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Guidelines

EAU Guidelines on Laser Technologies

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Abstract

Context: The European Association of Urology (EAU) Guidelines Office has set up a guideline working panel to analyse the scientific evidence published in the world literature on lasers in urologic practice.

Objective: Review the physical background and physiologic and technical aspects of the use of lasers in urology, as well as current clinical results from these new and evolving technologies, together with recommendations for the application of lasers in urology. The primary objective of this structured presentation of the current evidence base in this area is to assist clinicians in making informed choices regarding the use of lasers in their practice.

Evidence acquisition: Structured literature searches using an expert consultant were designed for each section of this document. Searches were carried out in the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, and Medline and Embase on the Dialog/DataStar platform. The controlled terminology of the respective databases was used, and both Medical Subject Headings and Emtree were analysed for relevant entry terms. One Cochrane review was identified.

Evidence synthesis: Depending on the date of publication, the evidence for different laser treatments is heterogeneous. The available evidence allows treatments to be classified as safe alternatives for the treatment of bladder outlet obstruction in different clinical scenarios, such as refractory urinary retention, anticoagulation, and antiplatelet medication. Laser treatment for bladder cancer should only be used in a clinical trial setting or for patients who are not suitable for conventional treatment due to comorbidities or other complications. For the treatment of urinary stones and retrograde endoureterotomy, lasers provide a standard tool to augment the endourologic procedure.

Conclusions: In benign prostatic obstruction (BPO), laser vaporisation, resection, or enucleation are alternative treatment options. The standard treatment for BPO remains transurethral resection of the prostate for small to moderate size prostates and open prostatectomy for large prostates. Laser energy is an optimal treatment method for disintegrating urinary stones. The use of lasers to treat bladder tumours and in laparoscopy remains investigational.

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1. Introduction

This document presents a synthesis of the European Association of Urology (EAU) guidelines on laser technologies published in 2011 [1]. The aim of this document is to supplement the information included in other EAU organ-specific guidelines, with a focus on technical considerations.

The application of lasers in treating urologic disorders has gained widespread clinical acceptance in multiple surgical indications, such as stones, benign prostatic obstruction (BPO), benign prostatic enlargement (BPE), bladder cancer, kidney cancer, urothelial tumours, strictures, and so on. In some therapeutic areas, lasers have become the primary method of treatment. This document addresses bladder outlet obstruction (BOO), BPE, bladder cancer, laser-assisted nephrectomy, laparoscopic nerve-sparing radical nephrectomy (LNSRP), renal tumours, ureteral stricture, ureteropelvic junction (UPJ) obstruction, upper urinary tract stones, and tumours.

These clinical guidelines present the best evidence available to the Guideline Working Panel, but particularly in the field of lasers, where technological advances are so rapid, many technologies are quickly superseded and not available for long-term study. The primary objective of this structured presentation of the current evidence base in this area is to assist clinicians in making informed choices regarding the use of lasers in their practice. However, although the aim is to help with decision making, simply following guideline recommendations can never replace clinical expertise in making treatment decisions. The individual circumstances and the personal values and preferences of both the physician and the patient are integral aspects of the process. This makes it difficult to establish an evidence-based discussion of the topic and also means these guidelines will need reevaluating and updating within a short time.

The acronym LASER stands for “light amplification by stimulated emission of radiation.” Laser radiation is simply directed light with a narrow bandwidth. This is synonymous with a single colour and applies to all regions of the invisible and visible electromagnetic spectrum [2].

2. Methodology

Structured searches were carried out in the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, and Medline and Embase on the Dialog/DataStar platform. The search strategies covered the last 25 yr for Medline and for Embase (since 1974). A separate literature search for cost effectiveness was carried out and yielded seven unique publications. Papers were assigned a level of evidence (LE), and recommendations were graded (grade of recommendation [GR]) following the system currently used by the EAU Guidelines Office.

3. Laser-based treatments for bladder outlet obstruction and benign prostatic enlargement

BOO and BPE can be treated with a range of different laser systems and applications. Laser treatment is regarded as an

alternative to transurethral resection of the prostate (TURP). The different systems produce different qualitative and quantitative effects in tissue, such as coagulation, vaporisation, or resection and enucleation via incision. The goal is to achieve similar efficacy parameters, with the same improvements in symptoms and quality of life but with less morbidity and shorter hospitalisation times in comparison with TURP [2].

4. Contemporary laser systems

Following the first generation of laser-based treatments for BOO and BPE, four groups of laser systems are currently used:

- Potassium titanyl phosphate (KTP):neodymium (Nd):yttrium-aluminium-garnet (YAG) (second harmonic generation [SHG]) and LBO (lithium borate):Nd:YAG (SHG) lasers
- Diode lasers (various)
- Holmium (Ho):YAG lasers
- Thulium (Tm):YAG lasers.

All of these contemporary (and historical) laser systems for the treatment of BOO and BPE use a physiologic sodium 0.9% solution for irrigation. This eliminates the risk of hypotonic hypervolaemic TURP syndrome, which has been reported in 1.4% of patients in large TURP series [3].

It should be noted that the term *green light laser* should be avoided when discussing lasers in this setting because “green light” refers to a particular feature of a group of lasers (eg, both KTP photoselective vaporisation of the prostate [PVP] and lithium borate [LBO] PVP emit green light).

4.1. Potassium titanyl phosphate lasers and lithium borate lasers

4.1.1. Urodynamic results and symptom reduction (Table 1)

In 1998, Malek et al. [4] showed that PVP using a 60-W KTP laser was both feasible and safe. Since then, most laser therapy trials up to 2010 have used 80-W KTP lasers. There are only limited data on the higher powered 120-W LBO laser. Almost 10 yr after the clinical introduction of 532-nm lasers, two randomised controlled trials (RCTs) were published that compared 80-W KTP with TURP with follow-up periods of up to 12 mo [5,6].

One RCT showed equivalent results to TURP [4] after 1 yr of follow-up; another nonrandomised two-centre study reported equivocal results [7]. In contrast, a second RCT clearly showed that TURP resulted in greater urodynamic improvement (maximum flow rate [Q_{max}]) than the KTP PVP [6]. Another study comparing KTP PVP with open prostatectomy (OP) showed equivalence in Q_{max} improvement, postvoid residual (PVR), and symptom score reduction after an 18-mo follow-up period [8]. KTP PVP laser was associated with a higher retreatment rate in larger prostates >80 ml in comparison with prostates <80 ml after a 12-mo follow-up [9].

An RCT that compared PVP using LBO lasers with TURP showed no significant differences between the two groups

Table 1 – Photoselective vaporisation of the prostate using potassium titanyl phosphate or lithium borate lasers: improvement in urodynamic parameters, symptom score, and prostate-specific antigen reduction

Study	Laser source, technique	Follow-up, mo	Patients, n	Mean prostate size, ml	PSA reduction, %	Change in symptoms, %	Change in Q_{max} , ml/s (%)	PVR change, %	LE
Bouchier-Hayes et al. [5]	KTP PVP	12	38	42.4	NA	49.83	+12.1 (167)	81.63	1b
	TURP		38	33.2	NA	50.23	+9.2 (149)	68.90	
Horasanli et al. [6]	KTP PVP	6	39	86.1	31.8	30.68	+5.8 (157)	87.05	1b
	TURP		37	88	44.6	68.31	+13.8 (225)	73.98	
Tasci et al. [7]	KTP PVP	24	40	108.4	56.8	82.66	+13.5 (307.7)	83.69	2a
	TURP		41	104.2	78.7	83.33	+12.8 (306.4)	84.91	
Skolarikos [8]	KTP PVP	18	65	93	61.2	50	+7.4 (186)	84.53	1b
	OP		60	96	68.2	59.52	+7.0 (187.5)	86.51	
Al-Ansari et al. [10]	LBO	36	60	61.8	38.4	60.29	+9.6 (239)	78.9	1b
	TURP		60	60.3	62.5	65.9	+13.6 (312.5)	80.2	

PSA = prostate-specific antigen; Q_{max} = maximum flow rate; PVR = postvoid residual; LE = level of evidence; KTP = potassium titanyl phosphate laser; KTP PVP = KTP photoselective vaporisation; NA = not applicable; TURP = transurethral resection of the prostate; OP = open prostatectomy; LBO = lithium borate laser.

after a 36-mo follow-up, with equivalence in Q_{max} improvement, PVR, and symptom score reduction, but it showed higher retreatment rates [10]. Retreatment rates of 13–23.1% are reported in patients with high-volume prostates [11]. In addition, prospective nonrandomised trials have demonstrated the safety and efficiency of LBO PVP in patients receiving ongoing oral anticoagulation [12] and in patients with retention or with prostates >80 ml [9].

In studies comparing the KTP PVP laser with TURP, the operating time (OT) with KTP PVP was significantly longer in prostates >80 ml, by 30–50 min [7]. This difference drops to 9 min using LBO for PVP (120 W) [7,10].

4.1.2. Safety and intraoperative complications

Several studies have proven the intraoperative safety of PVP with KTP and LBO lasers, including prospective studies [13] and RCTs, in comparison with TURP [6,14] or OP [8]. Safety has also been demonstrated in subgroup analyses of patients with large prostates and patients receiving anticoagulant therapy or in retention [15].

An RCT comparing 80-W KTP PVP with TURP demonstrated significantly less blood loss with KTP PVP (0.45 g/dl) versus TURP (1.46 g/dl; $p < 0.005$ [5]). Another RCT of 80-W KTP PVP in comparison with TURP supported these findings, with a blood transfusion rate of 8.1% for TURP [6]. In an RCT comparing LBO PVP with OP, the transfusion rate was 0% following KTP PVP but 13.3% for OP [8]. A total of 7.7% of patients in the KTP group required intraoperative conversion to TURP to control bleeding, most probably due to capsule perforation [8]. A study comparing LBO PVP with TURP reported a blood transfusion rate of 20%, a capsule perforation rate of 16.7%, and a TURP syndrome of 5% in the TURP treatment arm; however, none of these complications were reported for LBO PVP [10].

4.1.3. Late complications and durability of results

The longest follow-up period in an RCT evaluating the longevity and long-term morbidity of KTP and LBO was in a study comparing LBO PVP with TURP, with a follow-up period of 36 mo [10]. A longer follow-up of 60 mo was reported in a nonrandomised study [16]. Retreatment with PVP due to recurrent adenoma occurred in 7.7% of

246 patients; 3 patients (1.2%) underwent incision of the bladder neck, resulting in an overall retreatment rate of 8.9% [16].

In an RCT with a 6-mo follow-up, 8.1% of the patients in the TURP group and 5.1% of those in the KTP PVP group underwent internal urethrotomy in response to a urethral stricture. Reintervention was required in 17.9% of patients treated with KTP PVP because coagulated tissue was significantly obstructing the bladder outlet. Retrograde ejaculation rates were similar in the two groups (56.7% TURP and 49.9% KTP PVP) [6]. A study comparing LBO PVP with TURP reported a significantly lower retreatment rate of 1.8% for LBO PVP versus 11% for TURP. Bladder neck contractures were incised in 3.6% and 7.4% of patients, respectively [10].

There is evidence from RCTs that persistent urinary stress incontinence is rare. Incontinence varies from 1.4% for KTP PVP [17] to 0.7% for LBO PVP [18].

There are few published data on sexual function following PVP. After a 24-mo follow-up, overall sexual function in men undergoing KTP PVP was maintained. In those with an International Index of Erectile Function 5 score >19, the preoperative median value was significantly decreased from 22 to 16.7 ($p < 0.05$) [19]. In an RCT of LBO PVP compared with TURP, none of the 82 patients in the follow-up of 36 mo presented with erectile dysfunction, and there was a similar rate of retrograde ejaculation (PVP 49.9% versus TURP 56.7%; $p = 0.21$) [6]. Another study, comparing KTP PVP and OP, reported no change in erectile function postoperatively [8]. In a case series of PVP, erectile function remained stable or improved in patients with mild or mild to moderate erectile dysfunction [20].

4.1.4. Conclusions and recommendations for the use of KTP and LBO lasers

Conclusions	LE
In patients with small to moderate-sized prostates, TURP remains the standard of care.	1a
KTP PVP and LBO PVP are safe and effective in the treatment of BOO and BPE in patients with a small or medium prostate gland.	1b

Over a follow-up of 3–5 years, re-treatment rates appear comparable to those with TURP.	1b (at 3 yr) 4 (at 5 yr)
KTP PVP and LBO PVP are safe and effective for patients receiving anticoagulation medication or patients in retention.	4 (case series)
Recommendations	GR
KTP/LBO PVP is a treatment alternative for patients with BOO and BPE for small and medium glands.	A
KTP/LBO PVP can be offered as an alternative to TURP for patients with refractory urinary retention.	B
KTP / LBO PVP can be offered to patients using anticoagulant medication.	B
KTP / LBO PVP is a safe method for volume reduction in large size prostate glands.	A

4.2. Diode lasers

Laser radiation is generated by either a resonator or a diode. Radiation emitted by a diode may have different properties due to the different wavelengths used. The main advantages of diode lasers in comparison with Nd:YAG lasers are a smaller box size and a much higher wall-plug efficiency (ie, how much of the mains supply is converted into laser power). To date, only a few studies have investigated the clinical applications of diode lasers, and the maximum follow-up is 1 yr.

4.2.1. Urodynamic parameters, symptom score reduction, prostate-specific antigen reduction (Table 2)

Clinical data are limited to short-term follow-up (maximum follow-up: 1 yr) and comprise prospective cohort studies [21–23] and nonrandomised controlled trials (non-RCTs) [24,25]. Two trials compared the outcome of diode laser vaporisation with LBO PVP (24,25). The most substantial data are for the 980-nm diode laser.

At the end of the follow-up period, there was a significant improvement in urodynamic parameters (Q_{max} , PVR). The prostate-specific antigen (PSA) level, as a surrogate parameter marker for a reduction in prostatic tissue, showed a reduction in the range of 30% [22] to 58% [21]. However, an RCT, as well as a non-RCT, did not show significant differences in improved urodynamic parameters or symptom score reduction [24,25].

Prostate diode laser vaporisation appears to carry a high rate of late complications. In a case series, 32.1% of patients needed a repeat operation within a follow-up period of 12 mo after 980-nm diode treatment, due to obstructive necrotic tissue or bladder neck stricture [26]. This finding is supported by an RCT that compared the 980-nm diode laser with LBO: 9.6% versus 3.6%, respectively, of patients required a repeat operation with TURP because of bladder neck obstruction, 5.5% versus 0% developed urethral strictures, and 1.8% versus 0% developed urethral stone formation [24]. Another study, comparing diode lasers with LBO PVP, found higher rates of bladder neck stricture (14.5% versus 1.6%; $p < 0.01$), higher retreatment rates (18.2% versus 1.6%; $p < 0.01$), and persistence of stress urinary incontinence (9.1% versus 0%; $p < 0.05$) [25]. However, other reports showed only transient combined urge and stress incontinence in 4.3% of patients for 2 wk [22].

4.2.2. Practical considerations

The available data on diode laser vaporisation show that it is not a standard treatment option for BPE. The literature reports a retreatment rate of up to 35%. Transitory or permanent incontinence appears to be higher than for alternative treatments. However, this treatment may provide good intraoperative control of bleeding for patients receiving anticoagulant drugs [25].

4.2.3. Recommendation for prostate treatment with diode lasers

Recommendation	LE	GR
In patients presenting with BOO and BPE and who have bleeding disorders or are receiving anticoagulants, diode laser treatment is an alternative.	1b	C

4.3. Holmium (Ho:YAG) laser

In holmium laser enucleation of the prostate (HoLEP), bubbles of steam separate tissue layers by tearing the tissue apart [27]. In soft tissue surgery, tissue vaporisation is dominated by the way in which the bubbles of steam tear tissue and laser radiation is absorbed in tissue. This explains the white fibrous appearance of surgical sites during holmium laser surgery on soft tissue under irrigation. The

Table 2 – Results of diode lasers with regard to improvement of urodynamic parameters, symptom score, and prostate-specific antigen reduction

Study	Laser source (power, W)	Follow-up, mo	Patients, n	Mean prostate size, ml	PSA reduction, %	Change in symptoms, %	Change in Q_{max} , ml/s (%)	PVR change, %	LE
Chen et al. [21]	980 (200/150)	6	55	66.3	–58.82	–75.62	13.7 (349.01)	–87.74	3b
Erol et al. [22]	980 (132/80)	6	47	51.4	–30.31	–54.99	9.4 (205.97)	–58.11	3b
Ruszat et al. [25]	980 (NA)	6	55	64.7	–58.13	–75.93	5.1 (147.66)	–85.55	3b
Chiang et al. [24]	LBO PVP	12	65	67.4	–45	–57.89	11.3 (191)	–80.64	1b
	980 (200)		55	66.3	–42.19	–84.26	14 (425.58)	–86.37	
	LBO PVP		84	60.3	–58.82	–83.08	11.2 (303.64)	–85.40	

PSA = prostate-specific antigen; Q_{max} = maximum flow rate; PVR = postvoid residual; LE = level of evidence; NA = not applicable; LBO PVP = lithium borate photoselective vaporisation.

Table 3 – Results of HoLAP, HoLRP, and HoLEP with regard to improvement in urodynamic parameters, symptom score, and prostate-specific antigen reduction

Study	Laser source/ technique	Follow-up, mo	Patients, n	Mean prostate size, ml	PSA reduction, %	Change in symptoms, %	Change in Q _{max} , ml/s (%)	PVR change, %	LE
Mottet et al. [28]	HoLAP	12	23	39	NA	–70	11.1 (226)	NA	1b
	TURP		13	34	NA	–80	9.6 (229)	NA	
Elmansi et al. [29]	HoLAP	36	46	33.1	–0.40	–71	11 (264)	–0.81	1b
	KTP		42	37.3	–0.28	–64	12.10 (289)	–0.80	
Westenberg et al. [31]	HoLRP	48	61	44.3	NA	–76	13.6 (253)	NA	1b
	TURP		59	44.6	NA	–75	9.4 (203)	NA	
Kuntz et al. [34]	HoLEP	18	60	114.6	NA	–90	23.60 (721)	–97	1b
	TURP		100	113	NA	–90	24.40 (778)	–98	
Kuntz et al. [35]	HoLEP	12	60	53.5	NA	–92	23 (569)	–98	1b
	TURP		100	49.9	NA	–82	21.80 (469)	–88	
Briganti et al. [36]	HoLEP	24	60	73.30	NA	–83	NA	NA	1b
	TURP		60	58.20	NA	–83	NA	NA	
Gupta et al. [37]	HoLEP	12	18	57.9	NA	–78	19.20 (527)	–83	1b
	TURP		16	59.8	NA	–76	19.95 (487)	–77	
Naspro et al. [38]	HoLEP	24	41	113.27	NA	–61	11.36 (245)	NA	1b
	TURP		39	124.21	NA	–63	11.79 (242)	NA	
Wilson et al. [39]	HoLEP	24	31	77.8	NA	–77	12.6 (250)	NA	1b
	TURP		30	77.0	NA	–78	11.0 (233)	NA	
Montorsi et al. [40]	HoLEP	12	52	70.3	NA	–81	16.9 (306)	NA	1b
	TURP		48	56.2	NA	–82	17.20 (326)	NA	
Gilling et al. [41]	HoLEP	72	71	58.5	NA	–67	10.9 (235)	NA	3a
Kuntz et al. [42]	HoLEP	60	60	114.6	NA	–86	20.5 (639)	–96	1b
	OP		60	113	NA	–86	20.8 (678)	–98	

PSA = prostate-specific antigen; Q_{max} = maximum flow rate; PVR = postvoid residual; LE = level of evidence; HoLAP = holmium laser vaporisation (ablation) of the prostate; NA = not applicable; TURP = transurethral resection of the prostate; KTP = potassium titanyl phosphate; HoLRP = holmium laser resection of the prostate; HoLEP = holmium laser enucleation of the prostate; OP = open prostatectomy.

tissue effect is rapid and results in excellent haemostasis. Table 3 provides a comparison of results obtained with holmium laser therapy, OP, and TURP.

4.3.1. Holmium laser vaporisation (ablation) of the prostate

There are few published data on holmium laser vaporisation (ablation) of the prostate (HoLAP) treatment. A single RCT compared 60-W and 80-W HoLAP versus TURP in 36 patients [28]. Q_{max} improvement was equivocal at 3, 6, and 12 mo following surgery; prostate volume was reduced by 39% (HoLAP) and 47% (TURP), respectively. However, there are no RCTs for the new high-power 100-W HoLAP versus TURP or OP. One RCT comparing 100-W HoLAP with KTP PVP reported results from short- and intermediate-term follow-up periods. Anticoagulant medication was being taken by 12.2% of patients treated with HoLAP and 15.3% treated with KTP PVP. No difference was found except for OT, which was 1.5-fold longer than with KTP [29].

4.3.2. Holmium laser resection of the prostate

In contrast to HoLAP vaporisation, the holmium laser resection of the prostate (HoLRP) procedure uses vaporisation to cut small pieces out of the prostate. This results in multiple small prostate chips falling into the bladder before they are removed with a syringe at the end of the operation, similar to TURP. The HoLRP technique is limited to small to medium size prostates [30,31].

4.3.3. Holmium laser enucleation of the prostate

Holmium laser enucleation of the prostate (HoLEP) is based on the same physical principle as HoLRP. The introduction

of HoLEP was an important technical improvement. The entire lobes are enucleated, moved into the bladder and morcellated [32], or fragmented with the transurethral resection (TUR) sling at the bladder neck (mushroom technique) [33].

A meta-analysis observed a trend towards an improved symptom score with HoLEP during the entire follow-up period of up to 30 mo, with larger mean changes in postoperative measurements. However, differences between individual studies were not statistically significant (weighted mean difference: –0.82; 95% confidence interval [CI], –1.76 to 0.12; $p = 0.09$), with a similar result for Q_{max} at 12 mo of follow-up. In comparison with TURP, significantly higher Q_{max} rates were reported for HoLEP (weighted mean difference: 1.48 ml/s; 95% CI, 0.58–2.40; $p = 0.002$) [43].

In another meta-analysis, HoLEP resulted in a better catheterisation time (pooled estimates) in comparison with TURP (17.7–31.0 versus 43.4–57.8 h; $p < 0.001$) and a shorter hospital stay (27.6–59.0 versus 48.3–85.5 d; $p = 0.001$). In contrast, TURP resulted in a shorter operation time (pooled estimates of the difference) (33.1–73.8 versus 62.1–94.6 h; $p = 0.001$) [44].

In recent years, many studies have been published regarding the intermediate- and long-term outcomes with HoLEP alone or in comparison with TURP. Gilling et al. [41] reported long-term data with a mean follow-up of 6.1 yr (range: 4.1–8.1 yr) showing that HoLEP results are durable and most patients remain satisfied. In prostates >100 ml, HoLEP was as effective as OP in improving micturition, with equally low reoperation rates at the 5-yr follow-up.

Table 4 – Results of ThuVAP, ThuVARP, and ThuVEP for improvement in urodynamic parameters

Study	Laser source/technique	Follow-up, mo	Patients, n	Mean prostate size, ml	PSA reduction, %	Change in symptoms, %	Change in Q _{max} , ml/s (%)	PVR change, %	LE
Mattioli et al. [47]	ThuVAP	12	99	45 [*]	NA	–67 [*]	14.8 (289) [*]	–88.9 [*]	4
Xia et al. [48]	ThuVARP	12	52	59.2	NA	–84	15.7 (296)	–94.4	1b
	TURP		48	55.1	NA	–81	15.8 (290)	–92.8	
Fu et al. [49]	ThuVARP	12	58	49.8	NA	–85.4	14.9 (329)	–84.3	2b
	TURP		42	48.2	NA	–81.1	15.5 (312)	–84.8	
Bach et al. [52,53]	ThuVARP	18	54	30.3	NA	–67	12.8 (258)	–86	2b
Shao et al. [54]	ThuVEP	6	52	40.3	–40.8	–70	14.9 (350)	–80	1b
	HoLEP		46	37.3	–35.7	–60	15.5 (330)	–80	
Bach et al. [50]	ThuVEP	18	88	61.3	NA	–63	15.7 (664)	–72.4	2b
Bach et al. [55]	ThuVEP	12	90	108.59	–88	–79.7	18.7 (326)	–90.8	–

PSA = prostate-specific antigen; Q_{max} = maximum flow rate; PVR = postvoid residual; LE = level of evidence; ThuVAP = thulium laser vaporisation of the prostate; NA = not applicable; ThuVARP = Tm:YAG vaporesction; TURP = transurethral resection of the prostate; ThuVEP = Tm:YAG vapoenucleation; HoLEP = holmium laser enucleation of the prostate.

^{*} For both groups.

4.3.4. Recommendations for holmium (Ho:YAG) laser treatment

Recommendations	LE	GR
HoLAP can be offered to patients with BOO or BPE with small to medium-sized prostates.	1b	A
HoLRP can be offered to patients with BOO or BPE with small to medium-sized glands.	1b	A
HoLEP can be offered to any patient with BOO and BPE.	1a	A
HoLEP can be offered to patients in chronic urinary retention.	2b	B
HoLEP can be offered to patients on anticoagulant or antiplatelet medication.	2b	B

4.4. Thulium (Tm:YAG) laser

Laser radiation is emitted at a wavelength of about 2013 nm in a continuous-wave fashion [45]. A thulium laser has absorption characteristics comparable with those of a holmium laser in water and tissue, but due to the continuous-wave output it allows better tissue vaporisation. However, it does not allow lithotripsy.

Four different technical approaches have been described so far [46]:

- Tm:YAG vaporisation of the prostate (ThuVAP)
- Tm:YAG vaporesction (ThuVARP)
- Tm:YAG vapoenucleation (ThuVEP)
- Tm:YAG laser enucleation of the prostate (ThuLEP).

One retrospective cohort study reported safe treatment with ThuVAP/ThuVARP in patients receiving anticoagulant drugs [47].

4.4.1. Thulium laser vaporesction of the prostate

ThuVARP is a technique in which the prostate is resected in TUR-like tissue chips. One RCT [48] and one non-RCT [49] compared ThuVARP with monopolar TURP. The two procedures showed similar clinical outcomes and improvement in urodynamic parameters, with reduced morbidity. These data are supported by other prospective cohort

studies [50,51] (Table 4). The Tm:YAG-treated patient group showed reduced bleeding, with lower transfusion rates and shorter catheter and hospitalisation times, in comparison with the TURP-treated patient group [48,49].

4.4.2. Thulium laser vapoenucleation of the prostate

The development of Tm:YAG prostate surgery has been very similar to that of Ho:YAG surgery. ThuVEP was introduced in 2008 for patients with larger prostates [56].

The clinical efficacy of ThuVEP versus HoLEP was studied in one prospective RCT [54] and three prospective non-RCTs [46,50,55,56], as well as for different clinical scenarios in high-risk patients [57] and retention [51]. Low perioperative morbidity, efficient tissue reduction, and consistent improvement in clinical symptoms were observed during the follow-up period of up to 18 mo [46]. Blood loss was reduced in the Tm:YAG group in comparison with HoLEP, with equally effective deobstruction within a short follow-up interval of 3 mo [54]. All other studies [46,50,51,56,57] showed clinical and urodynamic results in a similar range to that of previously reported studies (Table 4), together with a durable improvement in voiding function at up to 18 mo of follow-up. Postoperative PSA levels, as a surrogate parameter for volume reduction, declined by 56% and 88% [58,55].

In contrast to ThuVEP, ThuLEP is a transurethral technique with wide blunt dissection of the adenoma, as in OP. To date, only a description of the technique has been published, and no clinical data have been reported [59].

4.4.3. Conclusions and recommendations for the use of thulium: yttrium-aluminium-garnet lasers

Conclusions	LE
ThuVARP showed equivalent efficacy in comparison with TURP in one RCT and one nonrandomized prospective controlled trial with small and medium-sized prostate glands. Tm:YAG-treated patients had shorter catheterization and hospitalization times. Adverse events were significantly lower than in TURP (intraoperative and postoperative bleeding).	1b

Currently, only one RCT with a short follow-up has compared ThuVEP with HoLEP. However, three prospective cohort studies with a follow-up of 18 mo demonstrated efficacy for ThuVEP, as well as low perioperative complications and retreatment rates.	1b	
Study data are awaited comparing ThuVEP and ThuLEP with HoLEP. HoLEP is the most extensively studied transurethral enucleation technique to date, and long-term anatomical data are of particular interest.	4	
Recommendations	LE	GR
ThuVAP is an alternative to TURP for small and medium-sized prostates.	1b	A
ThuVAP and ThuVEP are suitable for patients who are at risk of bleeding or who are taking anticoagulant medication.	3b	C
ThuVEP can be offered as an alternative to TURP, to HoLEP and OP for patients with large-sized prostates.	1b, 2b	B

5. Application of laser devices for the treatment of bladder cancer pathologies

The use of laser devices in urology was first reported by Staehler et al. in 1978 [60]. They described the successful destruction of urinary bladder tumours with an Nd:YAG laser. There have only been retrospective analyses on laser ablation, without biopsy retrieval, for bladder cancer, and most have been single-institution studies with small numbers of patients (LE: 3/4). Bladder tumours were resected en bloc for the first time in 2001 using a holmium laser, and a bladder malignancy was first resected with a thulium laser in 2008 [61]. Although various lasers have been used to treat bladder tumours, there has been no prospective comparison of the different devices.

A few studies have compared TUR of the bladder (TURB) with laser treatment in noncontrolled retrospective analyses [62]. Total complication rates were reported, ranging from as low as 5.1% up to 43%. Reported levels of morbidity and complications have included urinary tract infections (up to 24%), bleeding (2.8–8%), haemorrhage requiring transfusion (0.9–13%), and bladder perforation (1.3–5%). The use of holmium or thulium laser for en bloc resections may help to evaluate the accuracy of pathologic stages and grades in primary bladder tumours [63,64]. There are insufficient data at present to predict progression rates. However, on the basis of the data currently available, recurrence rates after holmium laser application in bladder cancer appear to be similar, or lower, in comparison with TURB. Table 5 provides a comparison of results obtained with laser treatments of superficial bladder cancer.

5.1. Conclusions and recommendations for laser treatment of bladder tumours

Conclusions	LE
The use of lasers is feasible for resection, coagulation and enucleation of non-muscle invasive bladder tumours.	3

Table 5 – Laser treatment of superficial bladder tumour

Study	Study design	LE	Patients, n	Surgical technique	Operation time, min	Complications	Follow-up, mo	Recurrences, %	
								Local	Out of field
Ho:YAG (holmium) laser									
Das et al. [62]	Prospective	3	23	Photoablation plus biopsy	18.6	One recatheterisation	NA	NA	NA
Saito [61]	Retrospective	3	35	En bloc plus biopsy	NA	None	NA	NA	NA
Soler-Martinez et al. [63]	Prospective	3	36	Biopsy plus photoablation	14 (5–17)	None	3, 6, 12	NA	14, 22, 25
Zhu et al. [64]	Prospective	2	101	En bloc	30.7 (±16.1)	One perforated bladder	34 (18, 43)	NA	NA
Xishuang et al. [65]	Prospective	2	64	En bloc	16.5 (±3.8)	One urethral stricture	24	NA	NA
Zhong et al. [66]	Retrospective	3	25	En bloc	21.5 (±12.5)	None	12, 24	NA	LR 15 IR 34.6 HR 31.7
Tm:YAG (thulium) laser									
Gao et al. [67]	Prospective	3	32	En bloc	25 (15–35)	None	3, 6, 12	3, 7, 11	6, 17, 21
Zhong et al. [66]	Retrospective	3	34	En bloc	29.1 (±16.5)	None	12, 24	NA	NA
Yang et al. [68]	Prospective	3	9	En bloc	7 (5–15)	One perforated bladder	7.5 [6.9]*	0	17.6, 29.9

LE = level of evidence; NA = not applicable; LR = low risk; IR = intermediate risk; HR = high risk

Transurethral resection of the bladder remains the gold standard. In laser coagulation of tumours, no tissue for pathological staging is obtained. Long-term recurrence and progression rates are unknown for this novel technique. Currently, no data are available to indicate superiority of one device over another in bladder pathology. Complications are generally directly related to the laser's wavelength (penetration depth) and surgical technique.	1a
Recommendation	GR
Laser treatment for bladder cancer should only be used in a clinical trial setting or for patients who, due to co-morbidities or other complications, are not fit for conventional treatment.	C

6. Applications of lasers in laparoscopy/endoscopy

6.1. Laser-assisted partial nephrectomy

In cases of laparoscopic partial nephrectomy (PN), hilar clamping is currently necessary to create a bloodless field for renal excision. However, hilar clamping increases the complexity of the operation due to the time constraint and the significant risk that increased time poses for warm renal ischaemia and subsequent postoperative compromise of renal function. Laser technology presents a promising alternative for achieving tumour excision, pelvicalyceal watertightness, and renal haemostasis in a time-sensitive manner, with or without hilar occlusion.

Several experimental studies have demonstrated the efficacy of laser-assisted PN in various experimental setups. However, so far only eight small series of clinically tested laser-assisted PN have been published, only two of which were performed laparoscopically (one conventional and one robotic) [69–76] (LE: 3). The evidence is therefore poor, and further investigation is necessary before the method can be established as a routine alternative to nephron-sparing surgery.

6.1.1. Conclusions on laser-assisted partial nephrectomy

Conclusions	LE
Current data on nephron-sparing surgery using laser energy as an ablative method remain inconclusive.	
Preliminary results indicate that laser-assisted laparoscopic PN without the need for hilar clamping is feasible.	3
No major complication has been reported in humans.	3
Laser-assisted PN is a promising alternative in renal surgery, which is worth further evaluation in clinical trials.	

6.2. Laser-assisted laparoscopic nerve-sparing radical prostatectomy

Experimental and preliminary clinical data have highlighted promising future applications for laser technology in LNSRP [77].

6.2.1. Conclusions on laparoscopic nerve-sparing radical prostatectomy

Conclusions	LE
Data are sparse and safe conclusions cannot be drawn yet.	
Preliminary results indicate that laser-assisted LNSRP is feasible and could possibly enhance prostate neurovascular bundle preservation.	3
Laser-assisted LNSRP remains experimental.	

7. Renal tumour interstitial laser ablation

The current consensus on small renal tumours supports thermal coagulation as an alternative treatment option but only in selected patients with comorbidities that make them unsuitable candidates for PN [78]. Clinical experience with renal tumour interstitial laser ablation is still limited.

7.1. Conclusions and recommendation for renal tumour interstitial laser ablation

Conclusions	LE
Data are poor, and safe conclusions cannot be drawn yet regarding oncological outcome and safety.	4
Renal tumour interstitial laser ablation remains experimental.	4
Recommendation	GR
Laser-assisted laparoscopic PN, laser-assisted LNSRP and renal tumour laser interstitial coagulation are still experimental and should only be used in a clinical trial setting	C

8. Retrograde laser endoureterotomy

Endoureterotomy is often the first line of treatment for benign ureteral strictures. Since its introduction in 1997, retrograde laser endoureterotomy has become a widely used tool for this procedure [79]. Publications on the approach are based on retrospective analyses (ie, single-institution studies) [79–90] (LE: 3/4). The success rates of laser endoureterotomy are not uniformly clear. Wide variations in success rates between published reports have most probably arisen because benign ureteral strictures consist of several different entities, each possibly responding differently to laser endoureterotomy. However, there is a lack of large retrospective studies to define which strictures respond well and which do not (LE: 4).

Because large studies are lacking and long-term studies are rare, the median time to failure has not yet been defined. Stricture recurrence as long as 18 mo postoperatively has been reported, but recurrences are most likely to become evident within the first 3 mo (LE: 3). Balloon dilation after laser incision and postoperative placement of ureteral stent for durations from 4 wk to 6 mo are common practices that appear to aid long-term effectiveness (LE: 4). However, there is still a lack of studies comparing treatment failure with or without balloon dilation and postoperative ureteral stenting.

8.1. Conclusions and recommendations for retrograde laser endoureterotomy

Conclusions	LE
Retrograde laser endoureterotomy is a feasible and safe treatment option for ureteral strictures.	3
Open surgical revision remains the gold standard.	1a
Ureteral strictures of different aetiologies appear to respond differently to treatment.	2b
In selected cases, the success rate can reach 90%.	
Ureteroenteric anastomosis strictures respond poorly to laser endoureterotomy.	3
Late recurrence of stricture should be expected up to as much as 18 mo postoperatively	3
Recommendations	GR
Retrograde endoureterotomy could be considered a first-line treatment option for ureteral strictures.	C
Longer follow-up is needed.	C

9. Retrograde laser endopyelotomy for ureteropelvic junction obstruction

Publications concerning retrograde laser endopyelotomy are mostly based on retrospective analyses (ie, single-institution studies producing LE 3 and 4) [91,92]. The optimal indication for laser endopyelotomy is a short (<2 cm) UPJ obstruction of intrinsic aetiology in the absence of a very large pelvis, high insertion of the ureter, renal split function <20%, and ipsilateral renal calculi (LE: 4). When particular inclusion criteria are used, success rates are reported to be around 80% or even higher in highly selected cases in the hands of an experienced urologist (LE: 4). Lower success rates have been reported when there is an extrinsic cause of UPJ obstruction and severe hydronephrosis in patients with poor renal function [91]. The outcome of retrograde laser endopyelotomy in comparison with open pyeloplasty is slightly inferior (LE: 2b).

9.1. Conclusions and recommendations for laser treatment for ureteropelvic junction obstruction

Conclusions	LE
Retrograde laser endopyelotomy is a feasible and safe treatment option for the treatment of UPJ obstruction.	3
Open or laparoscopic pyeloplasty remains the gold standard.	1a
In selected cases, the success rate can reach 90%.	
Treatment morbidity is minimal and major complications are rare.	3
Treatment failure may occur up to 1 year postoperatively.	3
Recommendations	GR
Retrograde laser endopyelotomy could be one of the first-line treatment options.	C
Follow-up should be prolonged for at least 1 yr postoperatively.	C
Open or laparoscopic pyeloplasty remain options in cases in which minimally invasive measures fail.	C
Ensure identification of crossing vessels, which is of particular relevance in reducing bleeding complications.	B
Ureteric stent placement before the procedure is an option that may affect the postoperative success rate.	C

10. Transurethral laser urethrotomy

Transurethral laser urethrotomy using the Nd:YAG laser was originally introduced in 1979 [93]. Since then, laser urethrotomy has become a common urologic practice throughout the world in the management of urethral strictures. Publications on this approach are based on retrospective analyses (ie, single-institution studies producing LE 3 or 4) [94–111]. Short-segment urethral strictures tend to respond well to this treatment modality (LE: 3). However, inferior results have been reported with long urethral strictures (>1.5 cm) and recurrent strictures (LE 3).

10.1. Conclusions and recommendation for transurethral laser urethrotomy

Conclusions	LE
Transurethral laser urethrotomy is a feasible and safe option for the treatment of urethral strictures.	3
Cold-knife optical urethrotomy remains the gold standard.	1a
Success rates as high as 100% are reported in selected cases.	3
Treatment morbidity is minimal and major complications are rare.	3
Recommendations	GR
Transurethral laser urethrotomy could be one of the first-line treatment options for benign urethral strictures.	C

11. Laser clinical applications in upper urinary tract stones and tumours

The entire upper urinary tract can be accessed and explored with flexible endoscopes. Endoscopic intracorporeal laser lithotripsy is widely used as a treatment for upper urinary tract stones [112,113]. Lasers are ideally suited for retrograde intrarenal surgery or a percutaneous approach [114]. Successful stone fragmentation is achieved in an average of more than 90% of stones.

In Ho:YAG lasers, energy is usually delivered in a pulsatile manner, using a thermomechanical action. Ho:YAG has minimal fragment migration and retrograde propulsion at low settings in comparison with Nd:YAG. The absence of a strong wave in holmium lasers avoids the retropropulsion phenomenon.

11.1. Upper urinary tract urothelial tumours and upper urinary tract stones

The aim in conservative management of upper urinary tract urothelial tumours (UUT-UT) is to preserve renal function [115]. Appropriate tumour staging (computed tomography, biopsy) is necessary to allow selection of patients for nephron-sparing surgery. Representative biopsy samples to determine the depth of invasion are necessary.

Although nephroureterectomy is the gold standard, the current literature supports laser therapy in patients with UUT-UT. However, meticulous and long-term follow-up is

needed [116]. In contrast to tumour resection (holmium/thulium), pathology specimens are not available following tumour vaporisation (Nd:YAG/holmium/thulium).

11.2. Conclusions and recommendations for laser treatment of upper urinary tract stones and urothelial tumours

Conclusions	LE
Nephroureterectomy is still the gold standard for UUT urothelial tumours.	1a
Pulsed lasers are an effective and safe treatment for UUT stones, using endoscopes.	
Lasers present a safe option for defragmenting stones in the upper urinary tract.	1
Recommendations	GR
Laser ablation of small low-grade upper tract transitional cell carcinoma with close follow-up can be a safe alternative treatment to nephroureterectomy in patients with normal contralateral kidneys.	B
Endoscopic conservative treatment can be the preferred treatment in high-risk patients, as well as those with bilateral disease, solitary kidney, or reduced renal function.	C

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