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Thermal lasers in urology

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Abstract

The thermal effect is the most common effect of tissue–laser interaction in urology. With the widespread use of endoscopic instruments laser applications in urology have dramatically increased. Various urological conditions can nowadays be successfully treated with lasers. In the treatment of benign prostate hyperplasia (BPH), holmium laser enucleation of the prostate (HoLEP) and photoselective vaporization of the prostate (PVP) have proven as reliable, safe and effective treatment alternatives. Urethral strictures, bladder neck sclerosis and ureteropelvic junction (UPJ) obstruction have also been treated successfully with lasers; however their role is limited to selected cases and conditions. For the treatment of malignant diseases, lasers can be applied in early stage upper urinary tract transitional cell carcinoma (UUTTCC) and penile carcinoma. This review summarizes the potential and limitations of thermal lasers in urology.

Keywords: Laser surgery; Thermal lasers; Benign prostate hyperplasia; Upper urinary tract transitional cell carcinoma; Penile carcinoma

Introduction

Lasers in urology have been subject to intense research since the 1980s. The most commonly used effect of tissue–laser interaction is the thermal effect. The light energy emitted by the laser is absorbed by the tissue and transformed into heat. Depending on the temperature reached in the tissue, a denaturation of proteins, shrinkage of arteries and veins, cellular dehydration, carbonization, or vaporization occurs. The tissue can be incised, coagulated or vaporized (Table 1). Laser applications have dramatically increased with the rapid development and continuous improvement of endoscopic instruments. In the treatment of benign prostate hyperplasia (BPH), the application of lasers is an established treatment alternative, while other applications of lasers are still controversial and under investigation. This review gives an updated overview of the application of thermal lasers in the treatment of various urological conditions.

Benign prostate hyperplasia

Lower urinary tract symptoms (LUTS), due to benign prostate enlargement by BPH, are a highly prevalent disease. At the age of 60 years, nearly 60% of men have some degree of clinical BPH [1]. The most common indication for surgery are LUTS refractory to medical treatment, refractory or recurrent urinary tract infections, recurrent hematuria, renal insufficiency due to obstruction or bladder stones [2]. Transurethral

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Table 1. Application of thermal lasers in urology.

Technique	Disease	Laser type
Resection, ablation	Benign prostatic hyperplasia (BPH)	Ho:YAG KTP, LBO (GreenLight) Diode Tm:YAG
	Upper urinary tract transitional cell carcinoma (UUTTCC)	Nd:YAG Ho:YAG Diode Tm:YAG
	Penile carcinoma (early stage)	CO_2 Nd:YAG
Soft tissue incisions	Urethral strictures Bladder neck contractures UPJ obstruction	Ho:YAG

Table 2. Lasers in the treatment of BPH.

Laser type	Wavelength (nm)	Method
Ho:YAG	2100–2150	Holmium laser enucleation of the prostate (HoLEP)
KTP, LBO (GreenLight)	532	Photoselective vaporization of the prostate (PVP)
Diode laser	940, 980, 1470	Diode laser vaporization of the prostate
Tm:YAG	2000	Thulium laser enucleation of the prostate Thulium laser vaporesection of the prostate Thulium laser vaporization of the prostate

resection of the prostate (TURP) is regarded as the gold standard in men with a prostate size that is smaller than 80 ml, whereas open prostatectomy (OP) is performed for prostates above 80–100 ml [2]. Despite the widespread use of TURP and OP, both techniques can be associated with severe complications and treatment-associated morbidity [3–6]. In recent years, various laser techniques have been developed to overcome complications encountered with TURP or OP (Table 2).

Holmium laser enucleation of the prostate (HoLEP)

The Holmium:yttrium–aluminium–garnet (Ho:YAG) laser is a solid state pulsed laser with a wavelength of 2100–2150 nm. Since the light energy is rapidly absorbed by water and cell fluid, a high energy density results in a penetration depth of 0.4 mm in prostatic tissue. With the laser, tissue can be precisely incised, dissected and enucleated. The enucleated tissue is morcellated in the bladder and removed. With the introduction of the mechanical tissue morcellator, a rapid development of the enucleation technique was initiated, which has proven to be superior over the now largely abandoned holmium laser ablation of the prostate (HoLAP) and holmium laser resection of the prostate (HoLRP) [7,8].

Numerous trials have shown the low intra- and postoperative complication rate of HoLEP alone or in comparison to TURP or OP at comparable functional outcome [9–12]. In recent years, a considerable number of studies have become available regarding the intermediate and long-term outcome of HoLEP, some of them in comparison to TURP or OP. Gilling et al. [13] reported long-term data with a mean follow-up of 6.1 years showing that the HoLEP results are long-lasting and most patients remain satisfied. Two meta-analyses assessed available randomized controlled trials comparing HoLEP and TURP [14,15]. Both analyses reported a significantly shorter catheterization time and hospital stay, a smaller blood loss and fewer blood transfusions but a longer operation time with HoLEP. Improvement of symptoms was comparable; Lourenco et al. [15] reported a peak flow rate at 12 months, which was significantly in favor of HoLEP. In prostates larger than 100 ml, HoLEP proved to be as effective as OP regarding improvement in micturition with equally low reoperation rates at 5-year follow-up [9]. Despite the high intra and postoperative safety, together with the excellent functional outcome, the steep learning curve of the technique will probably inhibit HoLEP's widespread use and will restrict its use to a few high expert centers.

Photoselective vaporization of the prostate (PVP)

In the early 1990s visual laser ablation of the prostate (VLAP) was introduced with the 1064 nm Neodymium:yttrium–aluminium–garnet (Nd:YAG) laser [16]. The low absorption coefficient resulted in deep coagulative necrosis of the tissue [7]. Since the improvement of symptoms and voiding parameters was inferior to TURP and the rate of reoperations was considerably higher, VLAP has now been abandoned [17,18]. By passing the Nd:YAG-produced beam through a KTP or LBO crystal, a green visible light beam (532 nm) is generated which has a completely different laser beam–tissue interaction. The wavelength is not absorbed by water but strongly absorbed by hemoglobin, resulting in enhanced hemostatic properties. The absorption depth in a vascularized tissue such as the prostate is only 1–3 mm, the high energy density leads to a rapid vaporization of the tissue, which is known as photoselective vaporization of the prostate (PVP) [19,20].

Most of the trials published until 2008 were based on the 80-W KTP laser, whereas currently only limited data are available on the higher powered 120-W LBO laser introduced in 2006. In several studies, the 80-W KTP laser has demonstrated a prompt and long-lasting improvement