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Prostate Artery Embolization for Benign Prostatic Hyperplasia[1]

Key Words: benign prostatic hypertrophy, benign prostatic enlargement, prostate artery embolization

Benign prostatic hyperplasia (BPH) can result in a constellation of lower urinary tract symptoms (LUTS) with significant effects on men's health and quality of life. Once a patient becomes symptomatic there is often a preference for pharmacotherapy or minimally invasive surgical therapies (MISTs), with key drivers being few adverse events and preservation of sexual function. With these factors driving decision-making, prostate artery embolization (PAE) has emerged as a minimally invasive treatment option, now supported by a large body of evidence leading to inclusion in the most recent version of the AUA guidelines.[1]

PAE differs from other MISTs in treatment approach (endovascular vs transurethral) and mechanism (embolic), and thus requires different considerations. Herein, we examine the data supporting PAE, as well as its reported safety and efficacy.

PAE CANDIDATES

PAE involves a percutaneous endovascular approach: selective embolization of each prostatic artery with microparticles resulting in gradual decrease in prostatic volume, leading to a decrease in LUTS.[2] Patient selection for PAE requires unique considerations and meaningful collaboration between urologists and interventional radiologists (IRs) to provide exceptional patient-centric care. The diagnosis of BPH as the primary cause of LUTS requires a thorough urologic evaluation, as well as exclusion of other etiologies not addressed by PAE such as urethral stricture disease or detrusor dysfunction.[2,3] Furthermore, severe atherosclerosis may portend difficulty of an intravascular approach and requires consideration of other options.[2,3] Patients referred to IRs undergo standard-of-care workup assessing potential risk factors for severe atherosclerosis (ie, claudication, personal history of vascular disease), which would necessitate further vascular workup with cross-sectional imaging to ensure there was no contraindication to PAE. In addition to patients with moderate-to-severe LUTS,[1] PAE has demonstrated benefit in catheter-dependent patients with acute or chronic urinary retention with preserved bladder function, patients wishing to avoid medical therapy, patients with hematuria of prostatic origin, or patients who are deemed nonsurgical candidates due to age, comorbidities, or coagulopathy.[2,3] With the evolution of imaging and tools, median lobe morphology and/or intravesical protrusion has been shown not to affect outcomes.[4,5] Finally, while there is no upper limit for gland size and no efficacy impact with the presence of a large median lobe, predictability of outcomes diminishes in smaller glands,[6] with a general size cutoff of 60 cc.

EFFICACY: CLINICAL TRIALS

The body of evidence supporting PAE now includes over 20 prospective studies and 6 randomized controlled trials (RCTs), 4 vs transurethral resection of the prostate (TURP),[6-9] 1 vs sham,[10] and 1 vs pharmacotherapy.[11] The longest follow-up includes 2 years post RCT[6] and 10 years with large cohorts from high-volume centers.[12,13] These studies demonstrate that PAE provides a significant reduction in LUTS in the short to medium term[14] with an International Prostate Symptom Score reduction ranging from 9 to 21 points.[6,8] Functional outcomes, including maximum flow rate and postvoid residual, however, remain inferior to TURP due to the embolic rather than resective nature of PAE. This corresponds to a maximum flow rate improvement range of 5 to 7 mL/s on meta-analysis.[14] Compared to pharmacotherapy, PAE provided significant improvements in LUTS (International Prostate Symptom Score) and sexual function (International Index of Erectile Function).[11] These trials report a PSA decrease of approximately 20% to 40%, reaching its nadir at 6 months.[6-8,10,11] MRI findings post PAE demonstrate a 20% to 30% decrease in central gland volume, with a decrease in T2 signal intensity, decreased enhancement, and occasional central gland infarction.[4] Overall, multiple

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Table. *Prostate Artery Embolization Randomized Controlled Trials*

Study	N (No. of patients)	Groups	Follow-up timeline	Study outcomes	Study findings
Carnevale 2016[9]	30	TURP vs PAE. Study included a separate retrospective analysis of another technique for PAE (PErFecTED).	Minimum of 1 y	Urodynamic parameters, PV, IPSS, and QoL	• All groups experienced significant improvement in mean IPSS, QoL, and Qmax compared to baseline ($P < .05$) • Mean posttreatment IPSS, QoL, and Qmax were significantly improved after TURP compared to PAE ($P = .012$) • Mean IPSS scores for PAE patients at 1 y reduced from 25.3 ± 3.6 (19-30) to 12.8 ± 8.0 (2-27; $P < .05$) • Mean QoL scores for PAE patients at 1 y reduced from 4.7 ± 0.6 (4-6) to 2.2 ± 1.2 (1-4; $P < .05$) • Mean IIEF scores for PAE patients at 1 y reduced from 14.3 ± 6.8 (0-21) to 12.6 ± 7.7 (0-21; $P < .05$)
Gao 2014[7]	114	TURP, PAE	24 mo	IPSS, Qmax, peak urinary flow, PVR, PSA, and PV	• Postoperative IPSS, QoL, PVR, peak urinary flow increased for both groups, comparable at 12 and 24 mo ($P = .001$) • Degree of improvement significantly greater in TURP group compared to PAE group at 1, 3 mo ($P = .001$) • IPSS scores after PAE decreased from 24.3 to 8.7 at 24 mo ($P = .001$) • QoL scores decreased from 4.8 to 1.6 at 24 mo ($P = .001$)
Pisco 2020[10]	80	PAE, sham group	6 mo open period	IPSS and QoL	• IPSS score reduction for PAE and sham were 17.1 ± 7.25 and 5.03 ± 8.13, respectively. Difference in IPSS between groups: 13.2, ($P < .0001$) • Mean QoL scores for PAE and sham were 1.35 ± 1.12 and 3.48 ± 1.38, respectively. Difference in QoL scores between groups: 1.99 ($P < .0001$)
Abt 2018[18] and 2021[4]	103	TURP, PAE	2 y follow-up has been completed	IPSS, functional measures, PV	• IPSS score reduction for PAE and TURP groups were 9.21 and 12.09, respectively (difference of 2.88, $P = .047$) • TURP more effective than PAE relative to maximum urinary flow rate (3.9 vs 10.23 mL/s, $P < .001$) • TURP more effective than PAE relative to reduction of postvoid residual (62.1 vs 204.0 mL, $P = .005$) • Fewer adverse events after PAE compared to TURP (43 vs 78; $P = .005$)
Insausti 2020[6]	45	PAE, TURP	12 mo	IPSS, Qmax, QoL, PV, and adverse events	• IPSS scores for PAE and TURP decreased 21.0 and 18.2, respectively; difference of 3.04 between groups ($P = .080$) • QoL scores for PAE and TURP decreased 3.78 and 3.09, respectively; difference of 0.92 between groups ($P = .002$) • Fewer adverse events reported for PAE compared to TURP group (15 vs 47; $P < .001$) • No significant difference between PAE and TURP relative to Qmax at 12 mo
Sapoval; PARTEM group 2023[11]	90	Combined therapy: oral dutasteride/tamsulosin hydrochloride treatment	1 yr	IPSS	• Nine-month decrease in IPSS was 10.0 and 5.7 for PAE and combined therapy drug groups, respectively. Difference in scores greater in the PAE group ($P = .0008$) • IIEF-15 score change was 8.2 (95% CI: 2.9-13.5) and −2.8 (95% CI: −8.4 to 2.8) in the PAE and combined therapy drug groups, respectively

Abbreviations: IIEF, International Index of Erectile Function; IPSS, International Prostate Symptom Score; PAE, prostatic artery embolization; PErFecTED, Proximal Embolization First, Then Embolize Distal; PV, prostate volume; PVR, postvoid residual volume; Qmax, maximum free urinary flow rate; QoL, quality of life; TURP, transurethral resection of the prostate.

RCTs have demonstrated that PAE clearly improves LUTS (Table).

LONG-TERM OUTCOMES

Several large-cohort studies have reported long-term PAE outcomes. These studies demonstrate that while PAE produces durable results in the majority of patients, a 20% recurrence rate within 5 years and 30% to 60% rate within 10 years can be seen; however, these retrospective data may underestimate the incidence.[12,13] This may be a natural consequence of glandular regrowth over time and the nonresective mechanism of PAE. Repeat PAE is safe and effective in these patients,[15] as is subsequent surgical intervention.[6,12,13]

SAFETY AND LIMITATIONS

PAE offers a safe outpatient procedure with no need for urethral catheter and 0% transfusion rate. However, the crux of a safely performed PAE is understanding pelvic arterial anatomy due to the prostatic artery's complex origins and potential for collateralization. PAE safety and efficacy is contingent on this knowledge to increase treatment effectiveness and

reduce the risk of nontarget embolization. Nontarget embolization leading to bladder necrosis (<1%) or penile (<1%) or rectal ischemia (<5%) remains rare and can be managed conservatively.[14] Maintaining this safety profile and accurate embolization requires both experience and utilization of advanced image guidance in the form of cone-beam CT. Cone-beam CT provides 3-dimensional images of the prostatic and pelvic vasculature, providing more information than angiography alone, facilitating safety and efficacy.[2,16] Initial reports of safety are representative of the early understanding of expected PAE outcomes. The RCT by Gao et al reported a 50% complication rate in the PAE arm; however, this included both treatment failures and postembolization syndrome, and vastly overestimated the true complication rate.[7] Collaboration between IRs and urologists has led to improved PAE postembolization syndrome management. A recent meta-analysis of PAE found few adverse events compared to TURP consisting of temporary irritative voiding, hematospermia, and UTIs, with major adverse events in 2.5% of patients without persistent sequelae. Specifically, PAE did not result in urinary incontinence or erectile dysfunction, with ejaculatory function preserved in the vast majority of patients.[14]

Naysayers of PAE cite concerns with ionizing radiation during PAE. However, a recent meta-analysis demonstrated the median effective dose for PAE corresponds to 2 to 3 abdominopelvic CT scans. This corresponds to a calculated mortality risk of less than 0.1%, less than that seen with more invasive surgical approaches.[17]

Safety and efficacy are contingent upon thorough identification of pelvic arterial anatomy, such that embolization is limited to the prostatic arterial supply while preventing nontarget embolization. To maximize safety and efficacy, an IRs experience and/or utilization of advanced imaging guidance is critical.[2,16] Following this paradigm, the adverse event profile favors PAE over invasive approaches, consisting of self-limited irritative voiding symptoms, hematospermia, and rare UTIs.[14]

Limitations to PAE include a slower, gradual relief in symptoms when compared to TURP, and retreatment rates of up to 20% at 5 years. Other contraindications to PAE include LUTS secondary to etiologies other than BPH, treatment of small prostates, severe atherosclerosis, renal dysfunction, and severe contrast allergy.[12-14] Despite these limitations, the favorable safety profile, preservation of sexual function, and safety of repeat PAE or surgery after PAE make PAE an excellent initial treatment option for many men.

DISCUSSION

PAE is a distinct minimally invasive treatment option for BPH/LUTS that has demonstrated its safety and efficacy and is now supported in the most recent AUA guidelines.[1] Collaboration between both urology and IR is critical to identify patients who may benefit from PAE. As the endovascular mechanism of action is entirely different than transurethral approaches, special factors must be considered. PAE must include a full urologic evaluation and be performed by IRs trained in this technique who have experience and anatomic knowledge to provide optimal outcomes.[2] PAE overcomes limitations seen with other MISTs without upper limits on gland size or the presence of a median lobe. However, results are less predictable in glands under 60 cc[6] and in patients with severe atherosclerosis.[3]

Patient preferences toward improving LUTS while maximizing safety and sexual function make PAE an ideal initial therapy in appropriately selected patients. Thus, choosing between options requires weighing the pros and cons of each approach with respect to the patient's age, comorbidities, gland size, and values regarding the adverse event profile and sexual function. Implementation of PAE into the treatment pathway of BPH/LUTS is therefore reasonable if patients are adequately counseled with shared decision-making between the patient, urology, and IR. Ultimately, collaborative multidisciplinary care is the cornerstone of overing PAE and the involvement of both urology and IR is essential for the PAE patient.

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