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Minimally Invasive Surgical Therapies for Benign Prostatic Hyperplasia: Current Advances and Future Perspectives

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ABSTRACT

Benign prostatic hyperplasia (BPH) is a highly prevalent urological condition characterized by progressive enlargement of the prostate gland, leading to lower urinary tract symptoms (LUTS) that affect quality of life in aging men. While medical management remains the first-line treatment, many patients eventually require surgical intervention due to refractory symptoms, intolerance to medications, or complications such as urinary retention. Traditional surgical approaches, such as transurethral resection of the prostate (TURP), are effective but associated with significant perioperative risks and functional side effects. In response, minimally invasive surgical therapies (MISTs) have emerged as viable alternatives, offering symptom relief with reduced morbidity, shorter hospital stays, and faster recovery. This review provides a comprehensive analysis of current MIST options, including laser-based therapies, prostatic urethral lift (UroLift), water vapor thermal therapy (Rezum), prostatic artery embolization (PAE), and aquablation. The mechanisms, efficacy, safety, and patient selection criteria for each technique are critically evaluated. Additionally, the review highlights recent technological innovations, long-term outcome data, and future directions for integrating these procedures into personalized BPH management.

Keywords: Benign prostatic hyperplasia, Minimally invasive surgery, Prostatic artery embolization, Aquablation, Laser therapies

INTRODUCTION

Benign prostatic hyperplasia (BPH) is a non-cancerous enlargement of the prostate gland that affects a majority of men as they age, with a reported prevalence exceeding 50% in men over the age of 50 [1]. The enlargement of the prostate can obstruct urinary outflow by compressing the urethra, leading to bothersome lower urinary tract symptoms (LUTS) [2]. These symptoms include frequency, urgency, nocturia, weak stream, hesitancy, and incomplete bladder emptying [1]. If left untreated, BPH can progress to complications such as acute urinary retention, recurrent urinary tract infections, bladder stones, and renal impairment [3]. Initial management of BPH typically involves lifestyle modification and pharmacological therapy, including alpha-blockers and 5-alpha reductase inhibitors [4]. However, up to 30% of patients eventually require surgical intervention due to inadequate symptom control, adverse drug effects, or disease progression [5]. While traditional transurethral resection of the prostate (TURP) remains the gold standard for moderate-to-severe BPH, it carries notable risks such as bleeding, retrograde ejaculation, erectile dysfunction, and prolonged catheterization or hospitalization [6].

In the past two decades, the development of minimally invasive surgical therapies (MISTs) has transformed the surgical landscape of BPH management. These therapies aim to minimize tissue trauma, preserve sexual function, reduce perioperative risks, and facilitate outpatient or same-day procedures [3]. This review outlines the current landscape of MISTs for BPH, including their mechanisms, indications, outcomes, and limitations, and explores future perspectives for expanding and personalizing these treatment options.

Current Minimally Invasive Surgical Therapies

Minimally invasive surgical therapies (MISTs) have revolutionized the management of benign prostatic hyperplasia (BPH), offering safe and effective alternatives to traditional procedures such as transurethral resection of the prostate

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(TURP) [7]. These therapies aim to reduce perioperative morbidity, shorten recovery times, and preserve sexual and urinary functions while achieving substantial relief from lower urinary tract symptoms (LUTS) [8]. This section highlights key MIST modalities currently in clinical use.

Laser-Based Therapies

Laser-based surgical interventions are among the most well-established MISTs in BPH treatment. Technologies such as Holmium Laser Enucleation of the Prostate (HoLEP), Green Light Photoselective Vaporization (PVP), and Thulium Laser Enucleation of the Prostate (ThuLEP) are increasingly adopted due to their precision, reduced blood loss, and ability to treat varying prostate sizes [9].

HoLEP involves the complete endoscopic enucleation of the adenomatous portion of the prostate using holmium\:YAG laser energy, followed by mechanical morcellation of the tissue [10]. HoLEP is highly effective across all prostate sizes, particularly large glands (>100 mL), and offers long-term symptom control with lower retreatment rates than TURP [11]. It also demonstrates favorable outcomes in urinary flow rate improvement and reduced post-void residual volume [9].

Greenlight PVP employs a 532-nm wavelength potassium-titanyl-phosphate laser to vaporize prostatic tissue. It is particularly suited for patients on anticoagulation therapy due to its strong hemostatic properties [12]. The procedure provides rapid symptom relief, is associated with shorter catheterization duration, and has a reduced risk of perioperative complications [13].

ThuLEP is analogous to HoLEP but utilizes a thulium YAG laser, which operates in a continuous-wave mode [14]. This allows for more precise cutting and reduced thermal damage to surrounding tissues. ThuLEP provides similar clinical efficacy and safety profiles, with an added advantage of better visibility during surgery due to less bleeding [14,15].

All three laser therapies are associated with significant improvement in IPSS scores, preserved erectile function, low complication rates, and short hospital stays. However, they demand significant operator expertise and access to high-cost laser platforms.

Prostatic Urethral Lift (UroLift)

The UroLift system is a mechanical, implant-based treatment that retracts the prostatic lobes using transurethral delivery of small permanent implants [16]. This expands the urethral lumen without removing or ablating tissue. Conducted under local anesthesia in an outpatient setting, UroLift is particularly advantageous for patients who desire a rapid recovery with minimal risk of sexual dysfunction [17].

UroLift offers quick symptom relief and does not impair ejaculatory or erectile function. It is best suited for patients with smaller prostates (<80 mL) and no significant median lobe obstruction [18]. Its ease of use and favorable safety profile have contributed to its growing popularity.

Water Vapor Thermal Therapy (Rezum)

Rezum uses convective water vapor energy to ablate prostate tissue through a transurethral needle. The steam causes immediate cell death, and the necrotic tissue is gradually reabsorbed, leading to urethral decompression [19]. This office-based procedure, typically performed with local anesthesia or mild sedation, has demonstrated durable symptom improvement up to five years post-treatment. It is associated with a low risk of sexual side effects and minimal perioperative morbidity. Rezum is appropriate for prostates up to 80 mL and is increasingly used in both primary and specialist care settings [20].

Aquablation

Aquablation therapy involves high-velocity saline jets directed by real-time robotic ultrasound imaging to remove prostate tissue with high precision and minimal thermal injury [21]. This method allows for tailored, reproducible treatment of prostates of varying sizes. Aquablation provides symptom improvement comparable to TURP, with the added benefit of preserving ejaculatory function [22]. It is especially advantageous for men with large prostate volumes (>80 mL) and those seeking a robotic, standardized approach to care [21].

Prostatic Artery Embolization (PAE)

PAE is a radiologic intervention in which microparticles are injected into the prostatic arteries to induce ischemic necrosis and reduce prostate volume [23]. Performed under local anesthesia, PAE is an attractive option for patients who are poor surgical candidates due to comorbidities [24].

While PAE has shown moderate effectiveness in symptom control, concerns persist regarding its long-term efficacy, anatomical variability, and lack of procedural standardization [25]. It is currently considered an emerging, rather than a frontline, option in surgical BPH management.

Comparative Effectiveness and Patient Selection

Selecting the optimal minimally invasive surgical therapy (MIST) for benign prostatic hyperplasia (BPH) requires careful consideration of several patient-specific factors, including prostate size, severity of lower urinary tract symptoms (LUTS), presence of a median lobe, comorbid medical conditions, and individual preferences regarding

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recovery time and preservation of sexual function [26]. Prostatic Urethral Lift (UroLift) and Water Vapor Thermal Therapy (Rezum) are preferred for patients with small to moderately enlarged prostates (typically less than 80 mL) and those who prioritize the maintenance of ejaculatory and erectile function [27]. These techniques are less invasive, associated with minimal recovery periods, and are well-suited for younger men or those who are averse to permanent changes in reproductive function. For patients with significantly enlarged prostates, Holmium Laser Enucleation of the Prostate (HoLEP) and Aquablation are highly effective [28]. These methods offer substantial and durable symptom relief, with HoLEP particularly excelling in long-term outcomes for prostates greater than 100 mL. Aquablation's robotic precision makes it appealing in institutions with access to advanced surgical platforms [29]. Prostatic Artery Embolization (PAE) serves as a suitable option for elderly patients or individuals with significant comorbidities who are unfit for general anesthesia [30]. Although its symptom relief is moderate and longer-term data are still emerging, it offers a low-risk alternative in medically complex cases. Each modality has unique advantages and limitations in terms of durability, procedural complexity, perioperative risks, and cost. Continued research, particularly direct comparative trials and real-world outcome analyses, will help refine patient selection strategies and develop personalized treatment algorithms.

CONCLUSION

Minimally invasive surgical therapies have transformed the treatment paradigm of benign prostatic hyperplasia by offering effective, safe, and patient-centered alternatives to traditional surgery. These interventions provide meaningful symptom relief with reduced recovery time, preservation of sexual function, and improved quality of life. As experience grows and data matures, MISTs will continue to refine their role in personalized urologic care. Future research and innovation will further enhance accessibility, outcomes, and integration into clinical practice.

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