REVIEW

Minimally invasive surgery for benign prostatic obstruction: new insights and future technical standards

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Purpose of review
This review aims to give a brief description of the latest minimally invasive surgical techniques (MISTs) for the treatment of benign prostatic obstruction (BPO).

Recent findings
In recent years technological advances have made the implementation of MISTs in the armamentarium of BPO surgery possible and in many cases could replace standard procedures.
These techniques offer many advantages –short recovery time, rapid symptomatic relief, few adverse effects, lower risk of sexual/ejaculatory dysfunction, acceptable durability and most can be performed as an outpatient procedure.
Many of the newer MISTs can be performed outside the operating room under local anesthesia, hence the term office-based MIST.

Summary
A tailored BPO surgical treatment should not only take into account the prostate volume, but also many other factors including possible adverse events and the patient's expectations.
Further studies and long-term data are necessary to standardize methods for evaluating the outcomes of these new procedures and to see which will pass the test of time and end-up replacing the gold standard procedures.

Keywords
benign prostatic hyperplasia, benign prostatic obstruction surgery, minimally invasive surgical technique, prostate surgery

INTRODUCTION

The most common urological diagnosis for men over fifty is benign prostatic hyperplasia (BPH), which causes lower urinary tract symptoms (LUTS).

Transurethral resection of the prostate (TURP) and open simple prostatectomy are still currently the most commonly used techniques around the world for surgical BPH treatment and have been the gold standard for over a century.

In the last two decades, transurethral laser prostatectomy has become a standard procedure.

Transurethral needle ablation of the prostate (TUNA) could be considered the first attempt at a minimally invasive surgical treatment for BPH in the 1990s, however, due to a high reoperation rate it is no longer recommended by the American Urological Association (AUA)/European Association of Urology (EAU) guidelines [1▪▪,2▪▪].

Transurethral microwave therapy (TUMT) was also removed from the EAU Guidelines in 2019, although it is still recommended by the AUA guidelines.

The defining criteria of a minimally invasive surgical technique (MIST) is unclear, however in the literature there seems to be a consensus in some basic aspects they must fulfill, like a short recovery time, well-tolerated, rapid symptomatic relief, few adverse effects, lower risk of sexual/ejaculatory

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KEY POINTS

- The development and use of new MISTs for BPO surgery have been made possible by advances in technology using different mechanisms and energy sources.
- The fact that most MISTs are easy to perform with a short learning curve makes them especially attractive and accessible for the majority of urologist, facilitating their general implementation as an alternative to standard surgical procedures.
- The most important advantages of MISTs are few adverse effects and low risk of sexual/ejaculatory dysfunction.
- The durability of new MISTs has only been studied up to five years.

dysfunction, short learning curve, acceptable durability and most can be performed as an outpatient procedure.

MISTs are not intended to replace standard surgical procedures, but in some cases, they can be an alternative to them as well as to medical therapy.

Over the past 6 years newer MISTs have been introduced, and many of them can be performed outside the operating room and using only local anesthesia, hence the term office-based MIST was coined (Table 1).

Furthermore, office-based MISTs and hospital-based minimally invasive procedures are considered one in the same, when in reality they are not, because generally the latter require an operating room, spinal or general anesthesia and at least a one-day hospital stay [3].

PROSTATIC URETHRAL LIFT

The Urolift (Neotract Inc., Pleasanton, CA, USA) is a nonablative technique based on mechanically opening the prostatic urethra with permanent suture-based implants delivered under cystoscopic guidance, creating a channel from bladder neck to the verumontanum. The prostatic urethral lumen is mechanically widened to relieve the obstruction using nitinol capsular anchor implants that create a transprostatic tissue compression.

The indications for the standard technique are glands < 80 g without an obstructing median lobe, however, Rukstalis *et al.* have reported that the obstructive median lobe can be treated safely and efficiently using a modified prostatic urethral lift (PUL) technique with similar results to the standard only lateral lobes technique [4].

The procedure can be performed in an office-based setting under local anesthesia and normally catheterisation is not required [5].

PUL has been shown to provide durable improvement in LUTS associated with BPH. At 5-year follow-up, International Prostate Symptom Score (IPSS) scores improved by a mean of 35%, urine flow rates improved 50%. PUL has been shown to successfully preserve sexual function, with no significant changes in IIEF-5 or MSHQ-EjD scores [5]. No anejaculation was reported after the procedure.

The 5-year surgical retreatment is 13.6% and the medical retreatment rate is 10.7%.

Sievert *et al.* [6] offered PUL as an alternative to TURP to 86 patients in a prospective and multicentric study. They reported a significant improvement in mean IPSS (51%), Quality of Life (QoL) (52%), post-void residual volume (PVR) (70%) and Qmax (27%) over the 2 year follow-up. Eleven patients (12.8%) reported persistent LUTS, 9 of which were retreated with TURP and 1 with another PUL procedure.

REZUM

Rezum (Rezum System, Boston Scientific, Marlborough, MA) is a treatment for benign prostatic obstruction (BPO), using radiofrequency energy to convert sterile water into steam, which is transurethrally injected under direct vision into the prostatic tissue with a small needle. The heat transfer mechanism is convection and the energy is precisely targeted and contained within prostate anatomy, avoiding damage to surrounding structures.

Rezum might seem similar to TUNA, when actually they are completely different procedures, the main difference is the mechanism of heat transfer (Table 2).

The objective is to create contiguous overlapping thermal lesions between the bladder neck and proximal to the verumontanum. Each treatment last 9 s and the average total procedure time is 2–4 min.

The procedure is done under local anesthesia with oral pain medication, prostatic block or under IV sedation.

The Rezum procedure is capable of treating not only the lateral lobes but also the central zone without any morphological restrictions (intravesical median lobe is not a limitation) [7].

Catheterization after the procedure is normally 2–7 days (according to the size of the prostate).

The prostate size limit is 80gr, however, some authors have reported promising results with larger glands, but requiring longer catheterization time [8▪,9,10▪,11].

Table 1. Comparative summary of Minimally invasive surgery for BPO

Procedure	Approach	Mechanism	EAU guidelines	AUA guidelines
Urolift	Nonablative	Mechanical compression-Permanent implant	*Nonablative technique* for patients interested in preserving the ejaculatory function in prostates up to 70 mL without a median lobe. Functional improvements at 2 years are inferior to TURP according to RCTs	For patients: prostate volume <80 mL, without obstructive median lobe and who want to preserve sexual/ejaculatory function. (Moderate Recommendation; Evidence Level: Grade C)
iTIND	Nonablative	Mechanical compression-Temporary implant	*Nonablative technique under investigation* RCT comparing it with TURP is being carried out currently	Not mentioned in the AUA guidelines
Spring System	Nonablative	Mechanical compression-Permanent implant	Not mentioned in the EAU guidelines	Not mentioned in the AUA guidelines
ClearRing	Nonablative	Mechanical compression-Permanent implant	Not mentioned in the EAU guidelines	Not mentioned in the AUA guidelines
Rezum	Ablative (delayed)	Convective water vapour energy therapy	*Alternative ablative technique under investigation*—stills lacks long term results and RCT compared to a gold standard technique.	For patients: prostate <80 mL, who want to preserve erectile/ejaculatory function. (Conditional Recommendation; Evidence Level: Grade C)
PAE	Ablative (delayed)	Embolization of prostatic vessels	*Alternative ablative technique* For patients who are willing to accept inferior outcomes compared with TURP	Not supported by current data and trial designs. Benefit over risk remains unclear. Not recommended outside the context of clinical trials.
TPLA	Ablative (delayed)	Percutaneous tissue ablation	Not mentioned in the EAU guidelines	Not mentioned in the AUA guidelines
Aquablation	Ablative (immediate)	Heat-free, Robotic waterjet ablation	*Alternative ablative technique*—RCT that demonstrated that Aquablation offers noninferior functional outcomes compared to TURP in prostates between 30-80 mL	For patients: prostate >30<80 mL (Conditional Recommendation; Evidence Level: Grade C). Long term evidence of efficacy and retreatment rates, remains limited

Procedure	Outpatient procedure	Feasible under local anesthesia	Office procedure	Prostate vol.	Median lobe	Post-OP Catheter	Anejaculation	Surgical retreatment rate
Urolift	Yes	Yes	Yes	<80mL	Feasible	No	0%	13.6% at 5 years
iTIND	Yes	Yes	Yes	<60mL	Not recommended	No	0%	8.6% at 3 years
Spring System	Yes	Yes	Yes	25–80mL	–	–	–	–
ClearRing	–	–		35–80mL	Not recommended	1–2 days	0%	–
Rezum	Yes	Yes	Yes	30–80mL	yes	2–7 days	0–10.8%	4.4% at 5 years
PAE	Yes	Yes	Yes	≥30 mL	Yes	–	16%	21% at 2 years
TPLA	Yes	Yes	Yes	<80 mL.	Yes	7–9 days	–	–
Aquablation	No	No	No	30–150mL	Yes	1–3 days	11–19%	4.3% at 3 years

BPO, benign prostatic obstruction; PAE, prostatic artery embolization; TPLA, transperineal interstitial laser ablation.

Table 2. Rezum vs TUNA

Rezum	TUNA
Heat transfer mechanism: convection	Heat transfer mechanism: Conduction
Controlled energy transmission	Uncontrolled energy transmission (directly into the tissue)
Anatomically contained energy	Uncontained energy (heating of prostate capsule may occur)
9 s per treatment (each injection)	3 min per treatment (each injection)
Average total procedure time: 4–8 min	Average procedure time 20–60 min
5-year surgical retreatment rate: 4.4%	5-year retreatment rate: up to 40%
EAU guidelines: Alternative ablative technique under investigation	Removed from the EAU Guidelines in 2019

EAU, European Association of Urology; TUNA, transurethral needle ablation of the prostate.

A multicenter randomized controlled trial (RCT) of Rezum with a follow-up period of 5 years including 197 subjects with symptomatic BPH, randomized to treatment and sham control (rigid cystoscopy) in a 2:1 ratio with prostate volume of 30–80 cm3 without morphological restrictions. Qmax increase was 49%. IPSS, QoL and BPH impact index improvements were 48%, 46% and 49%, respectively [12▪▪].

Most common related adverse events included: dysuria (18.1%), hematuria (11.7%), hematospermia (6.4%), urinary frequency (5.9%), retention (5.9%) and urgency (4.8%).

The 5-year surgical retreatment is 4.4% and the medical retreatment rate is 11.1% [12▪▪].

PROSTATIC ARTERY EMBOLIZATION

Prostatic artery embolization (PAE) has been considered a safe and efficient procedure for selected cases, however, it is technically complex and requires the participation of a multidisciplinary team of urologists and experienced interventional radiologists.

This procedure is mostly indicated for patients who refuse surgery or are unfit for surgery/anesthesia due to important comorbidities.

PAE can usually be done as outpatient procedure under local anesthesia without having to stop anticoagulant treatments [13].

A recent single-center randomized trial including 103 patients compared the efficacy and safety of PAE and TURP with 24 months of follow-up and reported lower mean reduction in IPSS in the PAE group vs TURP group (9.21 vs 12.09).

Qmax improvement was 3.9 mL/s and 10.23 mL/s in the PAE and TURP group, respectively [14▪▪].

PVR reduction was significantly less in the PAE than TURP arm (62.1 vs 204 mL).

Prostate volume reduction was 10.66 vs 30.20 mL in PAE and TURP groups, respectively.

Complications were less frequent after PAE than after TURP. The anejaculation was 16% vs 52% in PAE and TURP, respectively.

The reported surgical retreatment rate after PAE was 21% at 2 years [14▪▪].

The latest evidence demonstrates that PAE compared with TURP offers inferior functional outcomes and should only be offered in centers with experienced interventional radiologists to very select patients who are willing to accept a high surgical retreatment rate [14▪▪].

AQUABLATION

Aquablation (AquaBeam System, PROCEPT BioRobotics, Redwood Shores, California, USA) is a image guided robot-assisted water-jet ablation of the prostate procedure, combining an integrated cystoscope with intra-operative TRUS images as an alternative to TURP [15]. It is feasible for the treatment of large prostates (80–150 mL) [16], representing a potential option in place of simple prostatectomy and endoscopic enucleation of the prostate.

Aquablation is performed under general or spinal anesthesia and usually involves an overnight stay.

A large international blinded randomized trial showed that aquablation had a similar level of efficacy compared to TURP and better ejaculatory function preservation [15]; similar results were found in patients with larger (80–150 cc) prostates in a prospective multicentre trial [16]. Bach *et al.* reported similar functional outcomes in clinical routine, as reported in RCTs [17].

Aquablation is based on semi-autonomous, robot-executed tissue resection whose limits are automatically suggested by the computer [18].

This procedure is one of the first robotic platforms in urology to incorporate a type of artificial intelligence and offer procedure automation, even though in the end it is the surgeon who defines the limits of the resection area of the procedure [18,19▪▪]. Therefore, the success of Aquablation depends more on the instruments than on the surgeon's skill, and not depending only on a surgeon's ability is a big step toward surgical standardization in the future.

ITIND

iTind is a temporary nitinol implant (iTind; Medi-Tate Ltd, Hadera, Israel) that is left in for 5–7 days and reshapes the prostatic urethra. The device uses nitinol struts located at the 12, 5 and 7 o'clock positions which create ischemic pressure to incise the bladder neck and resolve the BPO.

The device is implanted under direct vision using a standard rigid or flexible 19F–22F cystoscope, as an outpatient procedure, under IV sedation or local anesthesia. The total average procedure time is 3–5 min. Catherization is not required after the procedure.

The implant is removed with an open-ended 22F Foley standard catheter under local anesthesia.

Amparore *et al.* [20▪▪] reported in a 3-year prospective, single arm, multicenter clinical study of 81 patients with average prostate volume of 40.5 ml, considerable functional improvements in IPSS, QoL, Qmax and PVR of $8.55 + 6.38$, $1.76 + 1.32$, $15.2 + 6.59$ ml/s and $9.38 + 17.4$ ml, improved from baseline by -58.2, $-55.6 + 114.7$, and -85.4% (all with $P < 0.0001$).

No intraoperative complications were reported. Postoperative complications were Clavien–Dindo I or II and resolved in a month. No sexual or ejaculatory dysfunction was observed.

The 3-year surgical retreatment rate was 8.7% (8 patients) and 6.2% (5 patients) required drug therapy [20▪▪].

Chughtai *et al.* [21] reported a prospective, randomized, controlled, single-blinded study compared to sham arm (insertion and removal of an 18F silicon Foley catheter). 175 patients (118 iTind vs 57 sham), prostate volume 25–75cc. An IPSS of -9.0 ± 8.5 points (40.1%) and -9.25 in IPSS ($P < 0.0001$) were noted in the iTind arm at 3 and 12 months, respectively.

Complications were mostly Clavien-Dindo grade I or II in 38.1% of patients in the iTind arm and 17.5% in the control arm. No de novo ejaculatory or erectile dysfunction occurred. The surgical retreatment rate a 12 months was 4.7%.

CLEARRING

ClearRing is a permanent, open ring-shaped nitinol implant with the objective of reshaping the prostatic urethra. The ring is placed in the prostatic urethra with a 24F delivery system composed of a tip with a balloon dilator over which a cutting cautery blade creates the space where the implant is placed. The device is inserted transurethrally and the balloon is inflated to expand the obstruction in the prostatic urethra and then a small electrode on the outside of the balloon creates a circumferential incision in the tissue around the prostatic urethra through which the implant will be inserted, and this way the implant is not in direct contact with the urine.

The patient is discharged with a catheter for 24–48 h.

Feld *et al.* in a multicenter single-arm clinical trial involving 29 cases, mean prostate size of 35–50 cm^3 reported mean improvements in IPSS, QoL, and Qmax by 45%, 41%, and 40% at 3 mo, and 53%, 52%, and 49% at 12 mo, respectively ($P < 0.05$). No loss of antegrade ejaculation or erectile disfunction was observed [22].

All procedures were done under spinal anesthesia. No serious complications occurred. The most common adverse events were transient hematuria (100%), dysuria (6%) and urgency (6%). Implantation failed in 38% of the cases because of implant malpositioning and all required a TURP.

SPRING SYSTEM

The Spring is a permanent nitinol implant that is placed into the prostatic urethra using a flexible cystoscope, however, it could be removed at any time if necessary.

This device is under investigation (the Zenflow Spring System Safety, Performance and Effectiveness Study, ZEST2, ClinicalTrials.gov identifier: NCT03595735). Currently in the literature, there are no publications.

TRANSPERINEAL INTERSTITIAL LASER ABLATION

This procedure is based on the principle of percutaneous tissue ablation. Depending on the prostate volume and shape, up to four applicators (21-gauge Chiba needle) are required and the procedure is guided by an ultrasound.

Transperineal interstitial laser ablation (TPLA) is performed under IV sedation combined with local perineal anesthesia and transrectal prostatic block [23].

Mauri *et al.* [24]. reported a retrospective multicenter study of 160 patients with a follow-up of at least 6 months and of 83 patients with a follow-up of at least 12 months. Mean hospital stay was 1.8 ± 0.4 days, and mean catheterization time was 12.6 days.

At 12 months, IPSS improved from 22.5 ± 4.5 to 7.0 ± 2.9 ($P < 0.001$), Qmax from 8.6 ± 5.2 to 15.0 ± 4.0 ml/s ($P < 0.001$). Complications were mostly low grade.

The authors reported 2/160 (1.2%) patients with lost of ejaculatory function (ejaculatory function was not evaluated with a specific questionnaire).

OUTPATIENT HOLMIUM LASER ENUCLEATION OF THE PROSTATE PROCEDURE WITH SAME DAY CATHETER REMOVAL

Holmium laser enucleation of the prostate (HoLEP) is one of the most studied surgical procedures in Urology. Since it was first described by Peter Gilling [25], HoLEP has evolved not only in the technique but also in the technology, using high power lasers and pulse modulation technologies [26,27].

Normally after the procedure patients are discharged in 24–48 h without catheter. Recently some authors have demonstrated that HoLEP is possible as an outpatient procedure in selected cases.

Krambeck *et al.* [28▪▪] reported a feasibility pilot study for same day catheter removal after HoLEP for patients not undergoing anticoagulation therapy and with prostates < 250 mL.

A high-power laser with Moses 2.0 optimized for BPH technology (Lumenis Ltd, Yoknaem, Israel) was used in all the procedures. Continuous bladder irrigation was employed postoperatively in all cases.

This was a retrospective study of 30 patients, median prostate volume of 81 mL (37–235 mL). 30% of patients had a catheter before the procedure.

The median enucleation time was 39.5 min, morcellation time 5 min and enucleated specimen weight was 52.5 g (33–81). 90% (27) of patients were same day catheter free after a median time of 4.9 h from the end of the procedure. No 90-day complications or surgical reinterventions were reported.

Functional outcomes: Median IPSS score was 5, QoL 1, PVR was 16 mL and PSA was 0.7 ng/dl.

Despite the fact that this is only a feasibility retrospective study with a small number of cases, it can still be considered a step forward in HoLEP's evolution into a truly minimally invasive outpatient catheter free procedure.

One of the known drawbacks of HoLEP is the steep learning curve and the high rate of ejaculatory dysfunction. Kim *et al.* [29] reported 76.9% of total anejaculation after HoLEP.

CONCLUSION

A tailored BPO surgical treatment should be offered according to the patient's clinical profile, age, prostate volume, anticoagulant treatment and comorbidities, taking into account the patient's expectations, possible adverse events, outcomes and durability of each procedure.

Future technical standards in the armamentarium for BPH surgery will rely on the implementation of new technologies and insights.

There are many emerging BPO surgical procedures currently under investigation and only time will tell which procedures will become the new standard.

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Conflicts of interest

E.R.: Boston Scientific, Meeting Speaker, Proctor, Advisory Board; Medi-Tate, Clinical studies; Olympus, Proctor, Speaker; Procept BioRobotics, Speaker, Proctor, Advisory Board.
R.H.: Boston Scientific, Meeting Speaker, Proctor, Advisory Board.
S.T.: None.
T.B.: Meeting Speaker, Trial participation: Boston Scientific, Boston, Medi-Tate, Olympus, Procept BioRobotics.

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- ▪ of special interest
- ▪▪ of outstanding interest

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