

NARRATIVE REVIEW



Prostatic artery embolization in the contemporary management of benign prostatic hyperplasia: A guideline-based narrative review

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Abstract

Background: Benign prostatic hyperplasia (BPH) is a common cause of lower urinary tract symptoms (LUTS) in aging men and substantially affects quality of life. Although transurethral resection of the prostate (TURP) remains the surgical standard, prostatic artery embolization (PAE) has become an effective minimally invasive alternative, particularly for elderly patients, those with significant comorbidities or receiving anticoagulation, and men seeking to preserve sexual function.

Objective: To review contemporary evidence on PAE, focusing on patient selection, procedural technique, clinical outcomes, safety, comparative effectiveness, and its role in current international guidelines. This review uniquely synthesizes the 2026 guideline updates with emerging evidence on patient selection biomarkers and procedural refinements, providing a practical framework for multidisciplinary decision-making.

Evidence Acquisition: A narrative review was performed using PubMed/MEDLINE, Embase, and the Cochrane Library. International guidelines, randomized controlled trials, systematic reviews, and meta-analyses published between 2020 and 2026 were prioritized, with landmark earlier studies included where appropriate.

Evidence Synthesis: Current evidence demonstrates that PAE provides durable improvements in LUTS, quality of life, urinary flow, and prostate volume with a favorable safety profile. Compared with surgery, it has lower perioperative morbidity, shorter hospitalization, and better preservation of ejaculatory function. However, urinary flow improvements are smaller, and retreatment rates remain higher than after TURP or endoscopic enucleation.

Conclusion: PAE is an established minimally invasive option for selected men with BPH-related LUTS, particularly those at increased surgical risk or wishing to preserve sexual function. Further long-term randomized studies are needed to optimize patient selection and confirm long-term durability.

KEYWORDS

Benign prostatic hyperplasia; Lower urinary tract symptoms; Prostatic artery embolization; Interventional radiology; Minimally invasive therapy; Clinical guidelines.

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Introduction

Benign prostatic hyperplasia is one of the most common chronic conditions in aging men and the main cause of LUTS [1,2]. Prevalence rises from midlife onward, and as global life expectancy increases, the associated burden of physician visits, pharmacotherapy, surgery, and retention-related hospitalization is increasing. Beyond urinary frequency, urgency, nocturia, and incomplete emptying, progressive bladder outlet obstruction can cause infection, stones, retention, and renal impairment; it also affects sleep, mental well-being, and sexual health, with many men reporting increasing restriction of daily activities as a result. Pathologically, BPH reflects androgen-dependent hyperplasia of both glandular and stromal elements within the transition zone surrounding the urethra, producing mechanical bladder outlet obstruction that is often compounded by a secondary, dynamic component related to increased smooth-muscle tone [1]. This dual mechanism explains why both pharmacotherapy, which targets smooth-muscle relaxation and androgen-driven glandular growth, and interventional approaches, which instead reduce or remove obstructing tissue, have a role in management; diagnosis and

severity assessment rely on validated symptom questionnaires, uroflowmetry, and prostate imaging, which together guide decision-making among the available treatments.

Management traditionally follows a stepwise pathway, from lifestyle modification and pharmacotherapy to surgery for patients with persistent symptoms, refractory retention, or medication intolerance. TURP remains the surgical gold standard, providing substantial and durable relief but carrying risks of perioperative bleeding, hospitalization, anesthetic exposure, and postoperative sexual dysfunction, especially retrograde ejaculation. Newer modalities — holmium laser enucleation of the prostate (HoLEP), Aquablation, Rezūm, the prostatic urethral lift (UroLift), and temporary implantable nitinol devices — have broadened the available treatment options, each with its own limitations related to prostate size, durability, learning curve, or effect on sexual function. Prostatic artery embolization (PAE) is a minimally invasive, image-guided procedure that induces ischemic shrinkage of hyperplastic tissue rather than resecting it. First applied clinically for BPH in the late 2000s, after interventional radiologists observed marked urinary improvement in patients embolized for refractory prostatic

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hemorrhage [3], the procedure has since improved with advances in cone-beam CT, microcatheter design, and embolic materials, alongside an expanding base of randomized trials, prospective registries, and meta-analyses. As evidence accumulated, PAE was incorporated into guidelines issued by the AUA, EAU, SIR, CIRSE, and NICE [1,2,4-6], which now define PAE as an option for appropriately selected patients managed within multidisciplinary pathways, even as each society continues to frame its exact place in the treatment algorithm somewhat differently. Questions remain regarding patient selection, durability, and its precise place relative to established surgical alternatives.

This review summarizes and critically examines current evidence on PAE, covering current guidelines, patient selection, technique, effectiveness, comparative outcomes against other BPH therapies, safety, controversies, and research priorities shaping its role in BPH management. Relevant studies were identified through PubMed/MEDLINE, Embase, and the Cochrane Library, with priority given to approved guidelines, randomized trials, and meta-analyses published between 2020 and 2026, supplemented by earlier studies of continued clinical relevance.

Current Position in International Clinical Practice Guidelines

Over the past years, PAE has moved from an emerging interventional technique to an evidence-based option incorporated into international guidelines. The 2026 AUA guideline states that PAE may be offered, using particle embolics, for men with prostates ≥ 50 cc when performed by an experienced interventional radiologist within a multidisciplinary pathway (Conditional Recommendation; Grade B evidence) — an upgrade from the Grade C evidence rating assigned in the prior 2023 amendment, reflecting the growing body of comparative and long-term data, including in patients receiving anticoagulation [1]. This is deliberately measured language rather than an unqualified endorsement: a Conditional Recommendation indicates that the balance of benefits and risks is close and depends on individual patient values, and that better evidence could still change this assessment. The EAU similarly frames PAE as an option rather than a preferred therapy, to be considered in men with moderate-to-severe LUTS who wish to pursue a minimally invasive treatment and are willing to accept potentially less optimal urinary flow outcomes than TURP, provided that work-up and follow-up involve both a urologist and a trained interventional radiologist [2]. The Society of Interventional Radiology's 2026 practice guidance and the multisociety consensus statement co-authored with CIRSE both frame PAE as an established treatment whose safety and effectiveness depend largely on operator expertise, standardized technique, and structured follow-up [4,5], while NICE continues to support routine use within appropriately governed health systems, provided patient selection and informed consent are maintained [6]. National radiological societies, including the German Society for Interventional Radiology, have also published clinical recommendations supporting PAE when performed in experienced multidisciplinary centers [7].

As clinical evidence has expanded, guideline recommendations have grown steadily more consistent: earlier guidance relied mainly on observational cohorts, whereas current recommendations depend on randomized trials, prospective multicenter registries, and systematic reviews with meta-analysis. Differences in wording nonetheless persist, largely reflecting each organization's threshold for recommending a therapy with a favorable safety profile but comparatively moderate objective flow improvement — a distinction that matters clinically, since it shapes how strongly a given guideline directs patients toward PAE versus TURP or HoLEP for a given clinical scenario. Grading systems used by the AUA and EAU also differ in methodology, so a given level of evidence is not always directly comparable between the two, an important consideration when interpreting differences among international guideline recommendations.

Across these organizations, consensus exists that PAE is effective for carefully selected patients, that multidisciplinary collaboration between urology and interventional radiology is essential, and that reduced perioperative morbidity and preserved sexual function are real advantages that must be weighed against a higher likelihood of retreatment. Ongoing debate centers on comparative effectiveness against anatomical procedures such as TURP and HoLEP, optimal management of very large prostates, and standardization of technique — questions that future trials and longer-term follow-up are expected to help resolve. With each update, professional societies have shown a gradual trend toward stronger support for PAE in selected patients, reflecting the growing weight of clinical evidence, though every current recommendation remains conditional on appropriate patient selection rather than unconditional.

Table 1. Guideline recommendations for prostatic artery embolization.

Guide line	Recommendation	Strength of recommendation	Important limitations
AUA (2026)	PAE may be offered with particle embolics for prostates ≥ 50 cc, including patients on anticoagulation	Conditional; Grade B evidence (upgraded from Grade C in 2023)	Requires an experienced interventional radiologist; retreatment more likely than TURP/HoLEP
EAU	PAE may be considered for men who wish to consider a minimally invasive treatment	Weak; contingent on accepting less optimal flow outcomes than TURP	Smaller flow gains; multidisciplinary work-up and follow-up required

Table 1 (continued)

Guide line	Recommendation	Strength of recommendation	Important limitations
SIR (2026)	Established minimally invasive therapy in appropriately selected patients	Practice guidance (consensus-based), not a graded clinical recommendation	Effectiveness closely tied to operator training and case volume
CIRSE	Co-endorses the SIR/CIRSE multisociety consensus position on PAE	Consensus statement, not independently graded	Same operator-dependence as above; limited long-term comparative data
NICE	Supports routine clinical use within governed health systems	Interventional procedures guidance (safety/efficacy judged adequate)	Conditional on informed consent, patient selection, and outcome audit

Patient Selection

Proper patient selection remains the single greatest determinant of successful outcomes. Selection should integrate symptom severity (using the International Prostate Symptom Score and quality-of-life questionnaire), prostate morphology, bladder function, comorbidity, anesthesia risk, and patient priorities regarding sexual function and recovery — not prostate volume alone. The strongest candidates are men with moderate-to-severe LUTS refractory to medical therapy, particularly those with large prostates, significant comorbidity, chronic anticoagulation, or a strong preference for preserving ejaculation, since PAE avoids the bleeding risk and anesthetic burden of surgery while achieving meaningful symptomatic benefit [8]. Carefully selected patients with catheter-dependent retention may also regain spontaneous voiding [9,10], depending on bladder contractility and duration of catheterization. Setting realistic expectations at this stage — particularly regarding the pace of improvement over the following months and the potential need for retreatment over the long term — is as important to overall satisfaction as technical success of the procedure itself.

PAE is less suitable for men with active urinary tract infection, suspected prostate cancer requiring evaluation, significant detrusor underactivity, or pelvic vascular anatomy that precludes safe selective catheterization; those prioritizing maximal urinary flow improvement are generally better managed by TURP or HoLEP. Proper pre-operative evaluation includes validated symptom questionnaires, laboratory assessment, uroflowmetry, post-void residual measurement, and imaging — ultrasonography for prostate volume, CT angiography for vascular mapping, and MRI where oncological or anatomical clarification is required.

Current research continues to identify predictors of treatment success. A small number of variables are already used routinely in clinical decision-making, while several imaging-derived and molecular candidates remain investigational; Table 2 summarizes the current evidence levels for each. Because no single parameter can predict treatment success in all patients, selection is best approached as a multidisciplinary, gradual process rather than a fixed checklist. Shared decision-making remains the cornerstone: patients should receive appropriate counseling on expected symptom relief, likely improvement in urine flow, recovery time, preservation of sexual function, recurrence and retreatment risk, so that the option chosen reflects both the clinical evidence and the individual patient's own wishes and expectations.

Table 2. Predictors of clinical success after PAE.

Predictor	Clinical readiness	Supporting evidence
Baseline symptom burden (higher IPSS)	Established—used routinely	Consistent across cohorts and meta-analyses
Successful bilateral embolization	Established—used routinely	Randomized and cohort data; lower retreatment than unilateral
Prostate volume ≥ 50 cc	Established—defines population	AUA-endorsed AUA (2026) Conditional Recommendation, Grade B [1]
Intact bladder contractility (in retention)	Established—used to counsel catheter-dependent patients	Cohort data on catheter-free rates after PAE
Prostate volume reduction at 1–3 months	Investigational—early-response biomarker	Single-center correlation studies; not yet validated prospectively
DCE-MRI perfusion parameters (e.g., baseline AUC)	Investigational	Small single-center studies; independent predictor in limited cohorts

Table 2 (continued)

Predictor	Clinical readiness	Supporting evidence
Intravesical prostatic protrusion / transition-zone morphology	Investigational	Emerging, heterogeneous single-center data
Radiomics / AI-derived imaging features	Investigational	Early feasibility studies; no external validation yet

In practice, this evaluation can be summarized as a structured pathway:

- Confirm LUTS are attributable to BPH and exclude malignancy or infection.
- Grade symptom severity and quality-of-life impact using validated questionnaires.
- Assess prostate morphology and pelvic vascular anatomy on imaging.
- Evaluate comorbidity, anesthesia risk, and anticoagulation status.
- Discuss all options within a multidisciplinary team and reach a shared decision.

Procedural Technique

Modern PAE is performed using a standardized procedural workflow that begins with pre-procedural CT angiography to delineate the frequently variable pelvic arterial anatomy, followed by super selective catheterization of the prostatic arteries using low-profile microcatheters and hydrophilic guidewires [11,12]. Cone-beam CT performed during the procedure confirms the perfusion territory and has substantially reduced the risk of non-target embolization to the bladder, rectum, or penis by identifying collateral vessels before particle delivery [13]. Bilateral embolization is preferred whenever technically feasible, as it is associated with greater volume reduction and lower retreatment than unilateral treatment [14]. Polyvinyl alcohol particles and calibrated microspheres remain the most used embolic agents, with no clear evidence of superiority between them; particle size instead governs the trade-off between deeper ischemic penetration and non-target risk. Emerging tools—three-dimensional rotational angiography, image fusion, and early artificial-intelligence-assisted vascular mapping—are beginning to further improve procedural precision.

The prostatic arteries arise from a variable pelvic circulation, most often from the internal pudendal, inferior vesical, or obturator arteries, and frequently share anastomotic connections with vessels supplying the bladder, rectum, and penis [11]. This complex anatomy is the main technical challenge of PAE and the reason detailed pre-procedural imaging is considered mandatory rather than optional. CT angiography is generally preferred for initial vascular mapping because of its wide availability, while MRI is reserved for cases requiring additional anatomical or oncological clarification of the prostate itself; neither modality alone, however, substitutes for meticulous intra-procedural angiographic assessment of each patient's individual anatomy [12].

Radial arterial access is increasingly used alongside the traditional femoral approach, offering earlier ambulation and fewer access-site complications in experienced hands, though it presents a learning curve of its own. Because fluoroscopy time can be substantial, radiation-reduction strategies — pulsed low-dose protocols, careful beam collimation, and selective use of cone-beam CT — remain important for minimizing radiation exposure to both patients and operators. Technical success depends heavily on operator experience: procedure duration, radiation exposure, and complication rates all improve significantly along the learning curve, reinforcing guideline recommendations that PAE be performed in experienced, high-volume

centers with close collaboration between urology and interventional radiology.

Selecting the appropriate embolization endpoint remains a key procedural decision, balancing the goal of achieving sufficient ischemia to maximize volume reduction against the risk of arterial stasis and reflux into non-target vessels. Professional societies increasingly recommend structured training, minimum case-volume requirements, and supervised mentorship during early independent practice to accelerate the learning curve and promote consistent procedural technique across centers, underscoring that procedural outcomes depend more on operator expertise and institutional experience than on technology alone. Post-procedural care typically involves same-day or overnight observation, oral analgesia, and clinical review at two to four weeks to assess early symptom response and identify any complications, followed by structured follow-up at three, six, and twelve months incorporating validated symptom questionnaires, uroflowmetry, and, where indicated, repeat imaging. This structured follow-up schedule not only supports ongoing patient management but also contributes valuable data to clinical registries, helping improve understanding of long-term outcomes.

Clinical Effectiveness

Across prospective cohorts, randomized trials, and multicenter registries, PAE consistently produces significant reductions in symptom scores and meaningful improvement in quality of life, typically progressing over three to six months as ischemic infarction reduces gland volume [15-17]. Pooled estimates from systematic reviews and meta-analyses report mean IPSS reductions of approximately 12–20 points and mean increases in maximum urinary flow rate (Q_{max}) of approximately 6–9 mL/s, alongside mean prostate volume reductions of roughly 20–30% [16,17]. These gains are generally smaller than after TURP or HoLEP, reflecting embolization's mechanism of ischemic shrinkage rather than anatomical tissue removal, and the relationship between volume reduction and symptomatic benefit is not strictly linear.

Patient-reported outcomes add an important dimension beyond these objective measures. Improvement in disease-specific quality of life is one of the most important findings after PAE, with patients commonly describing reduced nocturia-related sleep disturbance, less urgency, and fewer restrictions on daily activities and travel; these gains are further reinforced by the rapid recovery, minimal postoperative pain, and outpatient treatment pathway that PAE typically offers, all of which contribute meaningfully to overall patient satisfaction independent of the specific changes in any single urodynamic parameter.

Follow-up to five years shows that symptom improvement, quality of life, and flow parameters remain largely sustained, but retreatment rates are significantly higher than after TURP or HoLEP [15,16], and patients should be counselled accordingly. Reported 5-year retreatment rates cluster around 15–25% in nationwide cohort and claims-based studies, though rates as high as 47% have been reported in one randomized trial with extended follow-up, underscoring substantial variability across patient populations, embolization technique, and definitions of retreatment. In carefully selected men with catheter-dependent retention, PAE can restore spontaneous voiding, though success depends on bladder contractility and duration of catheterization. Erectile function is generally preserved, and preservation of normal ejaculation is superior to that seen after TURP

and HoLEP — a major reason sexually active men increasingly consider PAE.

Evidence from randomized controlled trials has helped establish this safety profile in controlled clinical settings, while large prospective registries, including national experience such as the UK-ROPE registry, extend these findings to broader, more heterogeneous real-world populations [18]. Together, this evidence base shows consistent results across healthcare systems and operator groups, reporting high technical success, low rates of major complications, and high patient satisfaction across experienced centers, and providing the reassurance of external validity that trial data alone cannot offer.

Comparative trials versus TURP, including those reported by Gao et al. and Abt et al., remain the most foundational studies in this field: both found significant improvement in symptoms and quality of life with PAE, although this is accompanied by smaller improvements in peak urinary flow and higher retreatment rates than those observed after TURP over intermediate follow-up [19,20]. These trials, together with subsequent systematic reviews and meta-analyses combining their results with observational data [16,17], form the principal evidence base for current guideline recommendations and continue to inform ongoing debate about optimal patient selection. Table 3 summarizes the major studies underpinning this evidence base.

Comparative Effectiveness

Medical therapy remains first-line for mild-to-moderate LUTS, but incomplete response and side effects such as hypotension, fatigue, and sexual dysfunction commonly lead to discontinuation; PAE offers a more durable alternative for patients failing or intolerant of pharmacotherapy. Compared with TURP, the surgical reference standard, randomized trials consistently show comparable improvement in symptoms and quality of life, but TURP achieves greater improvement in urinary flow and lower long-term retreatment through complete tissue removal, whereas PAE offers lower blood loss, shorter hospitalization, faster recovery, and superior preservation of ejaculation [19,20]. Neither should be viewed as replacing the other; the choice depends on whether maximal flow improvement or minimally invasive recovery is the greater priority for the individual patient.

HoLEP, particularly suited to large prostates, achieves durable relief and very low retreatment through complete enucleation, again at the cost of greater invasiveness than PAE and comparatively reduced preservation of ejaculation. Compared with newer minimally invasive surgical therapies — Aquablation, Rezūm, UroLift, and temporary implantable devices — PAE is applicable across a broader range of prostate volumes and avoids transurethral instrumentation, though some of these alternatives offer more immediate symptomatic relief or shorter procedure times; direct comparative trials with PAE remain limited [21-24].

Sexual and ejaculatory outcomes

Because preservation of sexual function is one of the most clinically important considerations when choosing among contemporary BPH therapies, this outcome domain warrants explicit, separate discussion rather than passing mention alongside urinary endpoints.

- **Erectile function:** generally preserved after PAE, with most series reporting stable or modestly improved erectile function scores; comparable preservation is reported after UroLift and Rezūm, whereas TURP and HoLEP carry a small but recognized risk of de novo erectile dysfunction.
- **Ejaculatory function:** antegrade ejaculation is preserved substantially more often after PAE than after TURP or HoLEP, representing one of PAE's clearest comparative advantages for sexually active men.
- **Retrograde ejaculation:** common after TURP (affecting a majority of men) and frequent after HoLEP, but uncommon after PAE, UroLift, and Rezūm, which do not resect periurethral tissue at the bladder neck.
- **Sexual satisfaction:** patient-reported satisfaction tracks ejaculatory preservation as closely as it tracks urinary improvement, which is why guidelines increasingly frame preservation of sexual function as a primary factor in shared decision-making rather than a secondary consideration.

Safety and healthcare resource considerations also influence treatment selection. PAE carries the lowest rates of perioperative bleeding and transfusion among contemporary BPH interventions, and its minimally invasive nature contributes to shorter hospital stays and earlier return to normal activity, advantages that may partially balance the procedural cost; higher long-term retreatment, however, must also be weighed in any cost-effectiveness comparison, which ultimately depends on patient selection and local healthcare-system characteristics. Formal cost-effectiveness data remain less mature for PAE than for TURP, and further prospective analyses incorporating retreatment rates, lifetime healthcare utilization, and patient-reported outcomes would strengthen future health-economic comparisons across all contemporary BPH therapies. Overall, PAE provides superior preservation of sexual function compared with most contemporary treatment options, but this benefit must be balanced against more modest gains in urinary flow and higher retreatment rates compared with anatomical surgical procedures. These considerations should guide patient-centered treatment selection.

In practice, treatment selection is increasingly individualized rather than governed by a single preferred procedure. Men with severe obstruction who prioritize maximal flow improvement and lowest retreatment risk are often better served by HoLEP or TURP, whereas elderly or comorbid patients, those on anticoagulation, and men for whom preserving ejaculation is a priority frequently represent the best candidates for PAE. Younger, sexually active men with moderate symptoms and favorable anatomy may instead be well suited to Rezūm or UroLift. Aligning the choice of therapy with these individual priorities, rather than defaulting to a single standard approach, is now a central concept of guideline-based BPH management.

Safety Profile and Complications

Complications following PAE are typically graded using the Society of Interventional Radiology adverse-event classification and the Clavien-Dindo surgical grading system, both of which confirm that the great majority of reported events are minor (Grade I-II) and resolve with observation or conservative management alone.

PAE has a favorable safety profile overall [13,16,17]. Most adverse events are minor and self-limiting — pelvic pain, dysuria, transient hematuria and hematospermia, urinary frequency, and post-embolization syndrome (low-grade fever and malaise) — resolving within days with conservative management. Major complications are less common in experienced hands, the most important being non-target embolization, in which particles reach the bladder, rectum, seminal vesicles, or penis through collateral vessels, causing localized ischemia [11]. Meticulous pre-procedural CT angiography, cone-beam

Table 3. Major trials and registries informing contemporary practice.

Study	Design	Key reported outcome
Pisco et al., [3]	Prospective cohort	Established technical feasibility and early symptomatic improvement
Pisco et al., [15]	Prospective cohort (n=630)	Durable medium- to long-term symptom relief
Gao et al., [19]	RCT vs. TURP	Comparable symptom improvement; smaller flow gains than TURP
Abt et al., [20]	RCT vs. TURP (non-inferiority)	Similar quality-of-life benefit with lower perioperative morbidity
Ray et al. (UK-ROPE), [18]	National registry, propensity-matched	Validated real-world effectiveness and safety across centers
Malling et al., [16]	Systematic review & meta-analysis	Pooled IPSS/Qmax/volume outcomes; confirmed efficacy and safety
Xiang et al., [17]	Meta-analysis of RCTs	Reinforced comparative efficacy and safety profile vs. TURP

CT confirmation, and superselective catheterization have reduced this risk, and clinically significant non-target embolization is now uncommon in specialized centers. Other risks include urinary tract infection, transient retention, access-site complications, and, rarely, prostatic abscess.

Treatment failure may result from incomplete or unilateral embolization, complex collateral circulation, underlying bladder dysfunction, or inappropriate patient selection; because embolization reduces rather than removes hyperplastic tissue, symptom recurrence and retreatment remain more frequent than after TURP or HoLEP. Risk is minimized through careful patient selection, standardized imaging-guided technique, and operator experience — factors that together underpin the guideline recommendation that PAE be performed in experienced, high-volume centers with structured post-procedural follow-up.

Important evidence gaps nonetheless remain, including the durability of safety outcomes beyond ten years, the comparative complication profile of different embolic materials, and the optimal balance between particle size and embolization endpoint for minimizing non-target risk without compromising efficacy. Structured adverse-event reporting using standardized classification systems, alongside continued audit within multidisciplinary registries, will be important for closing these gaps and further refining risk-reduction strategies as the procedure continues to evolve.

Sexual function deserves particular mention within the overall safety profile, since preservation of erectile and ejaculatory function is one of the most reported advantages of PAE relative to TURP and HoLEP; isolated reports of new erectile dysfunction exist but are uncommon and are more often linked to non-target embolization or pre-existing vascular disease than to embolization itself. Older age, extensive pelvic atherosclerosis, uncontrolled diabetes, and anatomically complex or heavily collateral vascular supply have been associated with a higher probability of difficult technique or complications, reinforcing the importance of thorough pre-procedural imaging and individualized risk assessment rather than a single approach to every patient. Informed consent should reflect this individualized risk profile explicitly, rather than relying solely on average complication rates drawn from the published literature.

Table 4. Complications of PAE.

Complication	Typical management
Pelvic pain, dysuria, hematuria	Conservative; self-limiting
Post-embolization syndrome	Supportive care
Urinary tract infection	Antibiotic therapy
Temporary urinary retention	Short-term catheterization
Non-target embolization	Depends on organ affected; multidisciplinary care

Table 4 (continued)

Complication	Typical management
Prostatic abscess (rare)	Drainage and antibiotics

Controversies and Future Directions

Several questions remain open, and some patient subgroups remain more controversial than others. Whether PAE should move earlier in the treatment algorithm, rather than being reserved largely for surgically unfit or medically refractory patients, remains debated. Its role in very large prostates is a particularly active area: single-center series in glands ≥ 200 cc report technical success exceeding 90% with significant symptomatic improvement, suggesting prostate volume alone should not automatically exclude patients from PAE, yet comparative data against HoLEP and Aquablation — the latter now endorsed by the AUA up to 150 mL — remain limited in this specific population, and technical success is generally lower above roughly 200 mL. Whether unilateral embolization should ever be accepted in place of repeat bilateral treatment, and which embolic particle size and material best balance ischemic depth against non-target risk, are similarly unresolved; head-to-head comparisons between polyvinyl alcohol particles, calibrated microspheres, and newer resorbable or drug-eluting agents remain a specific and largely unaddressed knowledge gap. Long-term durability beyond ten years is not yet established, and considerable heterogeneity in outcome definitions and follow-up across studies complicates comparison between them, underscoring the need for internationally standardized reporting criteria.

This heterogeneity extends to how studies define technical success, clinical success, and retreatment, as well as to differences in follow-up duration, imaging protocols, and patient-reported outcome measures—this heterogeneity reduces the reliability of pooled analyses and complicates direct comparisons between published studies. Establishing a standardized core outcome set through collaboration between urological and interventional radiology societies would enhance the quality and consistency of future clinical trials and registries.

A related, more practical concern is how quickly training and technique can be disseminated beyond the specialized high-volume centers where most of the existing evidence was generated. Because outcomes are closely tied to operator experience, expanding access to PAE without diluting quality will likely require structured fellowship training, formal proctorship for early independent practice, and prospective outcome auditing—an implementation challenge that is arguably as important to the future of PAE as any single technological advance.

In the future, artificial intelligence and radiomics are expected to enhance prediction of treatment response and enable more accurate patient selection, while advances in embolic materials and imaging techniques are expected to further improve procedural safety [25,26]. Predictive models that combine clinical, imaging, and procedural data may help identify patients most likely to achieve sustained symptomatic improvement before undergoing PAE—a significant step toward precision medicine in BPH care rather than a uniform treatment algorithm applied to all comers [25].

Expanding indications under investigation include catheter-dependent retention, very large glands, and combination with other minimally invasive therapies. Several ongoing and planned randomized trials are expected to help resolve the questions above: head-to-head comparisons of PAE against Aquablation and against Rezūm in prospectively defined prostate-size strata, extended (10-year) follow-up cohorts from existing RCT populations to clarify true long-term retreatment risk, and prospective studies comparing embolic particle types using standardized technical and clinical

endpoints. Together with longer follow-up and standardized endpoints, these studies will be essential to refine guidelines and confirm where PAE offers the greatest advantage within an increasingly personalized, multidisciplinary approach to BPH management.

Table 5. Key research priorities for the next decade.

Priority	Objective
Long-term durability	Define outcomes and retreatment risk beyond 10 years
Very large prostates (≥ 150 –200 cc)	Prospective comparison of PAE vs. HoLEP/Aquablation in this specific stratum
Embolic agent selection	Head-to-head trials of particle type/size vs. non-target risk and durability
Patient selection	Validate predictive imaging and clinical biomarkers
Standardization	Harmonize procedural technique and outcome reporting
Health economics	Strengthen cost-effectiveness evidence across healthcare systems

Conclusion

Prostatic artery embolization has evolved from an incidental clinical observation into a guideline-endorsed, minimally invasive treatment for carefully selected men with BPH-related LUTS. Current evidence supports significant and durable improvement in symptoms and

quality of life, an excellent safety profile, and superior preservation of sexual function relative to conventional surgery, balanced against smaller gains in objective urinary flow and a higher rate of retreatment. Rather than competing with TURP or HoLEP, PAE occupies a complementary role within an increasingly individualized treatment landscape, particularly valuable for elderly or comorbid patients, those on anticoagulation,

and men prioritizing preservation of ejaculatory function.

The progression of PAE over the past two decades shows a shift in BPH management toward image-guided, personalized, and less invasive care, in which treatment decisions are shaped by individual anatomy, comorbidity, and patient priorities rather than by a single default procedure. Realizing the full potential of this shift will depend on collaboration between urologists and interventional radiologists, high-quality comparative studies, and continued updating of patient-selection criteria as the evidence base matures further.

Continued progress will depend on high-quality randomized trials with long-term follow-up, standardization of technique and outcome reporting, and closer integration of imaging biomarkers and multidisciplinary decision-making into routine practice. As this evidence base increases, PAE is well positioned to remain a valuable, patient-centered option within the expanding therapeutic range for benign prostatic hyperplasia. Future practice is no longer about whether PAE is effective, but how best to match it to the patients most likely to benefit — a task that will depend on sustained collaboration between urologists and interventional radiologists as much as on any single technological advance.

Key notes

- PAE is a guideline-supported minimally invasive option for selected men with LUTS secondary to BPH, though current recommendations are conditional rather than unconditional.
- Appropriate patient selection and multidisciplinary collaboration are the strongest predictors of successful outcomes.
- Symptom and quality-of-life improvement is durable, with an excellent safety profile and superior preservation of sexual function versus TURP/HoLEP.
- Objective flow improvement and long-term retreatment rates remain less favorable than with anatomical surgery.
- Long-term comparative trials and standardized outcome reporting remain key research priorities, particularly for very large prostates and embolic agent selection.

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