REVIEW PAPER

FUNCTIONAL UROLOGY

Minimally invasive vs standard surgical treatment: A systematic review comparing prostatic artery embolization and transurethral resection of the prostate for benign prostatic hyperplasia

Hubert Konieczny, Bartosz Żabicki, Konrad Suchora, Maciej Salagierski

Department of Urology, Collegium Medicum, University of Zielona Gora, Poland

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Corresponding author
Maciej Salagierski
Department of Urology, Collegium Medicum, University of Zielona Gora, 26 Zyty St.
65-046 Zielona Gora, Poland
M.Salagierski@inm.uz.zgora.pl

Introduction Benign prostatic hyperplasia (BPH) is a common cause of lower urinary tract symptoms (LUTS). While transurethral resection of the prostate (TURP) is widely regarded as the standard surgical treatment, prostatic artery embolization (PAE) has emerged as a minimally invasive alternative. This systematic review compares the effectiveness and safety of PAE and TURP in the management of BPH.

Material and methods We conducted a systematic review in accordance with PRISMA guidelines, including prospective and retrospective studies that directly or indirectly compared PAE and TURP. Searches were performed in PubMed, Science Direct, and Cochrane Library. Key outcomes assessed included the International Prostate Symptom Score (IPSS), Quality of Life (QoL), maximum urinary flow rate (Q_{max}), post-void residual volume (PVR), prostate volume (PV), the International Index of Erectile Function (IIEF-5), prostate-specific antigen (PSA), and adverse events.

Results A total of 18 studies, published between 2005 and 2025, were included in the review. Both PAE and TURP demonstrated significant improvements in IPSS and QoL, with comparable outcomes in most studies. TURP, however, consistently resulted in a greater reduction in PVR and PV due to its mechanism of physically removing prostatic tissue. In terms of safety, PAE was associated with minor, transient complications such as post-embolization syndrome, while major complications were infrequent.

Conclusions Both PAE and TURP are effective treatments for LUTS leading to significant improvements in patient symptoms and quality of life. While TURP provides a greater reduction in prostate volume and residual urine, PAE offers a less invasive option with a favorable safety profile, making it a viable alternative, especially for high-risk surgical candidates.

Key Words: minimally invasive therapy ‹› treatment outcomes ‹› quality of life ‹› lower urinary tract symptoms ‹› adverse events

INTRODUCTION

Benign prostatic hyperplasia (BPH) leads to bothersome lower urinary tract symptoms (LUTS) that diminish quality of life [1]. While transurethral resection of the prostate (TURP) remains the surgical gold standard [2, 12], prostatic artery embolization (PAE) has emerged as a minimally invasive alternative [3]. According to the European Association of Urology (EAU) guidelines [8], PAE is a weak recommendation for men seeking minimally invasive treatment who accept less optimal objective outcomes compared to TURP. Similarly, the American Urological Association (AUA) emphasizes that PAE should be performed by experienced interventional radiologists within a multidisciplinary team [7]

PAE has been reported to offer potential advantages, including the avoidance of general anesthesia, preservation of sexual function (e.g. reduced risk of retrograde ejaculation, and suitability for patients receiving anticoagulant therapy, as well as those who prefer minimally invasive treatment [4–6, 9, 10].
Initially developed in the 1970s to control significant bleeding after prostatectomy or prostate biopsy [11], PAE has since been shown to progressively reduce prostatic volume and weight when employed for spontaneous hemorrhage in BPH patients.

MATERIAL AND METHODS

Literature search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive literature search was performed across three major electronic databases: PubMed (MEDLINE), Science Direct, and the Cochrane Library. The search included all relevant studies published from database inception up to January 2026. To ensure a rigorous and focused analysis, the search was limited to English-language, peer-reviewed publications.
The following Boolean search string was used to identify relevant records: "*(prostate artery embolization OR PAE) AND (transurethral resection of prostate OR TURP OR monopolar TURP OR bipolar TURP) AND (benign prostatic hyperplasia OR BPH OR lower urinary tract symptoms OR LUTS)*". The study selection followed the PICO (Population, Intervention, Comparison, Outcome) framework. The population was defined as men with LUTS secondary to BPH; the intervention was PAE; the comparator was the gold-standard TURP; and outcomes included functional parameters (Q_{max}, IPSS, QoL, PVR, and PV) and safety profiles.

Inclusion and exclusion criteria

Studies were included if they reported outcomes such as IPSS, QoL, PVR, and Q_{max} at follow-up points of up to 60 months. Following reviewer feedback, studies involving non-PAE therapies (e.g., Urolift, GreenLight laser, or HoLEP) were excluded to maintain a strict focus on the PAE vs TURP comparison.

Data extraction

For comparative analysis between PAE and TURP, we prioritized outcomes at 12 months post-intervention, using the closest available follow-up if 12-month data were absent. Key outcomes assessed were the International Prostate Symptom Score (IPSS), Quality of Life (QoL), postvoid residual volume (PVR), maximum flow rate (Q_{max}), prostate volume (PV), International Index of Erectile Function 5 (IIEF-5), prostate-specific antigen (PSA), and adverse events. Additionally, this study reviews the mean changes from baseline for each outcome at specific follow-up points: 3, 6, 12, 24, and 60 months.

Assessment of study quality

The quality of the RCTs was assessed by using the Jadad Composite Scale (Table 1). Research papers with a score of 0-2 are generally considered low quality, while those with 3-5 points are considered high quality.
Nonrandomized studies were evaluated using the Newcastle-Ottawa Scale (NOS) (Table 2). The scale is a widely used tool for assessing the methodological quality and risk of bias in non-randomized studies, specifically cohort and case-control studies. It is rated from 0-9 stars in three categories.

RESULTS

Systemic screening

As shown in Figure 1, a total of 2,337 studies were identified; 453 were screened for full text and, finally, 108 were assessed for eligibility. Of the 108 articles considered, 68 were excluded due to irrelevance and 22 due to different outcomes or indications. A total of 11 studies directly comparing PAE with TURP or sham were included in the final analysis [13–23].

Characteristics of included studies

Tables 3–5 display the attributes of the eleven studies [13–23] included in this systematic review. All studies compared outcomes with follow-ups of patients who underwent either TURP or PAE for LUTS due to BPH. The studies were published between December 2005 and January 2026.

Quantitative analyses

International Prostate Symptom Score (IPSS)

Quantitative analysis shows that both procedures significantly reduce IPSS scores. In the RCT by Abt et al. [13], the mean IPSS reduction at 24 months

was 9.2 ±0.9 points for PAE and 10.7 ± 1.1 points for TURP (p = 0.17), showing no statistically significant difference between the groups. Similarly, Gao et al. [14] reported reductions of 13.2 for PAE and 13.6 for TURP at 12 months. The most consistent finding across all studies on PAE is a lasting improvement in the IPSS. Numerous studies [15, 20, 21, 23] consistently report a substantial reduction in IPSS scores, often from a baseline of moderate-to-severe symptoms (IPSS >20) to a mild symptom range (IPSS <10). Typical results show a mean IPSS reduction of around 10 to 16 points, with these benefits sustained for several years. Furthermore, when compared directly with TURP, PAE's ability to improve IPSS is often statistically similar [13, 15, 16]. This suggests that for a patient's daily experience of symptoms and quality of life, PAE can be as effective as a surgical procedure.

Placebo-controlled evidence [19] provides definitive evidence that the improvements in IPSS and QoL are a direct result of the embolization. The PAE group had a significantly better outcome at 6 months compared to the sham group, which later achieved similar results after undergoing the PAE procedure.

Quality of life (QoL)

In parallel with the IPSS improvements, QoL scores were also found to improve significantly and were sustained over follow-up periods ranging from 12 to 36 months. Wang et al. [21] reported that these improvements were maintained up to 3 years post-PAE. Again, the sham-controlled randomized clinical trial by Pisco et al. [19] provides the strongest evidence for this. Carnevale et al. [16] also concluded that both TURP and PAE (specifically the PErFecTED technique) yielded similar QoL improvements.

Prostate volume (PV)

PAE consistently leads to a significant and measurable reduction in prostate volume. The degree of reduction varies, but is typically in the range of 25% to

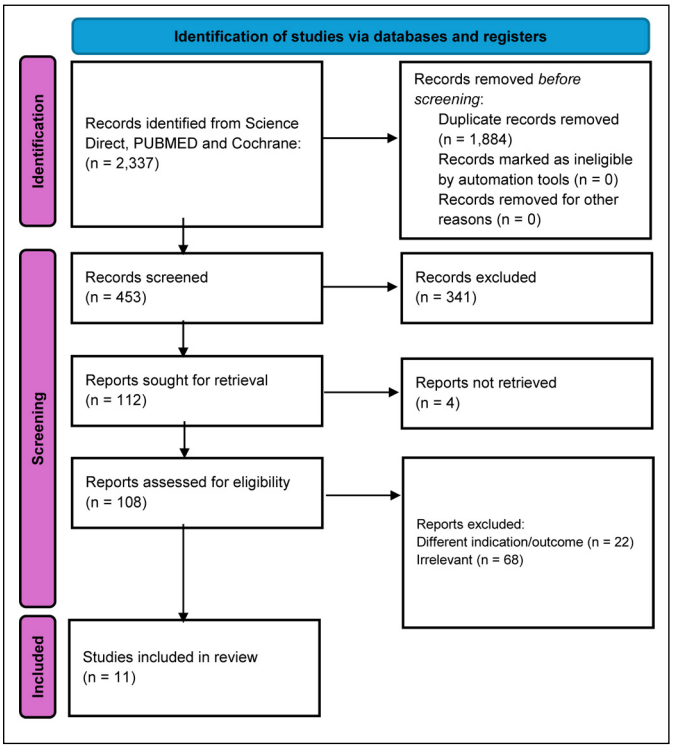

Figure 1. *PRISMA flow diagram.*

Table 1. *Jadad Composite Scale for assessing the quality of RCTs*

Study	Randomized	Sequence	Double-blind	Blinding method	Withdrawals	Total
Abt et al. 2021 [13]	1	1	0	0	1	3/5
Gao et al. 2013	1	1	0	0	1	3/5
Carnevale et al. 2015	1	0	0	0	1	2/5
Pisco et al. 2020	1	1	1	1	1	5/5
Lee et al. 2025	1	1	0	0	1	3/5

Table 2. *Quality assessment of non-randomized studies (Newcastle-Ottawa Scale)*

Study	Selection (max 4★)	Comparability (max 2★)	Outcome (max 3★)	Total score (Stars)	Quality rating
Dasgupta et al. 2018 [15]	★★★★	★	★★	7/9	High
Qiu et al. 2017 [17]	★★★	★	★★	6/9	Moderate
Lebani et al. 2024	★★★★	★	★★	7/9	High
Wang et al. 2015 [21]	★★★	★	★★	6/9	Moderate

over 40% at follow-up. This is a critical anatomical change that underlies the functional improvements. For example, Wang et al. [21] reported a mean PV reduction of 41.5% in patients with large prostates, while Pisco et al. [19] observed a 34.6% reduction. The comparative studies suggest that the magnitude of prostate volume reduction with PAE is not as great as that achieved with surgical procedures such as TURP, which physically remove tissue [12]. This is an important distinction when considering the goals of treatment. Qiu et al. [17] found that the TURP group had significantly greater prostate volume reduction than the PAE group. It was most noticeable at the 3- and 6-month mark.

Post-void residual volume (PVR)

PAE consistently leads to a significant decrease in PVR, which indicates improved bladder emptying. This was a consistent finding across most stud-

Table 3. *Characteristics of PAE vs TURP studies*

Study	Country	Design	Procedure	Inclusion criteria	Exclusion criteria	No. patients	Age (years)
Abt et al. 2021 [13]	Switzerland	RCT	TURP, PAE	1. Men ≥40 years old 2. Refractory LUTS/BPO 3. IPSS ≥8, QoL score ≥3 4. Prostate size 25–80 ml 5. Q_{max} <12 ml/s or urinary retention 6. Informed consent	1. Severe atherosclerosis, vascular anomalies 2. Neurogenic bladder, urethral stenosis, bladder stones or diverticula 3. Contrast allergy, GFR <60 ml/min 4. Prostate cancer	103 PAE: 51 TURP: 52	PAE: 65.7 ±9.3 TURP: 66.1 ±9.8
Gao et al. 2013 [14]	China	RCT	TURP, PAE	1. IPSS > 7 after failed medical therapy 2. Washout period ≥2 weeks 3. Prostate volume: 20–100 ml 4. Peak urinary flow <15 ml/s 5. Informed consent obtained	1. Detrusor hyperactivity or prospective comparative study hypocontractility 2. Urethral stricture 3. Prostate cancer 4. Diabetes mellitus 5. Previous surgery involving the prostate, bladder neck, or urethra 6. PSA > 4 ng/ml with abnormal DRE unless negative biopsy confirmed	114 PAE: 57 TURP: 57	PAE group: 67.7 ±8.7 TURP group: 66.4 ±7.8
Dasgupta et al. 2018 [15]	United Kingdom	Prospective comparative study	TURP, PAE	Patients suitable for surgical intervention for LUTS/BPH	Not explicitly listed in abstract; likely standard exclusions for TURP/PAE	305 PAE: 216 TURP: 89	Not specified
Carnevale et al. 2015 [16]	Brazil	RCT	TURP Original PAE (oPAE) PErFecTED PAE	1. Age > 45 years 2. IPSS > 19 3. LUTS refractory to meds ≥6 months 4. Prostate volume 30–90 cm^3 (by MRI) 5. Negative screening for prostate cancer 6. Confirmed BOO via urodynamics	1. Renal failure 2. Bladder calculi or diverticula 3. Suspected prostate cancer 4. Urethral stenosis 5. Neurogenic bladder disorders	45 oPAE: 15 PErFecTED PAE: 15 TURP: 15	oPAE: 63.5 ±8.7 PErFecTED: 60.4 ±5.2 TURP: 66.4 ±5.6
Qiu et al. 2017 [17]	China	Retrospective	TURP, PAE	1. Severe LUTS due to BPH 2. Failed 6-month treatment with α-blockers and 5α-reductase inhibitors 3. Contraindications to surgery, such as: • Severe cardiovascular/ cerebrovascular disease • Inability to stop anticoagulants • Limited mobility preventing lithotomy position • Severe urethral stricture • Refusal of surgery	Not explicitly listed in abstract; likely standard exclusions for TURP	57 PAE: 17 TURP: 40	PAE: 75.53 ±4.74 TURP: 73.35 ±4.75

BOO – bladder outlet obstruction; BPH – benign prostatic hyperplasia; GFR – glomerular filtration rate; LUTS – lower urinary tract symptoms; MRI – magnetic resonance imaging; PAE – prostatic artery embolization; PSA – QoL – Quality of Life; Q_{max} – maximum urinary flow rate; TURP – transurethral resection of the prostate

ies [14, 21]. When directly compared, TURP generally demonstrates a greater reduction in PVR than PAE [15]. A reduction in PVR is a key indicator of improved bladder emptying and a functional benefit for patients with BPH. The difference in the magnitude of improvement is related to the mechanism of each procedure. TURP is a surgical procedure that physically removes the obstructive prostatic tissue, creating a clear channel for urine to flow [12]. This direct reduction of the obstruction leads to a more immediate and often more substantial decrease in PVR. PAE works by inducing ischemia and necrosis of the prostate, which causes the gland to shrink over time [24]. While this shrinkage is effective at reducing obstruction and improving PVR, the effect may not be as dramatic or as quick as with direct surgical resection.

International Index of Erectile Function-5 (IIEF-5)

The studies focusing on PAE generally report that the procedure either has no significant negative impact on erectile function [21] or, in some cases, may even lead to a slight improvement [22].

Table 4. *Quantitative clinical outcomes*

Parameter	PAE mean change (Δ)	TURP mean change (Δ)	Significance (p)
IPSS	From –9.2 to –13.2	From –10.7 to –13.6	>0.05
Q_{max}	+5.1 ml/s	+11.2 ml/s	<0.001
PV reduction	25–41.5%	38–100% (resection)	<0.05
Retrograde ejaculation	Approx. 0%	Up to 100%	<0.001

IPSS – International Prostate Symptom Score; PAE – prostatic artery embolization; PV – prostate volume; Q_{max} – maximum urinary flow rate; TURP – transurethral resection of the prostate

Peak urinary flow

Functional improvements consistently favored the gold standard. Abt et al. [13] found a significantly higher Qmax increase in the TURP group (+11.2 ml/s vs +5.1\ ml/s, p <0.001). This trend was confirmed by Carnevale et al. [16], where TURP showed superior flow rates compared to original PAE techniques. Both PAE and TURP successfully increase Qmax from baseline. This is a critical functional outcome, indicating that both treatments effectively reduce bladder outlet obstruction. The difference in the results is directly related to the treatment mechanisms.

Adverse effects

Minor complications / approximately Dindo-Clavien Grade I–II

PAE is associated with a range of minor and transient side effects [20]. The most common is post-embolization syndrome, which was observed in 53.8% of patients and can include pelvic or perineal pain, dysuria, and hyperthermia. Other reported complications include acute urinary retention, urinary tract infection, inguinal hematoma, and rare issues from non-target embolization of anastomoses, such as rectal pain, bloody stools, or trophic skin damage to the glans penis. Pisco et al. [19] also reported transient hematuria and hematospermia, typically resolving within a few days to weeks postoperatively. Reported outcomes in the included comparative studies primarily focused on major complications and long-term outcomes.

Major complications / approximately Dindo–Clavien Grade III and higher

Larger cohort studies [19, 20] revealed a low incidence of major complications. One study [22]

Table 5. *Brief comparison of advantages and disadvantages of TURP and PAE*

Feature	TURP	PAE
Pros	• Gold-standard effectiveness in improving Q_{max}, PVR, and reducing prostate volume • Immediate and substantial anatomical debulking • Long-term durability of results	• Minimally invasive, no general anesthesia • Safe for high-risk or anticoagulated patients • Very low rate of major complications • Preservation of sexual function; minimal risk of retrograde ejaculation • Faster return to daily activities
Cons	• High rate of retrograde ejaculation • Risk of urinary incontinence, bleeding, TUR syndrome • Requires anesthesia and hospital stay	• Smaller improvement in objective parameters (Q_{max}, PVR, PV) compared to TURP • Post-embolization syndrome common but mild • Radiation exposure inherent to the procedure • Slower onset of symptom relief compared to TURP

PV – prostate volume; PVR – post-void residual volume; Q_{max} – maximum urinary flow rate; TURP – transurethral resection of the prostate

reported six cases of moderate erectile dysfunction, whose scores ranged from 8 to 11.

The two most clinically significant primary complications of TURP are retrograde ejaculation and urinary incontinence. The first one was the most frequently reported complication. Carnevale et al. [16] reported a 100% rate of retrograde ejaculation in the study group. Another significant complication noted by Carnevale et al. [16] was a 26.7% rate of early urinary incontinence. This type of incontinence is typically a temporary issue during recovery, but it can have a substantial impact on a patient's quality of life. Less frequently occurring complications such as urinary tract infection and urinary retention were reported by Hou et al. [30]. Carnevale et al. [16] also documented one case of rupture of the prostatic capsule.

Safety regarding radiation dosage

PAE, due to the increased level of complexity, is related to the higher radiation exposure of the patient in comparison to some simple endovascular procedures. Radiation dose is mostly dependent on anatomy, procedure strategy (unilateral vs bilateral PAE), technique and experience of the interventionist. PAE radiation exposure correlates directly with fluoroscopy time, number of angiographic runs, and cone beam computed tomography (CBCT) acquisitions [25]. CBCT increases radiation exposure, but additional imaging data and the 3D roadmap improve the efficacy in prostatic artery navigation, procedure success and safety. On the other hand, it decreases the number of angiographic runs and fluoroscopy time, which is directly related to the decrease in procedure time, radiation dose, and amount of contrast agent used [25]. Based on a systematic review of 22 studies by Zumstein et al. [26], patients undergoing PAE are exposed to a mean DAP (dose area product) of 181.6 Gy × cm^2 (range 33.15–863.4 Gy × cm^2). Intervention-related cancer death was calculated to be 0.117% and life expectancy was reduced by 5.3 days for an average 66-year-old patient, which seems to be accepted by men with proven effective PAE [26]. Radiation exposure risk must be interpreted in consideration of the mortality rates for other procedures, e.g. TURP – 0.7% [27].

The comparative data for all primary and secondary quantitative outcomes across the included trials are summarized in Table 4.

DISCUSSION

Our findings align with the comprehensive meta-analysis by Wang et al. [28], which concluded that while PAE is a safe and effective treatment, its objective functional outcomes Qmax and PVR remain inferior to the gold-standard TURP. According to Wang et al., patients undergoing TURP achieve significantly higher Qmax values and lower PVR volumes, a finding supported by our review of the recent literature.

In terms of safety, our results are consistent with Wang et al. [28] regarding the superior profile of PAE in reducing perioperative complications. PAE is associated with a significantly lower risk of hemorrhage and a complete absence of retrograde ejaculation, which affects up to 100% of TURP patients in some series. Furthermore, the sham-controlled trial by Pisco et al. [19] indicated that PAE symptom relief is not driven by a placebo effect. Additionally, the recent trial by Lee et al. (2025) [29] suggested that preoperative PAE may serve as a valuable tool to reduce intraoperative bleeding during TURP in patients with large prostates (>80 ml). Table 5 summarizes the advantages and disadvantages of both methods.

The evidence is currently limited by the small number of multicenter RCTs and follow-up periods that rarely exceed 24 months. Variations in PAE techniques (original vs PErFecTED) also influence the generalizability of results.

CONCLUSIONS

Both PAE and TURP are effective treatments for BPH, with distinct profiles. TURP demonstrates greater improvement in objective clinical parameters (PV, PVR, Qmax). On the other hand, PAE is associated with a favorable safety profile and may be particularly relevant for patients prioritizing preservation of sexual function, those unsuitable for general anesthesia, or those requiring ongoing anticoagulation therapy.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL STATEMENT

The ethical approval was not required.

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