Lower urinary tract (LUT) symptoms are an extremely common issue for men, with the most typical cause in middle and older age men being benign prostatic hyperplasia (BPH). Symptomatic BPH affects as many as 430 per 1,000 men aged 60 to 69 years, with an overall estimated prevalence of 33% in men aged 40 to 80 years in the United States. BPH leads to both a decline in urinary-associated and overall quality of life (QOL). This condition results in significant economic burden, with 8 million visits made to physicians with a primary or secondary diagnostic code of BPH reported in the United States in 2000. The estimated cost was $1.1 billion, without factoring in the cost of pharmaceuticals, as well as up to 38 million hours in lost productivity/time.

Initial therapy for symptomatic BPH is medication, typically 5-alpha-reductase inhibitors or alpha-blockers. However, for many patients, this is not sufficient, and operative or minimally invasive intervention is needed. Prostate artery embolization (PAE) has been developed as a minimally invasive means to treat BPH-related LUT symptoms. Initial early and midterm results have been very promising in reducing LUT symptoms and improving QOL. However, given its early developmental stage, PAE still requires further investigation. Specifically, many aspects of the technique itself have yet to be thoroughly investigated with regard to maximizing treatment safety and efficacy, both of which are paramount in the development of any new technique. This article reviews the current evidence for specific technique recommendations in PAE.

BILATERAL VERSUS UNILATERAL PROSTATIC ARTERY TREATMENT

The logic that bilateral PAE leads to improved size reduction and superior symptomatic outcomes has made bilateral treatment the goal for early investigators studying PAE. This clinical suspicion has specifically been evaluated by a single retrospective study that investigated outcomes in 122 patients treated with polyvinyl alcohol (PVA). The study compared 103 patients who underwent bilateral PAE to 19 who underwent unilateral PAE. They did not demonstrate significant differences in terms of International Prostate Symptom Score (IPSS), maximum flow rate (Qmax), or QOL improvements between the unilateral and bilateral PAE groups. However, they did show that poor outcomes (defined as an IPSS ≥ 20 and/or reduction < 25%, QOL ≥ 4 and/or reduction < 1, Qmax < 2.5 mL/s, and additional treatments required [i.e., medication or surgery]) were seen more in the unilateral group compared to the bilateral group. However, the statistical significance of this difference (P < .05) was lost when age was taken into account. Although this study did not show overwhelming proof that bilateral treatment is superior to unilateral treatment, it suggests a benefit to bilateral treatment without evidence of increased risk.

The issue of bilateral versus unilateral PAE was also one of the variables investigated in a retrospective review of two phase 2 prospective cohorts evaluating the recurrence of LUT symptoms at 12 months. This study presented data on 97 patients and recurrence of symptoms was defined as IPSS ≥ 8 or QOL ≥ 3 at 12 months. Although the primary goal was to investigate the difference between two embolization techniques (the proximal embolization first, then embolize distal for benign prostatic hyperplasia [PERFECTED] technique and original PAE discussed below), they did note that the symptom recurrence was significantly more common with original PAE when only a single prostatic artery was embolized. The same was not true for the PERFECTED technique, but this may have been because only one patient in this group underwent unilateral PAE.

In a recent case series, Amouyal et al reported on the use of bilateral PAE from a single-sided approach. In this series of three patients, intraprostatic anastomoses allowed the authors to pass a microcatheter from one prostatic artery across the prostate to the contralateral prostatic artery and perform embolization. Although previous anatomic studies have shown the presence of such anastomoses, this is the first report of their clinical utility. This interesting series may
provide a guide to achieving bilateral PAE in patients who have arterial occlusion on one side, preventing prostatic artery cannulation.

**USE OF CONE-BEAM CT**

Cone-beam CT (CBCT) allows increased spatial resolution to be obtained in real time. This powerful technique has led many to advocate for its use to help delineate the arterial anatomy in this complex anatomic region. Two retrospective studies have evaluated the usefulness of CBCT. In the first study, Bagla et al performed CBCT on 11 patients and found that CBCT provided information that altered treatment in five of 11 (46%) patients. CBCT altered management by demonstrating collaterals that would have placed the patient at risk of nontarget embolization, as well as identifying duplicate arterial supply not seen on digital subtraction angiography (DSA) that could be pursued for treatment.

In the second study, Wang et al reviewed 148 patients with a primary goal of delineating anatomy. However, the authors also evaluated the value added by CBCT. They discovered that the origins of the prostatic artery could be confidently identified in 94.7% of patients using CBCT as compared to 74.5% using only DSA. They also identified significantly more prostatic artery anastomoses ($P < .05$) with CBCT compared to DSA. In total, they found that CBCT provided more anatomic information, as compared to DSA alone in 95 of 148 (64.2%) patients. These data have helped to confirm the prevailing thought that CBCT provides valuable information, and this theory has largely been adopted by the authors.

**PARTICLE SIZE AND TYPE**

The published experience using different sizes of treatment embolization particles has widely varied from 50 µm to 300 µm to 500 µm. Two studies have specifically addressed this subject. The first study by Bilhim et al was a prospective randomized comparison of different PVA sizes. This study compared 80- to 180-µm PVA treatments to 180- to 300-µm PVA treatments and enrolled 80 patients. There was no significant difference in the adverse events experienced between the two groups. The larger particle cohort had a greater reduction in IPSS at 6 months (7.31 vs 3.64), which was found to be nearly significant ($P = .052$). Similarly, QOL improved more in the larger particle group, with an improvement of 1.2 points compared to 0.57 points in the smaller particle group; however, this was not significantly different ($P = .07$).

There were also nonsignificant trends of improvement in reduction of prostate volume and postvoid residual (PVR) urine volume in the smaller particle group. The only statistically significant difference was in the reduction of the prostate-specific antigen (PSA) level, which was greater in the small particle group ($P < .05$).

In the second study by Goncalves et al, 15 patients were prospectively treated with 300- to 500-µm trisacryl gelatin microspheres (Embosphere microspheres, Merit Medical Systems, Inc.), and another 15 were treated with 100- to 300-µm microspheres. They found no significant difference in IPSS reduction, QOL improvement, PSA reduction, or prostate size reduction between the two groups. No patients experienced a major adverse event; however, there was a nonstatistically significant trend toward increased minor adverse events in patients who underwent PAE with smaller microspheres ($P = .066$). The smaller particle size also demonstrated a significant regrowth in prostate size from 3 to 12 months, which was not observed in the larger particle size group. These differences led the authors to suggest that the larger particles would be preferable.

Although there are limited data available, both studies have suggested that larger particles (180- to 300-µm PVA and 300- to 500-µm trisacryl gelatin microspheres) tend to perform slightly better. However, these studies are difficult to compare given the difference in particle type, with one using PVA and the other using spherical trisacryl gelatin microspheres. Also, the larger particles performed better in different ways, with the larger PVA particles showing a trend toward improved outcomes and the larger trisacryl gelatin microspheres showing a trend toward decreased adverse events and reduced prostatic regrowth. These differences underline the importance of investigating the optimal type of particle to use. As was experienced in uterine artery embolization (UAE), the type of particle can have a significant impact on outcomes. These data relating to PAE are currently lacking and should be considered for future investigations.

**THE PErFEcTED TECHNIQUE**

The PErFEcTED technique as described by Carnevale et al constitutes embolizing the prostatic artery to near stasis after passing all collateral arteries, then the microcatheter is advanced deeper into the parenchymal branches, which are then embolized to complete stasis. This is compared to original PAE, in which the prostatic artery is embolized to stasis after passing all collateral arteries, without advancement into each parenchymal prostatic artery branch. The use of vasodilators prior to embolization is a frequent practice in both techniques and is likely a good practice to help reduce vasospasm and maximize embolic delivery.

The PErFEcTED technique has been compared to original PAE in two studies thus far. In the first study, the PErFEcTED technique was compared to original PAE in 30 patients who were prospectively enrolled but not randomized. The
**CONCLUSION**

PAE has shown promising results at short-term and midterm follow-up. Although we continue to investigate this technique, many areas need to be further evaluated to achieve the goal of procedural optimization. Basic technical aspects, such as the ideal embolization particle, remain unclear. However, the available data seem to support the use of CBCT, particles ≥ 200 μm, the PErFecTED technique, and bilateral PAE. In the future, these aspects warrant further investigation, ideally in a prospective randomized fashion.

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