomy under its roof.

Keywords Tm:YAG prostate · Thulium (laser) prostate · Thulium laser BPH · Thulium laser prostatectomy · Revolix · 2 μm continuous wave laser

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Introduction

In 2005, Xia et al. [1] published the initial report on Thulium:YAG (Tm:YAG) 2 μm continuous wave (cw) laser prostatectomy, using a 50-Watt Tm:YAG laser. Xia described the technique of Thulium Laser Resection of the prostate-tangerine technique (TmLRP-TT). In 2007, the first report on Tm:YAG laser prostatectomy using the technique of VapoResection with a 70-Watt Tm:YAG laser was

published by Bach et al. [2]. Even these first two publications indicate the dilemma of an innovative technique developing in different parts of the world. With different study groups, modifications of surgical techniques receive different nomenclature, which creates not only confusion, but also hinders comparability. Since then a fair number of cohort studies and one randomized controlled trial have been published proving feasibility and efficacy in an intermediate-term follow-up. Intend of this review paper was to compare the data published so far and crack down the different surgical techniques to their technical core. By this, the authors aim to define valid appellations for the different surgical techniques and propose further use of these nomenclature to ensure comparability of the different publications.

Materials and methods

A Web-based Medline research was conducted to identify peer-reviewed publications dealing with Tm:YAG 2 μm continuous wave laser prostatectomy. Search keywords included Tm:YAG prostate, Thulium (laser) prostate, Thulium laser BPH, Thulium laser prostatectomy, Revolix, 2 μm continuous wave laser. Published articles have been reviewed and combined due to the nature of the surgical approach. An analysis of the published functional data has been performed to identify surgical efficacy, durability and the risk for complications.

Results and discussion

A total of 16 peer-reviewed publications have been identified using Medline search. The first publication using a 50-Watt Tm:YAG laser prostatectomy was found in 2005 [1], followed by the first publication using a 70-Watt laser system in 2007 [2] and increasing numbers of publications in the following years [2008: $n = 4$; 2009: $n = 8$; Feb. 2010: $n = 2$]. Within these publications, two technical papers [3, 4], two experimental publications [5, 6] and 12 publications on clinical data, describing three different surgical approaches, were published [1, 2, 7–16]. The varieties of surgical techniques are ranging from pure vaporization to resection and enucleation techniques.

Vaporization

To date, two ex vivo publications and one clinical paper report data on vaporization efficacy using the Tm:YAG 2 μm cw laser. Wendt-Nordahl et al. report their experience with the 70-Watt Tm:YAG laser in an ex vivo porcine kidney model. Wendt-Nordahl was able to show increasing tissue ablation rate with increasing power, being superior to the established 80-Watt KTP laser in terms of tissue ablation. Furthermore, bleeding rate was comparable to the KTP laser, but considerably lower than in monopolar TUR-P [5]. A second publication analyzing Tm:YAG laser within the ex vivo blood perfused porcine kidney was published by Bach et al. [6] comparing ablation rate, bleeding rate and depth of tissue necrosis with the newly introduced 120-Watt device. Again, the authors were able to show increased tissue ablation with increasing power output. In contrast to increased bleeding rates with the 120-Watt LBO laser in the same model [17], the bleeding rate remained stable, independently released power. In addition, the authors demonstrate shallow penetration and energy-independent zone of tissue necrosis of 0.4 mm [6].

So far, one publication reports clinical data of pure vaporization of the prostate. Mattioli et al. [9] report their data on 99 patients with small prostates (<35 cc), showing clinically efficient vaporization in this groups of patients. Large-scale prospective studies, comparing the vaporization efficacy of the Tm:YAG laser with previously established devices are pending at the present time. The authors suggest the use of the term "Tm:YAG Vaporization of the prostate (ThuVaP)" to describe the above-mentioned technique.

Resection

The majority of the clinical publications deal with the efficacy of Thulium:YAG VapoResection of the prostate. The term "VapoResection" was introduced to point out the physical characteristics of the 2 μm continuous wave (cw) Tm:YAG laser system [2]. Having the well-known shallow penetration and excellent hemostasis like the previously introduced Ho:YAG laser, the type of energy emission in a cw mode leads to significantly increased vaporization capacity. Therefore, tissue ablation is not only achieved by resection of TUR-like tissue chips, but also by simultaneous vaporization. Consequently, the combination of two types of tissue reduction leads to higher tissue ablation rates per time interval [2]. A modification of the technique was described by Xia et al. and is called the tangerine technique. Instead of cutting out small tissue chips by moving the fiber in a semicircular fashion, Xia combines semicircular and transverse incisions and creates prostate segments in a tangerine-like shape. By the combination of vaporization and resection, Xia [3, 8] conducts efficient deobstruction within a reasonable time interval.

One randomized controlled [8] and one non-randomized controlled trial [15] compare Tm:YAG VapoResection with monopolar TUR-P, showing equieffective clinical outcome with reduced morbidity in the Tm:YAG group. In particular, the Tm:YAG laser group showed reduced bleeding with lower transfusion rates and shorter catheter and hospitalization times [8, 15].

Table 1 Overview on Thulium:YAG prostatectomy publications

	PreOP	postOP	1–3 m	6 m	9 m	12 m	16–18 m
Xia et al. 2005 [1]	ThuVaRP						
Patients (*n*)	30	NA	30	NA	NA	NA	NA
IPSS (points)	19	NA	7,1	NA	NA	NA	NA
QoL (points)	NA	NA	NA	NA	NA	NA	NA
Qmax (ml/s)	8	NA	24,7	NA	NA	NA	NA
PVR (ml)	NA	NA	NA	NA	NA	NA	NA
Bach et al. 2007, 2009 [2, 12]	ThuVaRP						
Patients (*n*)	54	54	NA	NA	NA	NA	NA
IPSS (points)	19.8	10.1	NA	NA	NA	6.9	6.5
QoL (points)	4	2.5	NA	NA	NA	1	1
Qmax (ml/s)	8.1 i	18.4	NA	NA	NA	20.1	20.9
PVR (ml)	86	23	NA	NA	NA	12	
Fu et al. 2008 [7]	ThuVaRP						
Patients (*n*)	72	72	69	67	NA	63	NA
IPSS (points)	24.6 ± 4.5 [21; 32]	NA	12.0 ± 3.7 [3; 16]	9.6 ± 2.6 [2; 18]	NA	6.8 ± 1.2 [1; 15]	NA
QoL (points)	4.8 ± 0.2 [4; 5)	NA	2.0 ± 0.6 [0; 4]	2.0 ± 1.1 [0, 4]	NA	1.4 ± 0.3 [0; 3]	NA
Qmax (ml/s)	5.7 ± 1.2 [2.3; 14.8)	NA	14.0 ± 1.5 [9.5; 35.6]	18.5 ± 3.2 [12; 39.2]	NA	20.8 ± 2.1 [16; 40.2]	NA
PVR (ml)	105 ± 2.6 [86; 540]	NA	65 ± 32 [0; 165]	49 ± 16 [0, 118]	NA	36 ± 12 [0; 62]	NA
Xia et al. 2008 [8]	ThuVaRP						
Patients (*n*)	52	52	NA	NA	NA	NA	NA
IPSS (points)	21.9 ± 6.7 [12; 35]	NA	6.8 ± 3.6 [0; 15]	4.0 ± 2.4 [0; 9]	NA	3.5 ± 2.9 [0; 12]	NA
QoL (points)	4.7 ± 0.9 [3; 6]	NA	1.6 ± 1.4 [0; 5]	1.1 ± 1.1 [0; 4]	NA	1.0 ± 0.9 [0; 3]	NA
Qmax (ml/s)	8.0 ± 2.8 [3.2; 14]	NA	23.8 ± 8.6 [6.4; 45.3]	24.5 ± 9.2 [7.8; 48.7]	NA	23.7 ± 6.0 [10.3; 40.4]	NA
PVR (ml)	93.1 ± 32.1 [30; 150]	NA	9.7 ± 9.1 [0; 40]	7.1 ± 6.6 [0; 35]	NA	5.2 ± 4.8 [0; 27]	NA
pDet max	85.9 ± 29.3 [44; 138.3]	NA		NA	NA	38.1 ± 17.5 [20.4; 95.5]	NA
Schäfer grade	3.8 ± 1.1 [2; 6]	NA		NA	NA	0.71 ± 0.67 [0; 2]	NA
Szlauer et al. 2009 [10]	ThuVaRP						
Patients (*n*)	56	NA	NA	NA	NA	NA	NA

Table 1 continued

	PreOP	postOP	1–3 m	6 m	9 m	12 m	16–18 m
TRUS	50.0 ± 28.8 [7.4; 123.0]	NA	NA	NA	NA	NA	NA
IPSS (points)	19.8 ± 5.4 [8; 31]	NA	NA	NA	8.6 ± 6.5 [1; 25]	NA	NA
QoL (points)	4.1 ± 0.9 [2; 6]	NA	NA	NA	1.4 ± 1.2 [0; 6]	NA	NA
Qmax (ml/s)	8.1 ± 4.4 [2.6; 15.0] j	21.9 ± 11.3 [8.8; 56.6] j	NA	NA	NA	NA	NA
PVR (ml)	151.6 ± 219.7 [0; 1,000]	57 ± 46.1 [0; 180]	NA	NA	NA	NA	NA
Mattioli et al. 2009 [9]	ThuVaP ThuVaRP						
Patients (*n*)	99; 101	NA	NA	NA	NA	NA	NA
IPSS (points)	21.5	7.8	7.5	NA	6.9	NA	NA
QoL (points)	NA	NA	NA	NA	NA	NA	NA
Qmax (ml/s)	[0; 7.8]	21.2	21.6	NA	22.6	NA	NA
PVR (ml)	112.7	14.6	12.8	NA	12.5	NA	NA
Bach et al. 2009, 2010 [13, 16]	ThuVEP						
Patients (*n*)	88	88	NA	NA	NA	NA	62
IPSS (points)	18.4 ± 7 [6; 35]	NA	NA	NA	NA	NA	6.8 ± 3.96 [0; 18]
QoL (points)	4.6 ± 1.1 [2; 6]	NA	NA	NA	NA	NA	1.45 ± 1.12 [0; 5]
Qmax (ml/s)	3.5 ± 4.7 [0; 14]	19.8 ± 11.6 [5.4; 47.5]	NA	NA	NA	NA	23.26 ± 10.33 [6.6; 47.9]
PVR (ml)	121.4 ± 339.9 [0; 2,500]	22.4 ± 32.7 [0; 250]	NA	NA	NA	NA	33.49 ± 47.01 [0; 200]
Bach et al. 2009 [14]	ThuVaRP ThuVEP						
Patients (*n*)	208	208	NA	NA	NA	NA	NA
IPSS (points)	20.65 (6–35)	NA	NA	NA	NA	NA	NA
QoL (points)	4.64 (2–6)	NA	NA	NA	NA	NA	NA
Qmax (ml/s)	7.8 (0–14)	19, 26	NA	NA	NA	NA	NA
PVR (ml)	158 (80–700)	22, 41	NA	NA	NA	NA	NA
Fu et al. 2009 [15]	ThuVaRP						
Patients (*n*)	58	NA	56	55	NA	52	NA
IPSS (points)	22.6 ± 4.5	NA	6.5 ± 1.6	4.0 ± 1.3	NA	3.3 ± 1.1	NA
QoL (points)	4.8 ± 0.6	NA	1.2 ± 0.9	1.1 ± 0.4	NA	1.1 ± 0.8	NA
Qmax (ml/s)	6.5 ± 1.8	NA	16.4 ± 1.6	20.2 ± 1.8	NA	21.4 ± 2.1	NA
PVR (ml)	197.4 ± 23.6	NA	26.3 ± 4.7	22.4 ± 4.3	NA	30.9 ± 1.5	NA

Table 2 Systematic review of the published studies

Systemic review (*n*:818 patients)	Mean (range)
IPSS reduction (points)	14.2 (11.2–18.4)
QoL improvement (points)	3.2 (2.7–3.7)
Catheter time (days)	1.5 (0–7)
Qmax improvement (ml/s)	14.5 (11.2–19.8)
PVR reduction (%)	82.8 (62.4–94.4)
Complications	
Transfusion (%)	0.8
Transient re-catherisation (%)	2.6
UTI (%)	8.2
Re-treatment (%)	2.6

In addition, Xia et al. [8] could demonstrate on the basis of computer urodynamic data that besides the symptomatic relief objective reduction of BOO could be registered.

To point out the unique physical characteristics of the 2 μm cw Tm:YAG laser, the authors propose the use of the term "Tm:YAG VapoResection of the prostate (ThuVaRP)" for any resection-based treatment modality with this laser.

Enucleation

To identify the efficacy of the Tm:YAG laser prostatectomy in patients with larger prostates, the technique of VapoEnucleation was introduced [13]. Again, the attachment "Vapo" describes the physical characteristics of this type of laser, which have direct influence on the surgical performance. The prostatic tissue is enucleated in a three-lobe technique (median lobe, lateral lobes) as described in HoLEP, but again, the vaporizing capacities of the Tm:YAG laser improve the tissue ablation by concurred vaporization. This effect causes smooth tissue incisions, which allow the surgeon to remove the adenoma at the layer of the surgical capsule. The clinical efficacy was reported by Bach et al. proving efficient tissue reduction and consistent improvement on the clinical symptoms within a follow-up interval exceeding 12 months. Shao et al. [11] report their prospectively collected results of Tm:YAG vs. Ho:YAG enucleation of the prostate, showing reduced blood loss in the Tm:YAG group with equieffective deobstruction within a short follow-up interval.

Therefore, the authors propose the term "Tm:YAG VapoEnucleation of the prostate (ThuVEP)" for this types of Tm:YAG laser-based prostatectomy.

Recently a modification of the VapoEnucleation was published by Herrmann et al. [4]. Unlike VapoEnucleation and HoLEP, ThuLEP employs the Tm:YAG laser for apical incision of the prostatic tissue down to the surgical capsule. In the following, the adenoma is enucleated bluntly with the sheath of the resectoscope, like using the index finger in open simple prostatectomy, and the laser is utilized for pinpointed coagulation of crossing vessels. Prostate specific antigen (PSA) reduction of 82% indicates efficient tissue removal. However, clinical data is lacking at this point of time.

Systematic review of the clinical outcome

To date, 11 clinical papers report analyzable data on Tm:YAG 2 μm cw laser prostatectomy in a total of 818 patients (Table 1). The longest follow-up published so far includes up to 24 months after surgery, with an average follow-up interval of 16 month. Summing up the clinical data, published so far, Thulium:YAG cw laser prostatectomy shows efficient relieve of obstructive symptoms, with durable improvement in voiding function (Table 2). When analyzing Table 2, it has to be kept in mind that the reported data is summing up different studies, with different follow-up intervals. Therefore, it has to be considered as systematic review and is not a meta-analysis. However, it provides relevant information on functional results after Tm:YAG prostatectomy.

Conclusion

Feasibility and efficacy of Tm:YAG prostatectomy have been shown by various publications. The surgical techniques can be broken down to pure "Tm:YAG Vaporization of the prostate (**ThuVaP**)", to resection-based techniques, which should be concentrated under the name

Table 3 Proposed nomenclature

	Basic principle	Consensus nomenclature
Vaporisation	Destruction	Tm:YAG Vaporisation of the prostate (**ThuVaP**)
TmLRP-TT/ VapoResection	Resection into small tissue chips, to be washed out through the sheath	Tm:YAG VapoResection of the prostae (**ThuVaRP**)
VapoEnucleation	Enucleation in combination with vaporisation of the median and the lateral lobes	Tm:YAG VapoEnucleation of the prostate (**ThuVEP**)
ThuLEP	Blunt enucleation with laser support	Tm:YAG laser enucleation of the prostate (**ThuLEP**)

of "Tm:YAG VapoResection of the prostate (**ThuVaRP**)" and enucleating techniques, proposed as "Tm:YAG VapoEnucleation of the prostate (**ThuVEP**)", due to the physical nature of this type of laser.

The blunt enucleation technique, introduced as "Tm:YAG laser enucleation of the prostate (**ThuLEP**)" has unique character so far. The authors recommend using this neologism for further studies with this technique. The authors suggest the use of the proposed technical terms to achieve standardized nomenclature (Table 3).

Although the published results are more than promising, Thulium:YAG laser surgery of the prostate has to take the challenge of previously introduced laser systems like HoLEP or KTP/LBO Vaporization [18]. Due to the long time-interval, that both systems are on the market, the number of studies, the evidence level reached by this studies and the number of patients treated exceed the Tm:YAG experience. Large-scale, prospective, randomized studies are necessary to prove these promising results.

To initiate and canalize these upcoming studies, the Urothulium Study Group© has been founded, including international experts on Thulium:YAG laser prostatectomy under its roof.

Conflict of interest statement There is no conflict of interest.

References

1. Xia SJ, Zhang YN, Lu J, Sun XW, Zhang J, Zhu YV, Li WG (2005) Thulium laser resection of prostate-tangerine technique in the treatment of benign prostatic hyperplasia. Zhonghua Yi Xue Za Zhi 85:3225–3228
2. Bach T, Herrmann TRW, Ganzer R, Burchardt M, Gross AJ (2007) RevoLix vaporesection of the prostate: initial results of 54 patients with a one-year follow-up. World J Urol 25:257–262
3. Xia SJ (2009) Two-micron (thulium) laser resection of the prostate-tangerine technique: a new method for BPH treatment. AJA 11:277–281
4. Herrmann TR, Bach T, Imkamp F, Georgiou A, Burchardt M, Oelke M, Gross AJ (2010) Thulium laser enucleation of the prostate (ThuLEP): transurethral anatomical prostatectomy with laser support. Introduction of a novel technique for the treatment of benign prostatic obstruction. World J Urol 28:45–51
5. Wendt-Nordahl G, Huckele S, Honeck P, Alken P, Knoll T, Michel MS, Haecker A (2008) Systemic evaluation of recently introduced 2-µm continuous-wave thulium laser for vaporesection of the prostate. J Endourol 22:1041–1045
6. Bach T, Huck N, Wezel F, Haecker A, Gross AJ, Michel MS (2009) 70 vs. 120 W thulium:yttrium-aluminium-garnet 2 µm continuous-wave laser for the treatment of benign prostatic hyperplasia: a systemic ex-vivo evaluation. BJU Int (Nov 13 [Epub ahead of print])
7. Fu WJ, Hong BF, Yang Y, Zhang X, Gao JP, Zhang L, Wang XX (2008) Vaporesection for managing benign prostatic hyperplasia using a 2-µm continuous—wave laser: a prospective trial with 1-year follow-up. BJU Int 103:352–356
8. Xia SJ, Zhuo J, Sun XW, Han BM, Shao Y, Zhang YN (2008) Thulium laser versus standard transurethral resection of the prostate: a randomized prospective trial. Eur Urol 53:382–389
9. Mattioli S, Munoz R, Recasens R, Berbegal C, Cortada J, Urmeneta JM, Teichmann H (2008) Treatment of benign prostatic hypertrophy with the Revolix laser. Arch Esp Urol 61:1037–1043
10. Szlauer R, Götschl R, Razmaria A, Paras L, Schmeller NT (2009) Endoscopic vaporesection of the prostate using the continuous-wave 2-µm thulium laser: outcome and demonstration of the surgical technique. Eur Urol 55:368–375
11. Shao Q, Zhang FB, Shang DH, Tian Y (2009) Comparison of holmium and thulium laser in transurethral enucleation of the prostate. Zhonghua Nan Ke Xue 15:346–349
12. Bach T, Herrmann TRW, Ganzer R, Blana A, Burchardt M, Gross AJ (2009) Thulum:YAG vaporesection of the prostate. First results. Urologe 48:529–534
13. Bach T, Wendt-Nordahl G, Michel MS, Herrmann TRW, Gross AJ (2009) Feasibility and efficacy of Thulium:YAG laser enucleation (VapoEnucleation) of the prostate. World J Urol 27:541–545
14. Bach T, Herrmann TRW, Haecker A, Michel MS, Gross AJ (2009) Thulium:yttrium-aluminium-garnet laser prostatectomy in men with refractory urinary retention. BJU Int 104:361–364
15. Fu WJ, Zhang X, Yang Y, Hong BF, Gao JP, Cai W, Zhang P, Wang XX (2009) Comparison of 2-µm continuous wave laser vaporesection of the prostate and transurethral resection of the prostate: a prospective nonrandomized trial with 1-year follow-up. Urology 75:194–199
16. Bach T, Netsch C, Haecker A, Michel MS, Herrmann TRW, Gross AJ (2010) Thulium:YAG laser enucleation (VapoEnucleation) of the prostate: safety and durability during intermediate-term follow-up. World J Urol 28:39–43
17. Heinrich E, Wendt-Nordahl G, Honeck P, Alken P, Knoll T, Michel MS, Haecker A (2010) 120 W lithium triborate laser for photoselective vaporization of the prostate: comparison with 80 W potassium-titanyl-phosphate laser in an ex-vivo model. J Endourol 24:75–79
18. Naspro R, Bachmann A, Gilling P, Kuntz R, Madersbacher S, Montorsi F, Reich O, Stief C, Vavassori I (2009) A review of the recent evidence (2006–2008) for 532-nm photoselective laser vaporisation and holmium laser enucleation of the prostate. Eur Urol 55(6):1345–1357