Benign Prostatic Hyperplasia: Review of Modern Minimally Invasive Surgical Treatments

Tony Nimeh, MD[1] Brenden Magnan, BS[1] Y. Zaki Almallah, MD[1]

[1] Department of Urology, University of Illinois at Chicago, Chicago, Illinois

Address for correspondence Y. Zaki Almallah, MD, Department of Urology, University of Illinois at Chicago, 820 South Wood Street, CSN 515. M/C 955, Chicago, IL 60612 (e-mail: yzam@uic.edu).

Semin Intervent Radiol 2016;33:244–250

Benign prostatic hyperplasia (BPH) is a common problem among older men and can have a significant impact on quality of life. BPH is a histologically diagnosed disease and is present in 8% of men aged 41 to 50, 40 to 50% of men aged 51 to 60, 70% of men aged 61 to 70, and more than 80% of men older than 80 years. The pathogenesis of BPH remains incompletely understood, but there are many known risk factors for developing this disease. These include race, family history of cancer, higher serum levels of testosterone and estradiol, alcohol consumption, prostatitis, and nonsteroidal anti-inflammatory drug use.[1–5] The classic clinical presentation of BPH is the experience of lower urinary tract symptoms (LUTS). These symptoms include frequency, nocturia, urgency, incontinence, slow or intermittent stream, straining, and terminal dribbling (►**Table 1**). These symptoms are experienced moderately to severely in 25% of men in their 50s, 33% of men in their 60s, and approximately 50% of men in their 80s. Like any other disease, the clinical evaluation for a man with suspected BPH begins with a thorough history and physical exam. The International Prostate Symptom Score (IPSS) index can be used to classify the severity of LUTS in patients. This consists of seven questions that assess the severity and frequency of different symptoms of BPH as well as a question asking the patient to rate how their quality of life is affected by these symptoms.[6]

Management of Benign Prostatic Hyperplasia

According to the American Urologic Association (AUA) guidelines, the preferred management strategy for patients with mild symptoms (IPSS <8) of BPH is watchful waiting.[7] It is also an appropriate option for patients with moderate-to-severe symptoms who have not developed complications, including renal insufficiency, urinary retention, or recurrent infection. Medical therapy is appropriate for patients with moderate-to-severe symptoms (IPSS >8) of BPH and includes α-blockers and 5-α reductase inhibitors. Surgical intervention is recommended for patients with moderate-to-severe symptoms of BPH and for patients who have experienced BPH-related acute urinary retention or other complications. Although most patients undergoing surgical intervention have failed a trial medical therapy, a failed medical trial is not a requirement for surgical intervention. Patients may choose surgical option as a first-line treatment if their symptoms are particularly bothersome and they want the most effective treatment possible (►**Fig. 1**; ►**Table 2**).

In this article, we review the most commonly performed minimally invasive treatments for BPH. We start with the bipolar transurethral resection of the prostate (TURP), considered as the gold standard, and proceed with Greenlight vaporization, Greenlight enucleation, holmium laser ablation, holmium laser enucleation, Button vaporization, transurethral microwave therapy (TUMT), transurethral needle ablation of the prostate (TUNA), Urolift, prostatic stents, prostatic artery embolization, and lastly ethanol and botulinum toxin injections.

Most minimally invasive treatments of BPH involve reducing the size of the prostate through either its surgical resection or the application of an energy source to it. In most cases, cystoscopy is used to reach the prostate: the urethra is inspected with a cystoscope equipped with the specific micro instrument designed to deliver the specific energy source needed.

Bipolar Transurethral Resection of the Prostate

The conventional TURP is performed by introducing a rigid resectoscope into the urethra, reaching the prostate, and resecting the prostatic tissue with a metal loop through which current is delivered. The first-generation TURP was performed with monopolar current, but since then bipolar TURP has been introduced which is discussed in this section. Current is generated at an active electrode and travels to a return electrode. This high current generated cuts the tissue as the loop is moved along it. These electrodes are both contained in

Issue Theme Men's Health; Guest Editor, Charles Burke, MD

DOI http://dx.doi.org/10.1055/s-0036-1586148. ISSN 0739-9529.

Table 1 BPH Symptoms[7]

Storage symptoms	Voiding symptoms
Increased frequency Nocturia Urgency	Feeling of incomplete emptying Intermittency Straining Weak stream

Abbreviation: BPH, benign prostatic hyperplasia.

the loop, resulting in a much shorter distance for the current to travel compared with a monopolar current. The use of a bipolar loop instead of a monopolar loop allows for the use of isotonic saline as an irrigation fluid during surgery. Isotonic saline allows for longer operating times without worrying about dilutional hyponatremia with glycine, which is used with monopolar. There is no increase in complications with BiTURP, and comparable stricture and bladder neck contracture rates were seen when compared with MonoTURP. In one study, lower clot retention rates were seen with BiTURP.[8] In a meta-analysis by Lee et al comparing MonoTURP with BiTURP, BiTURP showed a significant greater reduction in IPSS scores, improvement in maximum flow rates, improvement in patients' ability to empty their bladder as measured by the quantity of urine remaining in the bladder after voiding, and better satisfaction. BiTURP was also associated with fewer complications and shorter catheterization time.[9]

Greenlight Photo-Vaporization

Similarly to TURP, a cystoscope is used to gain access and visualization to the prostate. However, unlike a standard

Table 2 Complications of BPH-associated bladder outlet obstruction

Complications of BPH
Renal insufficiency
Acute urinary retention
Urinary tract infection
Bladder stones
Bladder decompensation
Urinary incontinence
Upper urinary tract deterioration and azotemia
Hematuria

Abbreviation: BPH, benign prostatic hyperplasia.

TURP, contact is not made with the tissue and the ideal working distance is between 1 and 2 mm from the tissue surface. The laser is swept across the tissue surface until complete vaporization of desired tissue is achieved. A 532-nm laser is utilized: this wavelength is used because it is preferentially absorbed by hemoglobin molecules, making it ideal for vascular tissue such as the prostate.[10] Tissue vaporization occurs when energy from the laser is absorbed by the hemoglobin within the target tissue. Advantages over TURP include technical simplicity, minimization of complications, and ability to treat larger glands with less physiological stress. The postoperative management typically involves analgesics and limited strenuous activity for 1 week. A catheter is used for bladder drainage and is typically discontinued after 1 day. Te et al compared TURP to Greenlight photo-vaporization

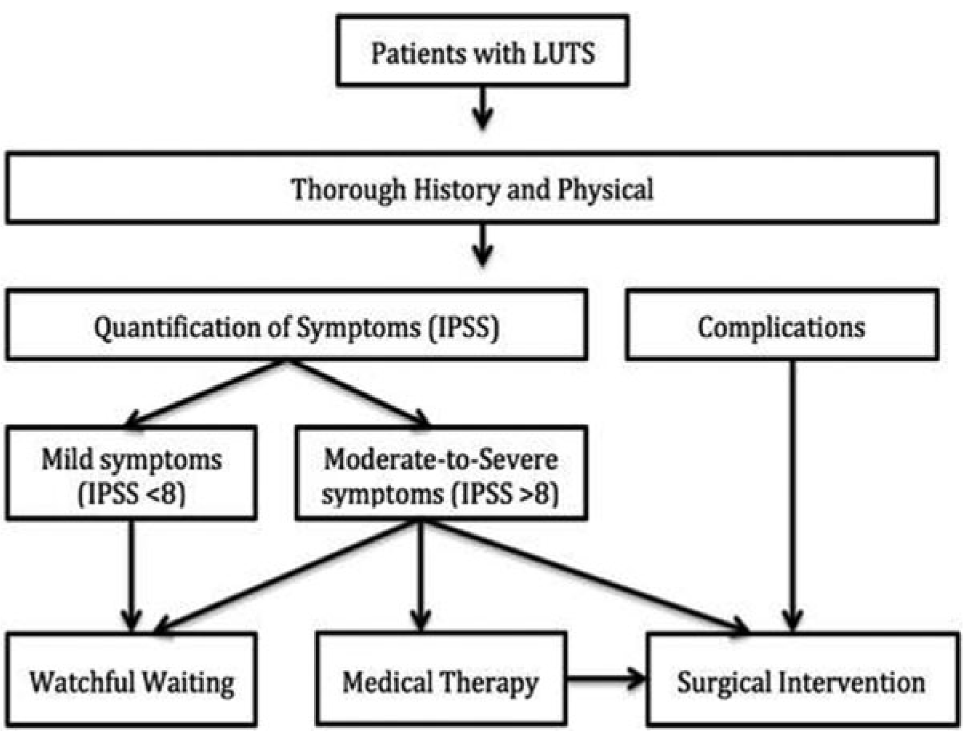

Fig. 1 Medical and surgical management of benign prostatic hyperplasia (BPH) according to symptom severity and complications.

(G-PVP) and found that complications are minor and can include mild-to-moderate dysuria, transient hematuria, postoperative retention, and retrograde ejaculation. They also found significant improvements in AUA symptom index scores (24–1.8), quality-of-life scores (4.3–0.4), Qmax (7.7–22.8 mL/s), and post void residual (PVR) volumes (114.2–7.3 mL) up to 12 months postoperatively.[11] Importantly, photoselective vaporization is safe to use in anticoagulated patients with high risk for clinically significant bleeding. In a study of 116 men on anticoagulation, Ruszat et al saw no clinically significant intraoperative bleeding and no postoperative blood transfusions were required.[12] Recently, Thangasamy et al[13] performed a systematic review with meta-analysis from 2002 to 2012. They reviewed 9 trials with 448 patients undergoing G-PVP (80 W in 5 trials and 120 W in 4 trials) and 441 undergoing TURP. And as seen in ►**Table 3**, they confirmed that perioperative outcomes of catheterization time and length of hospital stay were shorter with PVP; postoperative blood transfusion and clot retention were significantly less likely with PVP; and overall, no difference was noted in intermediate-term functional outcomes.

Greenlight Enucleation

An alternative is a more expedient enucleation and subsequent tissue morcellation rather than a lengthy vaporization. Laser enucleation applies the primary advantages of lasers over electrocautery to very large prostates, and there is no size limitation and allows patients who would otherwise undergo an open simple prostatectomy to receive the benefits of a minimally invasive procedure.[14] Vaporization of a large prostate may be limited by the time needed to complete the procedure. Transurethral laser enucleation of the prostate also utilizes a 532-nm laser. The first step with this technique is creating a midline groove at the 6-o'clock position through the median lobe down to the level of the trigone. Instead of large sweeping motions used in traditional vaporization, quick sweeping motions and proximal–distal movements of the fiber are used to create the groove. Another groove is then created on the 5-o'clock side of the median lobe. The tissue in between the grooves is then vaporized using larger sweeps starting from the apex. Small fragments of prostate tissue are enucleated and are evacuated at the end of the case. A similar procedure is repeated on the 7-o'clock side of the median lobe. This process is repeated for the lateral lobes with grooves created at the 11-o'clock and 1-o'clock positions. After the lateral lobes have been enucleated, the anterior prostate and then the apical tissue are vaporized.[15]

Holmium Laser Ablation

Similarly to Greenlight laser vaporization, the holmium laser may also be applied to prostatic tissue as an ablative modality. It can be used on prostates of any size, as studies show that this technique maintains its effectiveness in much larger glands. Holmium laser ablation is also an excellent option for anticoagulated patients due to its hemostatic properties. In previously radiated patients, holmium is preferred over all other energy modalities because of its minimal penetration depth and risk of overtreatment.[16,17] The wavelength of a holmium laser is 2,100 nm, which has a high absorption in water leading to a favorable absorption coefficient in the prostate. The prostate cells absorb the energy from the laser, resulting in their vaporization with excellent hemostasis. The energy from the laser is delivered via small, flexible fibers and is controlled through a foot pedal by the surgeon. It is one of the safest energies available due to the superficial absorption of the laser in a fluid environment. It has a relatively short learning curve compared with other surgical techniques for treating BPH.[18] Patients are typically managed with a two-way 20-F Foley catheter for 1 to 2 days after the procedure. If a patient was self-catheterizing before the procedure, it is recommended that the catheter be left in for 3 to 5 days and removed in clinic or at home after a voiding trial. Patients are discharged on an antimuscarinic and instructed to either stop α-blockers and 5-ARIs or finish what medications they have left at home. In a study comparing HoLAP to PVP, similar results were found with significant improvements in flow rate, PVR, IPSS, and bother scores. These results were durable with up to 3 years of follow-up.[19,20]

Holmium Laser Enucleation

Similarly to the Greenlight laser, holmium laser may also be used for the enucleation of the prostate rather than its vaporization. Holmium enucleation of the prostate utilizes a laser with a wavelength of 2,120 nm placed through a 6-F ureteral catheter for protection and is performed using a 27-F

Table 3 Comparison of G-PVP outcomes as compared with TURP in the treatment of symptomatic BPH[13]

Perioperative parameter evaluated	Outcome
Mean catheterization time	Shorter (−1.91 d)
Mean length of hospital stay	Shorter (−2.13 d)
Mean operation time	Longer (+19.64 min)
Safe for anticoagulated patients?	Yes (not with TURP)
Relative risk of blood transfusion	0.16 as compared with TURP
Relative risk of clot retention	0.14 as compared with TURP

Abbreviations: BPH, benign prostatic hyperplasia; G-PVP, Greenlight photo-vaporization; TURP, transurethral resection of the prostate.

continuous flow resectoscope. The procedure begins by making bladder neck incisions at the 5-o'clock and 7-o'clock positions. The median lobe is then dissected on the capsule toward the bladder neck in a retrograde fashion. The enucleation of the lateral lobes is then done by first extending the initial bladder neck incisions laterally and circumferentially at the apex working toward the 2-o'clock and 10-o'clock positions. A bladder neck incision is then made at the 12-o'clock position down to the capsule and the incision is continued circumferentially laterally to release the lateral lobes. The enucleated prostate tissue is then removed via morcellation. Out of all the laser modalities used for BPH surgery, HoLEP has the greatest level 1 evidence with the longest follow-up to date, is cost-effective, and is the only technique that can reliably replace open prostatectomy. A Foley catheter is placed post-procedure and can be removed the following morning. HoLEP was found to be superior to TURP in regard to postoperative complications. Perioperative and late adverse events including acute urinary retention (AUR) secondary to blood clot formation, urinary tract infection (UTI), bladder neck stricture, and urethral stricture formation were found to be similar to TURP.[21–23] Holmium laser enucleation has the largest number of randomized clinical trials comparing it with TURP and open prostatectomy compare with any other laser technology. These trials show that catheter time and hospital stay are consistently shortened in patients undergoing HoLEP. HoLEP also resulted in significantly greater improvement in Qmax, urodynamics, and IPSS reduction when compared against TURP.[21–23]

Plasma Button Vaporization

Similarly to the Greenlight and holmium lasers, "The Plasma Button" delivers energy to the prostate to allow for its vaporization rather than its resection. Plasma kinetic technology creates an ionized plasma corona using radiofrequency energy. This is accomplished using an electroconductive solution and an axipolar electrode. This electrode is in the shape of a button and functions as both the working element and the return electrode. The plasma corona created by this "button" vaporizes tissue while achieving hemostasis. A radiofrequency range of 320 to 450 kHz is utilized with a voltage range of 350 to 450 V and a 200-W capacity.[24–26] Compared with monopolar TURP, bipolar plasmakinetic vaporization of prostate (BPKVP) resulted in a significantly decreased rate of clot retention, TUR syndrome, hematuria, and rehospitalization for hemorrhage. It provides practitioners with shorter operative times for a similar complication profile. It was shown to result in a significantly greater decrease in IPSS and PVR.

Transurethral Microwave Therapy

TUMT is used by some urologists for patients who have failed medical therapy and want to avoid surgical intervention. A specially designed urinary catheter is placed into the bladder, allowing a microwave antenna to be positioned within the prostate. The antenna uses radiant heating to ablate the prostatic tissue. The prostate tissue is then heated to temperatures of 45 to55°C, causing necrosis of the prostate tissue. This procedure can be performed on an outpatient basis and takes between 30 and 60 minutes. It is far less invasive compared with other modalities and associated with a lower need for anesthesia and a shorter hospital stay. Postoperatively, the patients are managed with catheterization with times ranging from a few days to several weeks. Complications of TUMT include hematuria, urinary retention, dysuria, urgency, UTIs, retrograde ejaculation, erectile dysfunction, and stricture. When compared with TURP, incidence of hospitalization, hematuria, clot retention, blood transfusions, TUR syndrome, and urethral strictures is significantly lower for TUMT; however, the opposite was true for catheterization time, dysuria, and urinary retention.[27–29] A 5-year follow-up of patients undergoing TUMT showed sustained subjective improvements in IPSS despite a decrease of Qmax after 24 months. These outcomes have also been shown to persist in patients after 8 years of follow-up using urodynamic parameters for evaluation.[30,31] This treatment has fallen out of favor over the recent years due to the lack of long-term results and its use has declined in popularity in most urologic practices as a result.

TUNA

In TUNA therapy, low-level radiofrequency energy is utilized to heat prostate tissue and create a controlled, localized necrotic lesion. Radiofrequency energy is delivered directly into the prostate through a catheter device using adjustable needles that are placed in selected areas of the prostate tissue. An ideal candidate for TUNA is a patient with prostate volume less than 60 g and one with lateral lobe involvement. It can be performed in the office under topical anesthesia. Postprocedure management consists of either conducting a voiding trial or catheter placement. The most common complications include postprocedure acute urinary retention and irritative voiding symptoms. In one multicenter randomized trial, 14% of TUNA cases required further interventions for continuing BPH symptoms within 2 years.[32] In a meta-analysis performed in 2004, TUNA therapy resulted in a 50% reduction of mean IPSS scores at 1 year that was sustained for 5 years albeit with an increase from year 1 to 5. Qmax 5 years after treatment was greater than 50% increased from baseline.[33] This treatment has also fallen out of favor over the recent years due to the lack of long-term results.

Prostatic Tissue Approximation (Urolift)

The Urolift is a prosthesis that resembles a small suture connected to an anchor that is implanted under endoscopic guidance with the aim of retracting the prostatic urethra toward the prostatic capsule to open the prostatic urethral space. It is constructed from two tabs, a stainless steel urethral tab and a nitinol capsular tab. A needle is deployed transurethrally beyond the prostatic capsule and delivers suture-based implants that are placed under tension (►**Fig. 2**). This mechanically retracts the prostatic lobes to open the prostatic urethral space. This procedure can be performed on an outpatient basis under local anesthetic block. Urolift has been found to have significantly lower morbidity than other surgical treatments for BPH-associated LUTS. Documented complications include hematuria, dysuria, and bladder spasms. An expanded Australian multicenter study was performed in 2012 that evaluated 64 patients who received the Urolift procedure with follow-up up to 2 years. This study found a reduction in IPSS scores from a mean baseline of 22.6 to 12.6 after 2 years. Peak flow rate at 2 years increased to 10.3 mL/s from a baseline of 7.4 mL/s. Retreatment was necessary in 20% of men treated and included either photoselective vaporization of the prostate or TURP.[34]

Prostatic Stents

Prostatic stents are an attempt at decompressing the prostatic urethra, which is obstructed by compression of the enlarged prostate. Stents are placed endoscopically into the prostatic urethra to tent open adenomatous tissue and open the bladder outlet. These stents can either be permanent or temporary. Permanent stents promote epithelialization and anchor into the prostatic stroma. Temporary stents are prohibitive of tissue ingrowth and can either be retrievable or biodegradable. Temporary stents can be performed on patients who are poor candidates for procedures involving general anesthesia. In the 2007 systematic review consisting of 990 subjects with BPH receiving the permanent UroLume Wallstent, 16% of the 606 patients followed up after 1 year sustained stent failure with the majority due to stent migration. The removal of these stents after failure can be challenging and requires procedures under general anesthesia, effectively defeating the purpose of stent placement in high-risk patients.[35] IPSS scores decreased by 10 points to 12.4 and Qmax increased by 4.2 units to 13.1 mL/s.[35]

Prostatic Artery Embolization

Prostatic artery embolization requires a well-trained interventional radiologist, due to the complexity of the vascular anatomy of the prostate as well as the possible complications that could arise. The procedure is done under local anesthesia on an outpatient basis. Embolization is performed via unilateral femoral approach; the catheter is then advanced through the common femoral artery to the internal iliac artery and to the inferior vesicle artery before arriving at the ostium of the prostatic arteries. 100 to 300 and 300 to 500 µm microspheres mixed in a 20-mL 50–50 saline/contrast solution are then injected into the prostatic arteries.[36]

Patients are instructed not to move the punctured leg for 4 to 6 hours after the procedure to avoid bleeding complications. The Foley catheter is left in place for 2 to 4 hours and then removed if the patient is not in acute urinary retention. This modality can be an option for patients not eligible for minimally invasive procedures. Inclusion criteria for prostatic artery embolization include age more than 40 years, prostate volume more than 30 cm^3, diagnosis of BPH refractory to medical therapy for more than 6 months, IPSS greater than 18 and/or QoL greater than 3, and acute urinary retention.[37] Exclusion criteria include malignancy, bladder anomalies, chronic renal failure, acute urinary infection, unregulated coagulation parameters and tortuosity, and advanced atherosclerosis of the iliac or prostatic arteries. Common complications are similar to other visceral embolization procedures and include nausea, vomiting, and fever in the absence of infection. Other symptoms include dysuria, pelvic pain, and small amounts of blood mixed with urine and stool known as the "post-prostatic artery embolization (PAE) syndrome."[38] Short-term outcomes at 12 months show a 50% decrease in IPSS scores from 23 to 24 to a mean of 10.4, a 50% increase in Qmax, and a decrease in quality-of-life scores from 4 to 2. Similar results were seen at 24 months, although limited data are available. The only long-term data available include two patients at 4 years. Magnetic resonance imaging from these patients suggests signs of de novo prostate growth raising concern for the long-term efficacy of PAE.[39]

Ethanol Injection

Ethanol may be injected in the prostate to destroy tissue and decrease prostate size. Using an injection device, ethanol (in

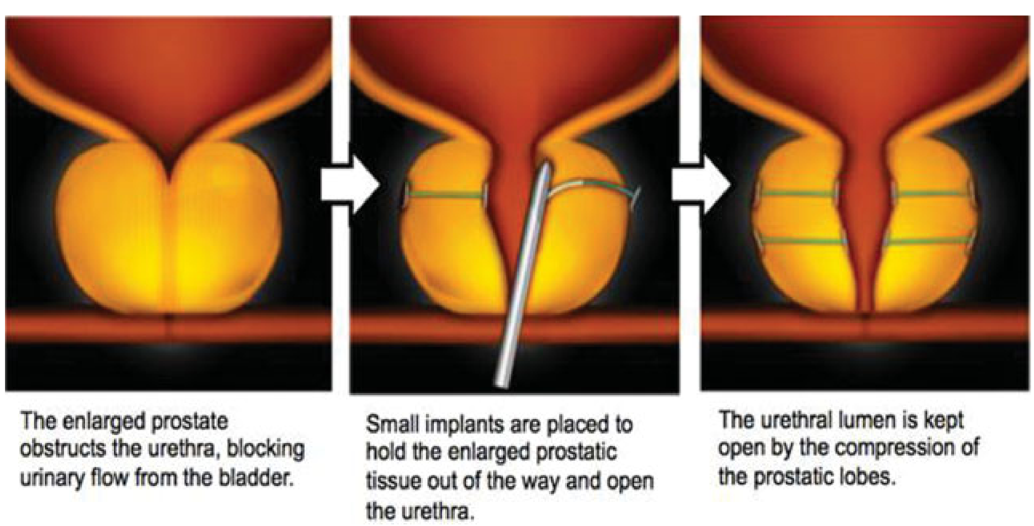

Fig. 2 Urolift device illustration (Image courtesy of NeoTract, Inc.)

the 95–98% anhydrous form) is injected into the prostate typically at the 3-o'clock and 9-o'clock positions with a variable third injection used for larger prostates. The injection dose is usually between 5 and 26 mL and is often calculated based on TRUS-measured prostatic volume.[40,41] Ethanol destroys prostatic tissue by creating inflammation, endothelial cell dehydration, and protein denaturation, ultimately leading to atrophy of the tissue. This procedure is minimally invasive, can be performed in the office, and does not require anesthesia. The most commonly seen side effect of ethanol injection is postoperative urinary retention requiring Foley catheterization. Other common side effects include dysuria, hematuria, and pelvic pain. A German review published in 2013 totaling 515 patients using injection quantities ranging from 2 to 26 mL showed unpredictable reductions in prostate volume, PVR, and increase in Qmax. All studies showed significant improvements in IPSS ranging from −40 to 74%.[42]

Botox Injection

Botox may be injected in the prostate to decrease prostatic outflow obstruction by decreasing prostatic smooth muscle tone and inducing atrophy. Under transrectal ultrasonographic guidance, patients receive botulinum toxin via a transperineal injection in the transition zone. The toxin exerts its effect by chemical denervation, leading to inhibition of smooth-muscle contraction and tissue atrophy. Botox injection can be performed on an outpatient basis and does not require general anesthesia. Sacco et al[43] found no complications during treatment or after follow-up at 3 months. Patients reported a decrease in mean IPSS scores of 49% from 19.7 to 10.0 and a mean reduction in quality-of-life scores of 44% from 4.17 to 2.3. This treatment is still a part of clinical trials and not standard urological care.

Summary

BPH-related symptoms are very common in the aging male. They are principally caused by the challenge the bladder faces (during urination) in surmounting the pressure exerted by the enlarged prostate positioned at its outlet. Invasive treatments are delayed until the risk of complications or degree of bother to the patient is significant. If patients fail a trial of medical therapy, invasive intervention is indicated. These patients seek to decrease the outlet pressure exerted by the prostate via the following strategies: (1) decreasing prostate size by removing prostate tissue (e.g., TURP, laser enucleations), (2) decreasing prostate size by tissue vaporization (e.g., plasma button, laser vaporization), (3) prostatic urethra stenting (e.g., Urolift, stents), (4) prostatic smooth-muscle paralysis (e.g., botox), and (5) prostatic tissue necrosis by (a) injecting toxic substances into the prostate (e.g., ethanol), (b) delivering radiofrequency energy to the prostate (e.g., TUNA), or (c) reducing oxygen delivery to the prostate (e.g., embolization).

The parameters used to assess all modalities are durability of resolution of storage and voiding symptoms, length of recovery period, complication rates, and patient eligibility. The gold standard of treatment for BPH remains the TURP, which utilizes electrocautery to endoscopically resect prostatic tissue. Although this treatment modality is more invasive than many others, it has stood the test of time, has the longest term data, is effective with acceptable complication rates, and remains the most used today.

Conclusion

The interventional radiologist should understand BPH and the modern, minimally invasive surgical treatment options. As outlined in the AUA guidelines, surgical intervention is recommended for patients with moderate-to-severe symptoms of BPH and for patients who have experienced BPH-related acute urinary retention or other complications. Multiple options are available to clinicians, which should be selected according to the patient's anatomy, comorbidity, and risk factors.

Conflict of Interests

Z.A. is/was an advisor for the UK National Institute for Health and Clinical Excellence (NICE) and the National Institute for Health Research (NIHR)—Health Technology Assessment (HTA) Program and user/trainer of various male anti-incontinence devices manufactured by American Medical Systems.

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