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REVIEW ARTICLE

Benign prostatic hyperplasia: A review of current trends in surgical management

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Abstract

Benign prostatic hyperplasia (BPH) is a common cause of lower urinary tract symptoms (LUTS) in men. It is a disorder that interferes with normal daily activities, thereby affecting the quality of life of the individual. Multiple modalities of treatment can be utilised. These include lifestyle advice, watchful waiting, medical therapy and surgical therapy. In terms of surgical therapy, varied patient, regional, socioeconomic and prostate characteristics, as well as technical skills, influence therapy choice. Currently, established techniques worldwide still confirm endoscopic resection using monopolar energy in pole position, while open surgery (particularly in sub-Saharan Africa) still prevails in the choice of surgeons because it is more accessible, both from a socio-economic standpoint and in the training of the surgical personnel. In this article, we will review the evolution of surgical therapy and current trends in surgical management and how this can be adapted to developing regions in terms of technological advancement and economic implications. Deliberate focus is placed on those contemporary minimally invasive surgical techniques that are emerging as providing strong and reproducible levels of efficacy.

Keywords: *benign prostatic hyperplasia (BPH)*; *minimally invasive surgical therapy (MIST)*; *Prostate*; *lower urinary tract symptoms (LUTS)*; *transurethral resection of prostate (TURP)*

Benign prostatic hyperplasia (BPH) is a common cause of lower urinary tract symptoms (LUTS) in men. It is a disorder that interferes with normal daily activities, thereby affecting the quality of life of the individual. Multiple modalities of treatment can be utilised. These include lifestyle advice, watchful waiting, medical therapy and surgical therapy. In terms of surgical therapy, varied patient, regional, socio-economic and prostate characteristics, as well as technical skills, influence therapy choice. Currently, established techniques worldwide still confirm endoscopic resection using monopolar energy in pole position, while open surgery (particularly in sub-Saharan Africa) still prevails in the choice of surgeons because they are more accessible, both from a socio-economic standpoint and in the training of the surgical personnel. In this article, we will review the evolution of surgical therapy and current trends in surgical management and how this can be adapted to developing regions in terms of technological advancement and economic implications. Deliberate focus will be placed on those contemporary minimally invasive surgical techniques that are emerging as providing strong and reproducible levels of efficacy.

Benign Prostatic Hyperplasia

BPH is the non-cancerous enlargement of the prostate gland. It involves both stromal and glandular epithelial hyperplasias that arise in the periurethral transition zone of the prostate (Fig. 1). It is a histologically diagnosed disease and is present in 8% of men aged between 41 and 50 years, 40–50% of men aged between 51 and 60 years, 70% of men aged between 61 and 70 years, and more than 80% of men aged older than 80 years [1]. The causes of BPH are not fully known, but the overgrowth of smooth muscle tissue and glandular epithelial tissue is attributed to a number of different causes such as ageing, race, late activation of cell growth, genetic factors and higher serum levels of testosterone and oestradiol [2, 3].

Clinically, it manifests as a constellation of symptoms broadly divided into storage or irritative symptoms

(frequency, urgency, nocturia) and voiding or obstructive symptoms (hesitancy, a weak and interrupted urinary stream, straining to initiate urination, a sensation of incomplete bladder emptying). These altogether are referred to as lower urinary tract symptoms (LUTS). The severity of these can be assessed with the aid of a questionnaire (International Prostate Symptom Score [IPSS]) (Fig. 2). The prevalence of LUTS due to BPH increases with increasing age [4]. Prolonged obstruction may eventually lead to acute urinary retention (AUR), recurrent urinary tract infection (UTI), bladder calculi, renal insufficiency and haematuria [5].

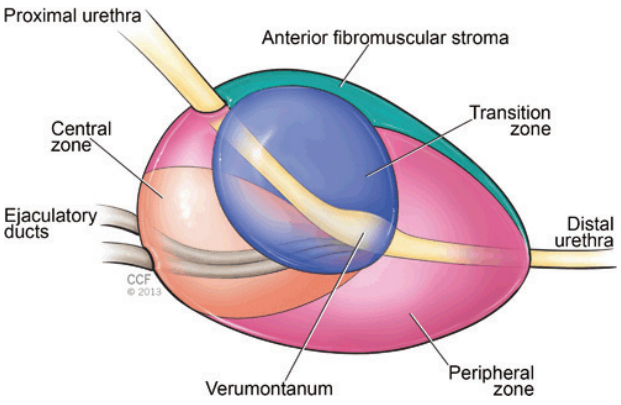

Fig. 1. Prostate zonal anatomy [6].

The specific approach used to manage BPH in the individual patient depends upon a number of factors including severity of symptoms, age, prostate size, prostate-specific antigen level and, of course, the availability of relevant technical skills and equipment (Fig. 3).

Evolution of surgical therapy in BPH

The enlarged prostate with its concomitant problems has plagued men over the ages. In 1649, Jean Riolan was the first to suggest that the enlarged prostate could cause urinary retention [7]. Catheters and tunnelling techniques were used to relieve retention. In 1575, Ambrose Parè [8] is credited with performing the first definite operative procedure on the enlarged prostate. He devised a punch-type instrument that consisted of a hollow sound through which a harp-edged hemispherical tip fastened to a wire was passed, so that the operator could advance the tip after passage. When the tip was pushed forward, the surrounding tissue would fall into this space and be clipped off when the tip was then pulled back against the sharp edge of the sound. This principle of using a cutting implement through a hollow tube inserted into the urethra to incise, crush or remove obstructing prostate tissue is the basis of endoscopic prostatic surgery today. Chopart also wrote in 1831, stating that in 1756, Lafaye passed a lance-shaped stylet through an open-end catheter to pierce the median lobe. His patient lived in comfort with only occasional need for catheterization for about 10 years.

IPSS questionnaire

Over the past month, how often have you...	Not at all	Less than 1 time in 5	Less than half the time	About half the time	More than half the time	Almost always	YOUR SCORE
1. ...had a sensation of not emptying your bladder completely after you finish urinating?	0	1	2	3	4	5	
2. ...had to urinate again less than two hours after you finished urinating?	0	1	2	3	4	5	
3. ...stopped and started again several times when you urinated?	0	1	2	3	4	5	
4. ...found it difficult to postpone urination?	0	1	2	3	4	5	
5. ...had a weak urinary stream?	0	1	2	3	4	5	
6. ...had to push or strain to begin urination?	0	1	2	3	4	5	
7. Over the past month, how many times did you most typically get up to urinate from the time you went to bed at night until the time you got up in the morning?	None	Once	Twice	3 times	4 times	5 times or more	
						TOTAL	

8. QUALITY OF LIFE DUE TO URINARY SYMPTOMS
If you were to spend the rest of your life with your urinary condition the way it is now, how would you feel about that?

Delighted	Pleased	Mostly satisfied	Mixed – about equally satisfied & dissatisfied	Mostly dissatisfied	Unhappy	Terrible
0	1	2	3	4	5	6

Fig. 2. International Prostate Symptom Score questionnaire for assessing LUTS.

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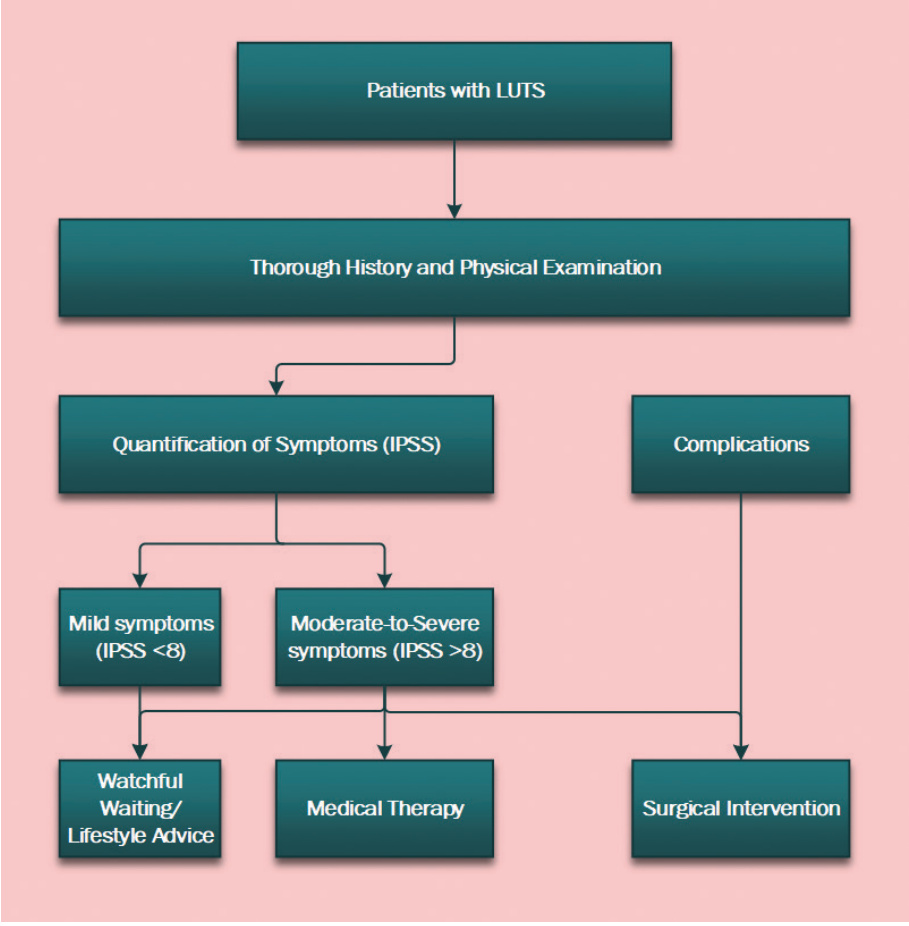

Fig. 3. Management of BPH according to the severity of symptoms and complications.

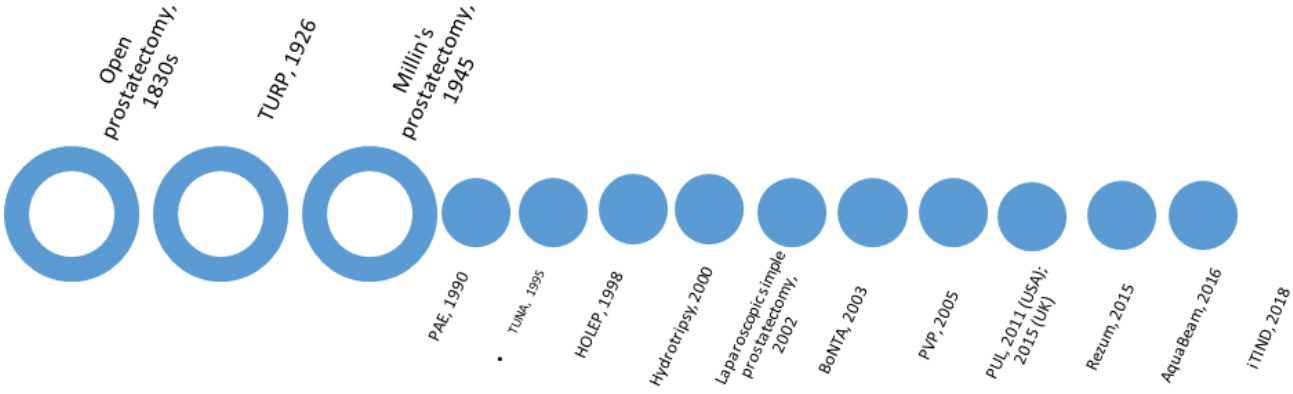

Fig. 4. Timeline of surgical therapies for BPH.

However, an enlarged prostate with a false passage was confirmed at autopsy [7].

Open adenectomy was discovered by accident in the treatment of stones, particularly through perineal lithotomy. Apparently, the first person to recognize the possibility of treating the enlarged prostate by removing obstructing prostatic tissue while performing a perineal lithotomy was Sir William Fergusson in the 1830s [9]. During the procedure, some prostatic tissue was caught in the forceps and inadvertently removed. The patient voided more easily afterwards, and this was replicated in further procedures. He did not suggest that this

operation be done primarily for the enlarged prostate, but only as an adjunct to a lithotomy. In 1903, H.H. Young [10] described his perineal prostatectomy operation using a prostatic retractor to hold the prostate steady in the perineal wound whilst the capsule was incised and the lobes enucleated under direct vision. Various attempts at suprapubic prostatectomy failed as they left obstructing tags of tissue. However, Terence Millin popularised the retropubic technique in 1945 by suturing the capsule and draining the bladder with a urethral catheter [11].

Transurethral resection of the prostate (TURP) developed following the invention of the cystoscope by Nitze in 1877, the first practical incandescent light bulb by Edison in 1878, the fenestrated tube by Young in 1900 and the use of high frequency electrical current under water by Beer in 1910 [12]. The Stern-McCarthy resectoscope [13, 14], as it became known, was the first practical cutting-loop resectoscope, and monopolar TURP (M-TURP) emerged as the dominant method used to treat the enlarged prostate for the next 80 years.

A quest for a minimally invasive surgical therapy (MIST) comparable to M-TURP but with less complications, recurrence of LUTS or need for reoperation has been ongoing [15]. Prostate ablation with thermal energy was the initial technique employed with post-operative oedema and sloughing causing preliminary exacerbation of pre-existent LUTS [16], and collateral damage to sexual function as well as inconsistent outcomes. These therapies include microwave, steam or radiofrequency ablation. Lasers were improved to make them less traumatic, with small prostate volumes (PV) and at lower powers [17]. Nd:YAG laser used in 1992 by Costello for visual laser ablation of the prostate caused a 7 mm coagulative necrotic depth (CND) and was eventually replaced by potassium-titanyl phosphate (KTP) with a 2 mm CND with a shorter wavelength (532 nm) [17]. Various hybrid techniques between Nd:YAG and other lasers have been tried such as holmium laser in 1994 by Peter Gilling [18] and KTP by Graham Watson [19] in 1995, with sole use of the latter lasers being eventually adopted. Holmium laser enucleation (HoLEP), probably the most common current iteration holmium prostate surgery for BPH, was developed in the 1990s. The quest to avoid thermal therapy birthed the prostatic urethral lift and water-jet ablation that were more psychologically acceptable to consumers and had a lower incidence and shorter duration of post-operative haematuria or peri-operative exacerbation of LUTS. The persistent need for concomitant medical therapy in up to 25% despite receipt of MIST drove research for more effective techniques [20].

By serendipity, Mirandolino Mariano in 2002 [21] discovered simple adenomatous enucleation during a laparoscopic radical prostatectomy and reported its use in a 71-year-old with a 173 g benign prostate and blood loss of 800 ml. With better experience, blood loss became significantly less than the open procedure; it could be used for very large prostates, obviated the TURP syndrome and was also deemed advantageous in reducing hospital stay, pain and immobilisation. However, it had such a steep learning curve, was time-consuming and was ergonomically tasking [22, 23]. Neither extraperitoneal or transperitoneal approaches, nor the use of the robot has conferred significant advantages although it is reasonable to acknowledge the ergonomic advantages of the robotic technique [24]. In addition, neither has gained widespread use with more focus on the development of more minimally invasive endoscopic options in the last decade. Figure 4 summarizes some key milestones in the evolution of BPH surgical therapy.

Current trends

This will be discussed using Table 1 to highlight the characteristics of each procedure. Note incremental cost-effectiveness ratio of various MIST in comparison with combined medical therapy (α-blocker + 5-α reductase inhibitor) by the 2-year follow-up mark are depicted in Figure 9.

Table 1. Surgical procedures for various prostate volumes

Prostate volume	Day case/office	In-patient
≤30	Prostatic urethral lift (PUL) Aqua ablation	
>30–80	PUL (up to 60 cc) Photoselective vaporisation of the prostate (PVP) Prostiva (up to 50 cc) Rezum (up to 80 cc) iTemporary implantable nitinol device (up to 60 cc) Botulinum neurotoxin A (BoNTA) (200 U)	Aqua ablation (up to 60 cc) PVP
>80	Prostatic artery embolisation (PAE) BoNTA (300 U)	Transurethral resection of prostate (TURP)/TURiS (Trans-urethral resection of prostate in saline) Holmium laser enucleation of prostate (HoLEP) Laparoscopic prostatectomy/robot-assisted simple prostatectomy

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In-patient MISTs

TURP monopolar versus bipolar

TURP is still considered the benchmark of BPH surgical management as it is the standard against which other therapeutic measures are compared. It is useful in the management of patients with a prostate volume between 30 and 80 cc [1]. In experienced hands, this could also be performed in prostate sizes up to 120 cc.

It is performed with the insertion of a rigid resectoscope to cut off the prostatic tissue with a metal loop through which current is delivered. When this is monopolar current, it is known as monopolar TURP (M-TURP), while with the use of a bipolar resectoscope, this is the bipolar TURP (B-TURP) [5]. The use of a bipolar loop allows for the use of isotonic saline as the irrigating fluid, thus allowing for longer resecting times and larger prostates [25].

The complications associated with the procedure include post-TURP syndrome, bleeding, urethral stricture, bladder neck contracture, retrograde ejaculation, erectile dysfunction and incontinence. In a prospective randomised clinical trial (RCT) comparing M-TURP with B-TURP, 497 patients with a mean age of 67.4 years and a prostate volume of 54 cm^3 were divided into the two groups and followed up for 36 months. There was no statistical difference in the parameters studied which included surgery time, catheterisation time, peak flow improvement (Qmax), occurrence of urinary retention, IPSS and quality of life (QoL) scores and PSA drop. B-TURP, however, proved to be superior in relation to hospitalisation time, blood transfusion rate, post-TURP syndrome, serum sodium rate and lower occurrence of urethral stenosis [26].

In a systematic review and meta-analysis evaluating the Qmax and IPSS as well as the safety of B-TURP versus M-TURP, 31 RCTs with 3,669 patients were studied [27]. Regarding efficacy (Qmax and IPSS), relevant clinical differences in the Qmax were observed in favour of B-TURP. Regarding safety, the almost non-occurrence of post-TURP syndrome and the low incidence of clot retention, urethral stenosis and bladder neck stenosis/contracture have recently led to a greater use of B-TURP compared with M-TURP.

Some studies done in the developing world have considered using other irrigating fluid apart from saline and glycine as well as the option of caudal anaesthesia [28] to reduce hospital stay and cost implications. The irrigating fluid in these instances has been water. However, the risks of water precipitating a dilutional hyponatraemia are well recognised.

Advantages

Sustained improvement in LUTS, short learning curve, short hospital stay compared to simple open prostatectomy, longer resection times and reduced TURP syndrome risk with B-TURP.

Contraindications

Not advised in exceptionally large prostates (>120 cc) or in patients with coagulopathies. Requires dedicated training with longish learning curves.

Cost

Capital cost: 16,000 USD for generator and setup. Consumables: Electrodes 40 USD and irrigation fluid 55–1790 USD.

Technology required

Resectoscope setup, consumables (electrodes and irrigation fluid).

Adaptability to low resource settings

Caudal anaesthesia, careful selection of patients suitable for day-case procedures and use of water rather than saline or glycine reduces costs (water vs. saline vs. glycine: 1–29 USD vs. 5.5–179 USD vs. 55–1,790 USD).

HoLEP

Holmium enucleation of the prostate uses a holmium laser to core out the prostate and a morcellator to break it up into retrievable pieces. It is termed the 'endoscopic alternative to open prostatectomy' as it can be used for prostates of any size, even as large as 800 g [29]. When compared with TURP, it was superior in PV reduction, with a shorter hospital stay, catheterisation duration and reoperation rate (0 to <1% vs. 7.6–18% for TURP). It had a longer resection time but was equivalent in LUTS resolution and sexual function post-operatively [30]. It caused significantly smaller blood loss, shorter hospital stays and shorter catheterisation periods than open surgery for prostates >70 g [31] and >100 g [32] but had equivalent efficacy and complication profile.

Advantages

Useful in prostates >100 cc, non-inferior to TURP/open prostatectomy, shorter hospital stay and catheter time, and tissue retrievable for histology.

Contraindications

Active UTI/prostatitis.

Cost and technology required

Significant capital costs for the morcellator and laser generator (Versapulse, Lumenis Inc., Santa Clara, CA, USA). A resectoscope and a stack are also needed. Consumables consist of single-use laser fibres, stabilising 6Fr Catheter, morcellator blade, omni-jugs and suction tubes. If HoLEP fibres (SlimLine™ 550 end-firing, Lumenis or DuoTome™ SideLite™ side-firing, Boston Scientific, Marlborough, MA, USA) were reused, 188 USD would be saved [33]. When compared to open prostatectomy, HoLEP was cheaper and cost 2919.4 USD

versus 3556.3 USD [34]. The technique has a longish learning curve and is relatively difficult to learn; this may increase the cost initially, but with improved skill, shorter operation time and lower complication rates, it becomes cheaper [35].

Adaptability to low-resource settings

Reusable fibres would be cost-effective. Low power adaptations would also save cost. The report of a recently concluded clinical trial, NCT0273724, comparing 50 and 100 W HoLEP laser is awaited from Egypt.

Laparoscopic/robotic-assisted simple prostatectomy

This is useful in patients with a prostate volume >80 cc with moderate to severe IPSS scores as an alternative to open simple prostatectomy or endoscopic enucleation with HoLEP. These techniques emerged to reduce morbidity associated with the standard open technique. Open, simple prostatectomy is invasive with associated morbidity such as rates of bleeding and blood transfusion ranging from 7 to 14% [36, 37], bladder neck stenosis in up to 6% [38, 39], as well as prolonged hospitalisation time and post-operative catheterisation; and its noted that the risk of these complications rise with prostate volume [40].

Mariano et al. [21] published the technique to perform simple laparoscopic prostatectomy (LSP) for BPH. This allowed for transcapsular or transvesical adenomectomy through extraperitoneal access. In 2008, robot-assisted simple prostatectomy (RASP) was first reported utilising the intraperitoneal approach [41].

In a recent meta-analysis, 27 studies involving 764 LSP and RASP were evaluated. This concluded that minimally invasive techniques offer similar improvement in functional outcome (Qmax and IPSS) but have a longer surgical time when compared with simple open prostatectomy with the advantage of lesser blood loss and shorter hospital stay [42].

The largest retrospective multicentre study evaluating minimally invasive techniques with 487 RASP and 843 LRP looked at 1,330 patients in 23 American and European institutions. This concluded that the functional results are similar, regardless of the technique used, with similar IPSS, Qmax and sexual function in a 12-month follow-up [43]. Similar to HoLEP, these techniques are technically demanding with a more intensive training requirement.

Advantages

Useful in prostates >100 cc, non-inferior to TURP/open prostatectomy, shorter hospital stay and catheter time, and tissue retrievable for histology.

Cost, technology and adaptability to low-resource settings

Could be introduced as part of an intensive laparoscopic/minimally invasive programme in an institution already performing other established laparoscopic urological procedures, but still relatively costly in time and training requirement.

Day-case MISTs

Prostatic artery embolisation (PAE)

PAE was first used to treat BPE in 1990, but had been used to control reactionary haemorrhage following a TURP since 1977. High-risk surgical candidates such as the elderly, those with significant co-morbidities who had failed medical therapy, or patients with intractable or recurrent significant haematuria of prostatic origin are amenable to therapy with PAE [43, 44]. PAE is useful with prostate sizes above 100 cc, resulting in up to a 29% size reduction, and is in fact not limited by prostate size [43, 45, 46]. Russo et al. [47] advocated it for prostates ≥80 cm^3 and patients with Charlson co-morbidity indices ≥3.

A trans-radial or trans-femoral catheter is passed to the most distal arterial feeding vessels supplying the prostate gland unilaterally or bilaterally, with resultant cessation of haematuria and gland involution, as well as improvement in LUTS [46]. The embolising agent could be gel foam, cyanoacrylate and coils but balloon occlusion catheters and smaller embolising agents (nanoparticles or microspheres) improve selectivity [46]. The nanoparticles are usually made of polyvinyl alcohol and range between 150 and 250 μm. The use of particles ≤100 μm resulted in a faster relapse of LUTS due to time-lag revascularisation of the vessels, while use of microspheres >300 μm could end up in more proximal vessels leading to loss of limb. Technical complications could arise from aberrant anatomy, 'premature stasis' which could result in inadequate or non-target vessel embolisation. This could be minimised by the use of dilute solutions, intermittent saline flushes, use of microcatheters to access even the small calibre vessels, and ensuring distal microcatheter placement and further embolisation after initial embolisation (**PE**r**F**ec**TED** technique: '**P**roximal **E**mbolisation **F**irst **T**hen **E**mbolise **D**istal') [48].

Advantages

Can be done under local anaesthesia or sedoanalgesia, as a day-case procedure [46]. Useful in high-risk patients with significant co-morbidities.

Contraindications

Severe arteriosclerosis. Superselective embolisation may not be possible because of unfavourable vascular anatomy. Other contraindications include urethral stricture,

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contrast allergy, prostate <40 cc, acute prostatitis and prostate cancer.

Cost

It costs 2,062 USD per procedure. Cost reductions gained by the use of local anaesthesia or sedoanalgesia; 1472.77 USD for TURP versus 1080.84 USD for PAE and the shorter hospital stay and catheter requirements (5338.31 USD for TURP vs. 1678.14 USD) were reduced by the more expensive consumables (2153.64 USD for PAE vs. 1667.10 USD for TURP), but overall, PAE was cheaper than TURPs and a viable option for out-of-pocket expenditure, which occurs commonly in African nations [49].

Technology required

Pre-procedural computerised angiography or less commonly, magnetic resonance angiography to define the vascular anatomy. Consumables (embolising agents).

Adaptability to low-resource settings

Hardware for procedure and imaging on loan/donation/research funding will be required.

Transurethral needle ablation of the prostate (TUNA) Prostiva® RF therapy by Urologix Inc. (Medtronic, Minneapolis, MN, USA)

This is a technique introduced in the late 1990s which uses low energy radiofrequency delivered through two needles to ablate prostatic tissue by heating and creating a localised necrotic lesion which is slowly resorbed. Prostiva® RF therapy reaches intraprostatic temperatures of 110°C allowing it to create a lesion in the tissue in just 2 min and 20 sec while preserving the urethra [50]. It deploys these adjustable needles under direct vision with the aid of a cystoscope. A transrectal ultrasound scan of the prostate is required for treatment planning purposes. The ideal patient is one with a prostate volume between 20 and 50 cc with a prostate transverse diameter between 34 and 80 mm [51]. It can be carried out under local anaesthesia as a day-case procedure and poses low or no risk for incontinence and impotence. It is contraindicated in patients with penile implants, implantable defibrillators or neurostimulation devices. Complications include post procedure AUR and irritative voiding symptoms as well as chronic prostatitis. In one multicentre randomised trial, 14% of TUNA cases required further interventions for continuing BPH symptoms within 2 years [52].

Histotripsy

This is a modification of high intensity focussed ultrasound (HIFU). It can be done under sedation and is safe in anticoagulated patients [53]. It became FDA-approved in 2000 for the treatment of BPH. It uses extra-corporeal high-frequency long-pulsed ultrasonic waves under TRUS-guidance to generate agitation-induced thermal energy up to 60–85°C and a 'micro-bubble cloud' or cavitations in the prostate following tissue liquefaction. The process is contained within the capsule, with minimal attendant, bruising, haematoma or fibrosis [53].

Peri-urethral tissue requires higher frequency pulses than glandular tissue for ablation. Pulses above 10,000/cm^3 may damage the rectum, but not the bladder neck, trigone or urethral sphincter, with trigonal oedema and transient hydronephrosis when pulses ≥100,000/cm^3 are used [54]. Rectal mucosal protection through cooling is also advised. A time-limited response (24–28 months) to HIFU was seen in 66% of patients with PV ≤ 75 cc before requiring TURP [55], with no significant improvement in Qmax and PVR recorded. Thus, HIFU is not a recommended therapy for BPH by NICE in the UK [56]. In addition, the more modern histotripsy devices and software are expensive and associated with a steep learning curve.

Botulinum neurotoxin A (BoNTA)

Although the therapeutic use of botulinum toxin in man began in 1980, it was not till 2003 that its use in BPE in humans was documented. It has been shown to be capable of reducing the static and dynamic obstruction in BPH [57]. Of the seven *Clostridium botulinum* serotypes (A–G), A is the most effective one. It may be administered transrectally, transperineally or, less commonly, transurethrally [58] as 100 U, 200 U and 300 U, respectively, or even up to 600 U, 100 U and 200 U doses are recommended for volumes of ≤30 cc and >30 cc [59], and 300 U for prostates >80 cc. It causes a dose-dependent inhibition of urethral norepinephrine release, and down-regulation of α_1-adrenergic receptors occurs to reduce urethral resistance and prostatic bulk. BoNTA is able to reduce dopamine, enkephalin and VIP concentrations as well, in addition to glycine, γ-aminobutyrate and 5-hydroxytryptamine [60]. It also decreases existent detrusor overactivity. It is peculiar in its ability to cause atrophy without necrosis or attendant inflammation seen in other minimally invasive techniques. Despite the acclaimed benefits, a randomised controlled trial found no significant difference when 315 men with PVs between 30 and 80 cc were treated with either BoNTA or placebo [61].

Green light photoselective vaporisation of the prostate (PVP)

This was first described in 1995 and approved in 2005 for BPH treatment [17, 62]. KTP laser is transmissible through fluids and is absorbed by haemoglobin in prostatic tissue; it heats up intracellular water, resulting in photoselective vaporisation. Its beam is green; thus, the name 'greenlight' laser. It initially was made to generate a wattage of 80, but this gradually increased to 180

(GreenLight XPS®, Boston Scientific, USA), with improved outcome. It effects pulsed coagulation for rapid and effective haemostasis. Although prostates up to 60 cc may be treated within half an hour, Ajib et al. [63] reported a 62-min resection time average for 370 men with an average PV of 78.8 cc.

When compared to TURP, although it took significantly longer, there was less blood loss and it was equivalent in LUTS resolution by the 6-month follow-up, with a slightly lower complication rate, low reoperation rates, less hospital stay and days of catheterisation [64]. One study reported removal of catheters within 24 h post-PVP [65]. It is deemed to be more cost-effective than TURP (4,661 USD vs. 4,821 USD). More fibres may be required for larger prostates [65]. This cost-effectiveness remains true when the capital cost of the laser generator is not included. The savings incurred are less when PVP is compared to mTURP; in the publicly funded NHS of the UK, the potential to save over 3.2 million pounds sterling yearly is entertained if PVP is adopted in lieu of TURP [62]. Such hospitals have the offer of obtaining the laser generator on loan if they expect large turnovers. Green light laser is technically less demanding with a shorter learning curve in comparison with HoLEP.

Fig. 5. PUL implant delivery device.

Advantages
Less collateral damage (urethral strictures/ bladder neck stenosis) due to short penetration depth.

Contraindications
Anticoagulant use or PVs ≥ 100 cc were previously absolute contraindications [17] but one study enrolled patients on anticoagulants without significant adverse effects [65].

Cost
It costs 4,661 USD/procedure. Each laser fibre costs 735 USD.

Technology required
22Fr cystoscope, special 'side-emitting' MoXy® laser fibre. GreenLight XPS™ Laser System (180 W), reusable MoXy™ liquid-cooled fibres, protective video camera filtres, KTP/532 protective eyewear, gas seals.

Adaptability to low-resource settings
System on loan, water as irrigant instead of saline.

Prostatic urethral lift (PUL)
With the UroLift® (NeoTract, Pleasanton, CA, USA), non-absorbable sutures are used to abduct the intraurethral lateral prostatic lobes, anchoring them to the prostatic capsule. An average of four sutures is required. The ideal patient has an IPSS > 12, Qmax ≤ 12 ml/s, 30–80 cc prostate, voided volume of >125 ml and post-void residuals (PVR) <250 ml [16]. A 20Fr cystoscope is required through which the implant delivery device is inserted (Fig. 5), which is then able to deploy a 19G needle containing monofilament with metallic 'staples' that secure them in place at 10 and 2 o'clock, 1.5 cm away from the bladder neck (Fig. 6). With improved practitioner skill, there is a decreased need for post-operative catheterisation and greater IPSS reduction. The **L**uminal **I**mprovement **F**ollowing prostatic **T**issue approximation (LIFT) study compared it to placebo resulted in no ejaculatory or sexual dysfunction [66], but did show a 13.6% requirement for re-operation, with 32% needing post-operative

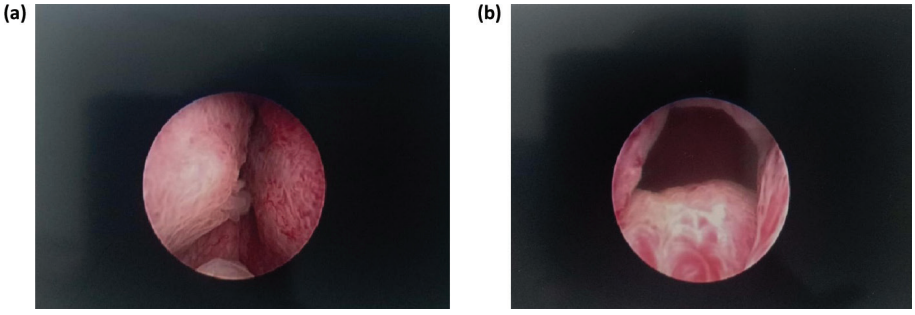

Fig. 6. Before and after PUL.

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catheterisation. Although the metallic 'staple' is meant to invaginate into the prostatic urethra, epithelialise and therefore pose no obstruction to future urethral instrumentation, 6.7% still developed implant encrustations from improper implant deployment [16]. Other side effects include perineal discomfort, implant-related haematuria, UTIs and chronic epididymitis [67]. A MedLIFT study showed PUL to be effective in the presence of median lobes as well. The technique is modified to pull the intravesical protrusion intraurethrally and staple it laterally. This required additional sutures, maintained day-case status of the procedure, but resulted in a 1–2 day post-operative catheter requirement [68].

PUL serves a narrow patient cohort [16, 69]. In Africa, the larger prostate volumes may render this option moot. In one of the Nigerian sub-populations, an average PV of 83.8±37.7 cc was reported [70]. In addition, concern has been expressed about the difficulties in assessing the prostate (for prostate cancer) by MRI subsequently due to minor but definite signal interference on MRI scanning.

Advantages

Preservation of continence and sexual function, day-case procedure under local anaesthesia and short learning curve.

Contraindications

Prostates >80 cc, UTIs including prostatitis, prior MIST for BPE, post-void residual >350 ml, prior urine retention or detrusor overactivity. A median lobe is a relative contraindication. The MedLIFT study has shown relevance in the presence of median lobes.

Cost

In the USA, it is quite expensive and requires a cystoscopy and urodynamic studies to exclude a median lobe/bladder stones and detrusor overactivity, respectively, in addition to the implants, the total cost of which is quoted as 6,230 USD by the 2-year follow-up under the Medicare/Medicaid insurance scheme [71]. In comparison to TURP and Rezūm, each additional reduction in IPSS attributable to UroLift is 240 USD and 3,058 USD more expensive to achieve, respectively [71]. On the contrary, on the UK front, when the savings from reduced hospital stay, operating time or tariffs were input, there was a net saving of 28,727 USD in one hospital when compared with TURP over a half-year period [72].

Technology required

20Fr cystoscope, implant delivery device, disposable 19G needles and implants.

Adaptability to low-resource settings

Careful patient selection. Research into cheaper materials to be used as implants with development of a multiple implant delivery device.

Transurethral water vapour (steam) thermal therapy (Rezum, Boston Scientific, Marlborough, MA, USA)

This is a relatively new minimally invasive water vapour thermal therapy utilising convective radiofrequency. It is often referred to as convective **WA**ter **V**apour **E**nergy (WAVE) ablation therapy of the prostate [73]. It has been used in patients with moderate to severe IPSS scores with prostate volumes between 30 and 80 cc. It works by converting water into vapour, which condenses and changes to water, with transfer of heat energy to the tissues to cause heat denaturation of membranes and cell death.

This thermal energy is provided by a radiofrequency generator. With endoscopic viewing access provided by a 30° Storz^{tm} cystoscope, a specially designed handheld device with a retractable needle delivers the vapour into the target tissue, under direct vision, within a 9 sec cycle (Fig. 7). Each 9-sec treatment uses 0.42 ml of radiofrequency-heated sterile water vapour. Over 1–3 months, this ablated tissue is resorbed by the body (Fig. 8).

Studies have been carried out in a prospective and randomised manner to either the active group or sham group. So far, the data have been promising with a surgical retreatment rate of 4.4% over 4 years and a 47% decline in IPSS score with 50% improvement in Qmax [74].

In a recent meta-analysis [75], 5 cohorts comprising 514 patients were included. The median prostate volume was 46 cc with a median IPSS score of 20 and median Qmax of 9.9 ml/s pre-treatment. The results across board showed significantly improved Qmax (13 ml/s) and IPSS scores [11] post-treatment.

Advantages

Suitable as a day-case procedure, medium-term outcomes now available show sustainable improvement in symptoms, suitable for patients with median lobe, preservation of sexual function.

Contraindications

Patients with penile prosthesis or urinary sphincter implant, high pressure chronic retention and large prostate burden.

Cost

It costs 1600 USD per procedure for the consumables. RF generator.

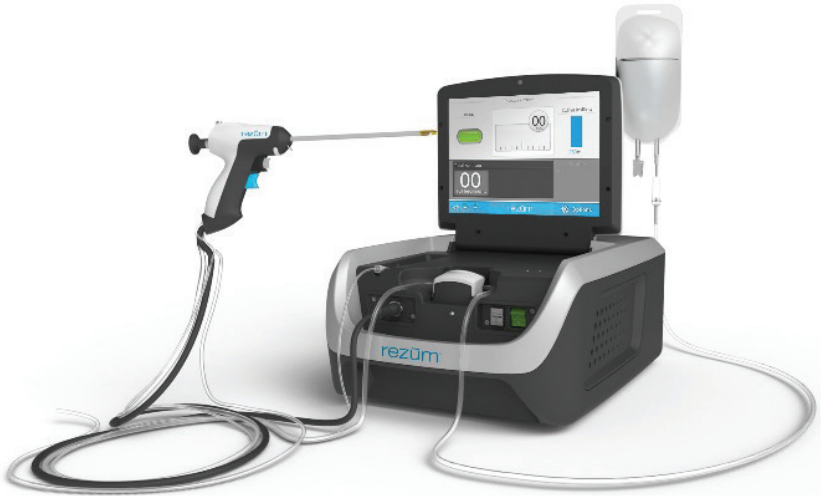

Fig. 7. Rezum setup showing radiofrequency generator with handpiece [73].

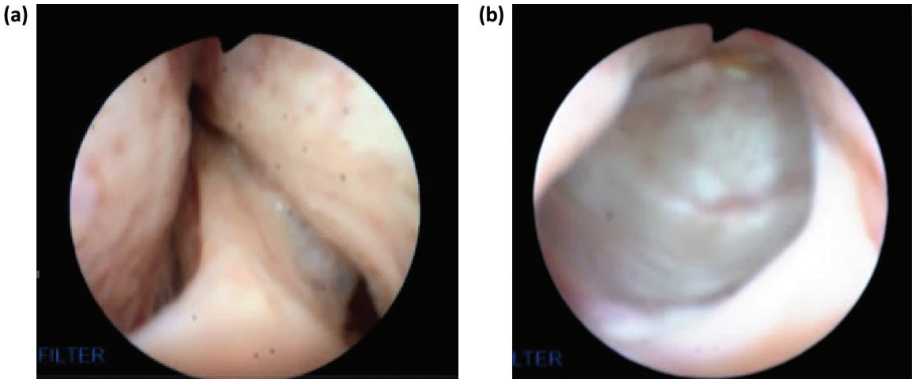

Fig. 8. Cystoscopic appearance of the prostatic lobes pre-Rezum therapy and 6/12 post-procedure.

Technology required

Cystoscopy setup and radiofrequency generator. Each hand-held device is of single use.

Adaptability to low-resource settings

Would require supply of the radiofrequency generator and the hand-held devices likely at a subsidised rate by the parent company.

Aqua ablation

Water-jet ablation (AquaBeam®, Procept BioRobotics, Redwood Shores, CA, USA), introduced in 2016, uses the principle of hydro-dissection using saline under variable flow rate, without heat generation, to ablate prostatic tissue, which is retrievable for histological analysis with an aspiration pump [76]. It is performed under general/spinal anaesthesia, under TRUS guidance and as an in-patient. The handpiece is inserted via a 22Fr cystoscope to the bladder neck, where its balloon is inflated intravesically to occlude the bladder neck, and the handpiece restricted to the prostate. A conformal planning unit is required for mapping and planning of the resection, preservation of the sphincter and the anatomy in general. Resection time is very rapid, spanning <10, with an average of 3–5 min [77]. The **W**aterjet **A**blation **T**herapy for **E**ndoscopic **R**esection of prostate tissue (WATER) study compared the AquaBeam® to TURP [78] and found it superior in IPSS reduction, continence and potency preservation, with a shorter operating time, hospital stay and complication rate.

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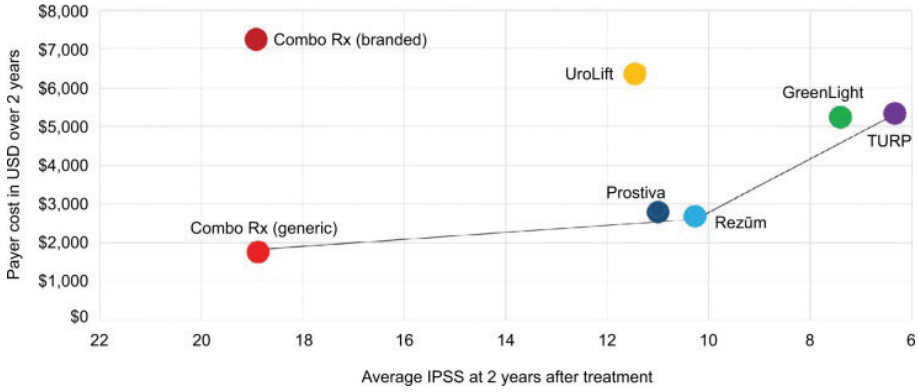

Fig. 9. Incremental cost-effectiveness ratio of various MIST in comparison with combined medical therapy (α-blocker + 5-α reductase inhibitor) by the 2-year follow-up mark [71].

Advantages
Sample for histology obtainable, able to individualise verumontanum protection zones during conformal planning, lacks side effects of sexual dysfunction and continence loss, rapid learning curve. Useful in larger and trilobar prostates and avoidance of thermal energy.

Contraindications
Its indications and contraindications mimic the PUL, except that it can be used in the presence of a median lobe [79], active infection and prostate cancer.

Cost
It costs 8,940 USD per procedure [80]. Capital costs include the robotic console and handpiece while recurrent cost arises from the disposable probe.

Technology required
22Fr cystoscope, AquaBeam robotic console, handpiece, TRUS and disposable rectal probe, laser generator (3–5 W) and single-use laser fibres.

Adaptability to low resource settings
Monopolar diathermy instead of laser for haemostasis or 'low-pressure inflation' of the balloon of a Foley catheter.

Temporary implantable nitinol device – TIND and iTIND (TIND; Medi-Tate)
The temporary nitinol implantable device (TIND) and the second-generation version (iTIND) have emerged over the past decade as one of the latest additions to the armamentarium of minimally invasive surgical therapies available for the treatment of LUTS secondary to BPH [81]. Currently, it is undertaken in patients with a prostate volume <60 cc and no median lobe. This device has 3 struts made of nitinol wires configured at 12, 5 and 7 o'clock positions. This is left in situ for 5 days. It works by remodelling the bladder neck and prostatic urethra by a process of localised ischaemic necrosis, thereby leading to a channel formation with improvement in urinary outflow.

Advantages
No general anaesthesia requirement can be carried out in an office or ambulatory setting, post-procedure catheterisation not required and sexual function is preserved. No thermal damage or ionising radiation. No catheter post procedure.

Contraindications
Presence of median lobe, not for large prostate burden.

Cost
It costs 1900 USD per procedure.

Technology required
Cystoscopy setup, delivery device and short learning curve.

Adaptability to low resource settings
Area of interest would be to research suitable materials which can be sourced locally in replacement of nitinol which can then be produced locally.

Conclusion
The significant burden of LUTS due to BPH, the unwanted side effects of standard therapies and the increasing prevalence of ageing and co-morbid patients has driven the search for newer interventions. TURP remains a good and viable option based on judgement in trained hands. Depending on various factors already discussed, newer modalities such as PUL, Rezum water vapour therapy and HoLEP are currently holding their

own and are in current established and emerging 'routine' urological practice throughout the world. The authors feel that in the near future, TURP will continue to hold its place with strong competition from the Rezum water vapour/steam therapy in small to moderate to enlarged prostates up to 100 cc, while in larger prostates, HoLEP and PAE will emerge as stronger options depending on additional patient factors to be considered. The significant reduction in erectile dysfunction and retrograde ejaculation associated with PUL and Rezum make them particularly attractive in sexually active men. With regard to LUTS improvement, all these newer alternatives have been demonstrated in one way or another to be non-inferior to TURP. More research and adaptations will no doubt continue to be developed towards the steady stepwise improvements we have summarised in this overview.

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