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Laser Application in Surgical Treatment of Benign Prostatic Hyperplasia

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Abstract: ***Benign prostatic hyperplasia (BPH) is a prevalent condition among middle-aged and elderly men, often causing lower urinary tract symptoms (LUTS). Current treatment options encompass watchful waiting, pharmacological therapy, and surgical intervention. Among these, surgical treatment rapidly alleviates LUTS and enhances quality of life, making it the most effective approach for moderate to severe BPH. In recent years, with the rapid development and clinical application of various laser technologies, transurethral resection of the prostate (TURP), once considered the "gold standard," has faced controversies due to its higher surgical morbidity and limitations in treating large prostate volumes. Laser technologies, with their remarkable surgical efficacy, safety, and reduced morbidity, have increasingly gained favor among clinicians. This article primarily delves into the clinical advancements of diode laser minimally invasive technology in BPH treatment, aiming to provide a theoretical basis for clinicians in addressing clinical challenges.***

Keywords: Laser, Benign prostatic hyperplasia, TURP**.**

1. Introduction

Benign Prostatic Hyperplasia (BPH), a common condition among men over 50 years old, is primarily characterized by symptoms such as frequent urination, urgency, and dysuria, severe cases often necessitate surgical intervention to relieve urinary obstruction [1]. The surgical approach for BPH has evolved from traditional open surgery to TURP, which has now become the gold standard for surgical treatment of BPH. However, given that BPH patients are typically elderly and may have numerous comorbid conditions, such as cardiopulmonary diseases, they face increased risks of complications like transurethral resection syndrome and bleeding during surgery [2]. Consequently, there is an urgent need to explore safer surgical methods. With technological advancements, laser technology, as a new, efficient, and safe minimally invasive surgical approach, has increasingly been recognized and accepted by clinicians, following electrocision and plasmakinetic resection. This article provides a comprehensive review of the application, development, complications, and future prospects of lasers in prostate surgery.

Since Staethler et al. [3] reported the application of lasers in urology in 1976, laser technology has undergone continuous advancements and developments over the past five decades, leading to its widespread use in urological surgery. Compared to the initial application of CO2 lasers in partial nephrectomy, the subsequent utilization of holmium lasers in urological stone surgery marked a pivotal era, ushering in the minimally invasive era of urological surgery through natural orifices.

In 1992, Costello et al. [4] first reported intraluminal laser surgery for human BPH. With the continuous improvement of laser equipment, various types of lasers with distinct characteristics, such as holmium, green light, thulium, and diode lasers [5], have been developed and utilized, achieving remarkable outcomes in prostate surgery. Lasers exhibit significant biological effects, and lasers with different parameters possess distinct characteristics, resulting in varied interactions with biological tissues.

2. The Principle of Laser Surgery for BPH

The principle of laser surgery for the prostate primarily involves the use of high-energy laser beams emitted through optical fibers to rapidly cause the prostate tissue to shrink and vaporize, thereby achieving the purpose of tissue cutting [6]. Different wavelengths of lasers correspond to different biological effects, and by utilizing the varying absorption effects of tissues, water, and blood on different wavelengths of lasers, various objectives can be achieved [7]. Its greatest advantage lies in its ability to effectively reduce intraoperative bleeding. Additionally, because the energy source differs from electrical cutting, intraoperative electrical cutting syndrome and other electrical stimulation reactions do not occur, significantly lowering intraoperative risks, particularly for elderly patients and those with numerous underlying diseases. It also provides a safety guarantee for patients who take anticoagulants and antiplatelet drugs for a long time, allowing them theoretically to continue using these drugs without interruption or to resume them promptly after surgery, thereby reducing the occurrence of cardiovascular and cerebrovascular accidents.

3. The Surgical Methods for Transurethral Laser Resection of the Prostate

Transurethral laser prostate surgery primarily includes laser resection, vaporization, and enucleation procedures. These surgical techniques have evolved from the traditional TURP method. Thanks to the efficient hemostatic properties of lasers, the surgical procedures have been significantly optimized, greatly reducing the operative time and the learning curve for urologists [8]. Currently, there are three main common approaches: transurethral laser vaporization of the prostate (TuLVP), transurethral laser resection of the prostate, and transurethral laser enucleation of the prostate (ThuLEP).

Laser vaporization is a technique that directly vaporizes prostate tissue with the high energy of a laser, creating a layer of eschar on the tissue surface to achieve a synergistic hemostatic effect [9,10]. When using the laser vaporization method for prostate surgery, intraoperative and postoperative bleeding is significantly reduced compared to conventional TURP surgery. However, for larger prostate glands, the vaporization method requires a longer operative time, which may increase intraoperative risks and complications. Additionally, it is not possible to obtain an effective volume of tissue for pathological examination, posing a potential risk of missed tumor diagnosis [11,12].

Laser resection is a method that utilizes a laser beam emitted from an optical fiber to cut prostate tissue. Compared to laser vaporization, it can obtain more tissue for pathological examination while also maintaining the characteristic of effective hemostasis. However, due to the shape of the laser fiber and the linear transmission of light, there may be limitations in the angle of operation. Additionally, for surgeons with less experience, managing bleeding from blood sinuses in deep tissue gaps during the cutting process can be challenging.

Laser enucleation is a technique that involves using a laser, assisted by an endoscope, to lever and dissect the prostate gland, which is then removed using specialized tools. Compared to the first two surgical methods, enucleation demands higher operational experience from surgeons, and the learning curve is slightly longer. However, the learning curve and operational difficulty of laser vaporization resection are significantly lower compared to TURP with plasmakinetic technology. Moreover, the use of laser enucleation does not reduce the incidence of complications other than bleeding, and thus does not fully demonstrate the advantages of laser surgery [4,13].

4. Introduction to Holmium Laser, Thulium Laser, Green Laser, and Semiconductor Laser

Holmium laser is the first laser widely used in the field of urology, especially advantageous in the treatment of urinary calculi. It has a wavelength of 2100nm, uses water as the chromophore, and employs pulse detonation energy output with a penetration depth of approximately 0.4mm, thereby destroying the target tissue [14]. In various clinical studies, the use of holmium laser in enucleation is significantly superior to other surgical techniques, effectively reducing intraoperative bleeding. The newly emerged Moses technology in prostate surgery further enhances its surgical efficiency. This technology involves two consecutive pulses: the first pulse displaces the liquid between the optical fiber and the target tissue, while the second pulse, with low attenuation, delivers energy directly to the target tissue.

Green laser, with a wavelength of 532nm, delivers energy in a continuous form and has a penetration depth of 0.8mm. It is primarily used for prostate vaporization surgery and has significant advantages in managing complications such as bleeding. In multiple multicenter retrospective studies, 180W green laser surgery has been proven to be unaffected by oral anticoagulants and antiplatelet drugs. However, for prostate glands exceeding 100ml in volume, the surgical duration is significantly prolonged, which may be related to the choice of surgical technique.

Thulium laser, with water molecules as its chromophore, currently comes in two main types: Tm: YAG laser (Revolix) at 2013nm and Tm fiber laser (VelaXL) at 1940nm. It vaporizes tissue and performs cutting through continuous energy emission, with a shallow penetration depth of only 0.2mm [16]. The commonly used surgical techniques are still enucleation and vaporization. However, in enucleation cases, the incidence of transient urinary incontinence is relatively high.

Semiconductor lasers refer to a class of lasers that generate laser radiation using semiconductor rods, encompassing several different wavelengths such as 940nm, 980nm, 1318nm, and 1470nm laser systems [6, 17]. Currently, 980nm and 1470nm wavelengths are used more frequently. Among them, the 980nm wavelength laser is characterized by its strong hemostatic effect, while the 1470nm wavelength laser excels in tissue vaporization. In the semiconductor lasers currently available in the market, German Biolite 1470/980nm dual-wavelength semiconductor laser combines these two wavelengths on the same emission terminal, enabling it to simultaneously achieve efficient tissue vaporization and hemostatic effects.

5. Possible Postoperative Complications

Multiple clinical studies have consistently demonstrated the advantages of laser-based surgeries over TURP in reducing bleeding and shortening operative duration. However, there may not be significant differences in the incidence rates of other complications. The most prominent complication is incontinence, which frequently occurs after transurethral prostate surgeries and can be categorized into three types: stress incontinence, urge incontinence, and overflow incontinence [18]. Stress incontinence is often attributed to irritation and damage to the urethral sphincter during surgery, particularly in prostate enucleation where traction and manipulation of the endoscope can lead to transient stress incontinence due to sphincter injury. Currently, stress incontinence is uncommon after Photoselective Vaporization of the Prostate (PVP) surgery [19], as the limited depth of energy conduction in lasers results in minimal direct thermal damage to the sphincter. The higher incidence of incontinence after enucleation, which is mostly transient, may primarily be due to intraoperative traction stimulating the urethral sphincter. With improvements in enucleation techniques, such as lobular enucleation for larger glands, the occurrence rate can be significantly reduced. Patients with urge incontinence often exhibit symptoms before surgery, typically due to unstable bladder detrusor muscle, and postoperative urinary tract infections may also contribute to this condition. Symptoms can be improved with medications such as M-receptor antagonists and β3-agonists [20]. For those with urinary tract infections, sensitive antibiotics should be promptly administered to control the infection. Overflow incontinence is mainly caused by postoperative urethral stenosis and bladder neck scar hyperplasia, often accompanied by symptoms such as thin urine stream and dysuria. Regular follow-up and, if necessary, cystoscopic re-examination and urethral dilation can be performed postoperatively.

Postoperative infections are primarily considered to be caused by incomplete control of pre-existing infections, with a possible contributing factor being an uneven or irregular surgical wound surface after prostate surgery. Efforts should be made during surgery to trim and flatten the wound surface as much as possible, and prompt postoperative infection control and prevention measures should be taken [21].

Postoperative sexual dysfunction mainly manifests as difficulty in achieving penile erection and ejaculatory disorders. Due to the removal of prostate gland tissue, patients may experience retrograde ejaculation after surgery, which should be explained to the patient before the operation. Postoperative erectile dysfunction needs to be considered as a possible result of sexual nerve damage [22]. During TURP, electrical current stimulation is considered a major factor affecting sexual nerves. Currently, the depth of laser energy conduction ranges from 0.2mm to 0.8mm, and laser energy has a strong directionality. Resecting or enucleating the prostate along the inner side of the capsule can minimize the impact on sexual nerves. In some patients, improved urination after surgery may actually enhance erectile function.

6. Conclusion and Future Prospects

Although prostate laser surgery may also entail a series of potential complications, its incidence rate does not exceed that of traditional TURP surgery. Most of the potential causes are related to the choice of surgical method and the surgeon's experience. Prostate laser surgery has unique advantages in controlling bleeding, shortening operation time, and reducing the learning curve for urological surgeons. Therefore, laser surgery can still be considered an advantageous option in transurethral prostate surgery. Moreover, its application is not limited to prostate surgery; it also has corresponding advantages in transurethral resection of bladder tumors and partial nephrectomy for renal tumors. With the development of technology, more lasers with excellent biological effects will emerge iteratively, becoming even sharper surgical tools for urological surgeons.

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