Prostatic Artery Embolization Using 100–300-μm Trisacryl Gelatin Microspheres to Treat Lower Urinary Tract Symptoms Attributable to Benign Prostatic Hyperplasia: A Single-Center Outcomes Analysis with Medium-Term Follow-up

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ABSTRACT

Purpose: To report medium-term outcomes of prostatic artery embolization (PAE) using 100–300-μm trisacryl gelatin microspheres to treat lower urinary tract symptoms (LUTS) from benign prostatic hyperplasia (BPH) and to evaluate how cone-beam computed tomography-measured prostate gland volume (PGV), median lobe enlargement (MLE), age, and Charlson Comorbidity Index (CCI) affect these results.

Materials and Methods: Seventy-four consecutive patients who underwent PAE from April 2014 through August 2018 were retrospectively reviewed. Patients had International Prostate Symptom Score (IPSS) >12, Quality of Life (QoL) score >2, prostate gland volume (PGV) >40 mL, age older than 45 years, and medical therapy failure. Twelve patients were excluded for bladder pathology or prostate cancer. Patients (n = 62, age = 71.8 ± 9.3 years, CCI = 3.5 ± 1.7, PGV = 174 ± 110 mL) had pre-procedure IPSS = 22.4 ± 5.6, QoL score = 4.4 ± 0.9, and post-void residual (PVR) = 172 ± 144 mL. Post-procedure values were compared to baseline at 1, 3, 6, 12, and 24 months. Associations between outcomes and PGV, MLE, age, and CCI were evaluated. Adverse event recording used Clavien-Dindo classification.

Results: One month after PAE (n = 37), IPSS improved to 7.6 ± 5.2 ($P < .0001$) and QoL score improved to 1.7 ± 1.4 ($P < .0001$). At 3 months (n = 32), improvements continued, with IPSS = 6.4 ± 5.1 ($P < .0001$), QoL score = 1.2 ± 1.2 ($P < .0001$), PVR = 53 ± 41 mL ($P < .001$), and PGV = 73 ± 38 mL ($P < .0001$). Results were sustained at 6 months (n = 35): IPSS = 6.4 ± 4.1 ($P < .0001$), QoL score = 1.2 ± 1.2 ($P < .0001$), PVR = 68 ± 80 mL ($P < .0001$), PGV = 60 ± 19 mL ($P < .001$). At 12 months, patients (n = 26) had IPSS = 7.3 ± 5.5 ($P < .0001$), QoL score = 1.2 ± 0.8 ($P < .0001$), PVR = 89 ± 117 mL ($P < .0001$), PGV = 60 ± 48 mL ($P < .01$). At 24 months, patients (n = 8) had IPSS = 8.0 ± 5.4 ($P < .0001$), QoL score = 0.7 ± 0.5 ($P < .0001$), PVR = 91 ± 99mL ($P = 0.17$), and PGV = 30 ± 5mL ($P = .11$). Improvements were independent of PGV, MLE, age, and CCI. Two grade II urinary infections occurred.

Conclusions: PAE with 100–300-μm microspheres produced sustained substantial improvements in LUTS, PGV, and PVR, which were independent of baseline PGV, MLE, age, or CCI.

ABBREVIATIONS

BPH = benign prostatic hyperplasia, CCI = Charlson Comorbidity Index, IIEF = International Index of Erectile Function, IPSS = International Prostate Symptom Score, MLE = median lobe enlargement, LUTS = lower urinary tract symptoms, PAE = prostatic artery embolization, QoL = quality of life, PGV = prostate gland volume, PVA = polyvinyl alcohol, PVR = post-void residual

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EDITORS' RESEARCH HIGHLIGHTS

- Retrospective, single-arm, single-center study of 62 prostatic artery embolization (PAE) patients using 100–300-μm trisacryl gelatin particles in 62 patients (mean age, 72 years; mean baseline prostate volume, 174 cm^3). Protective coil embolization was performed in 53% of patients. After exclusions, cohort was 58 patients.
- Follow-up reached 35 patients at 6 months, 26 patients at 12 months, and 8 patients at 24 months. PAE results with 100–300-μm trisacryl gelatin microspheres were similar to most studies using 300–500-μm particles. International Prostate Symptom Score/Quality of Life score improved 14–17 and 2–3.5 points, respectively; prostates shrank 43%–71%. Adverse event rate was 29% (26% grade I events and 3% grade II events), including acute urinary retention (n = 4), urinary tract infection (n = 2), and urinary obstruction due to sloughing necrotic tissue (n = 2). Seven percent of patients required prostatic surgery, and 19% continued benign prostatic hyperplasia medication after PAE.
- Limitations are as follows: Follow-up in 35 of 60 patients at 6 months dropped to 8 of 10 patients at 24 months. Changes from baseline compared different subgroups after PAE from the baseline cohort. Statistical analysis plan did not account for losses to follow-up, limiting the generalizability of study results (eg, 71% reduction in prostate volume at 24 months that did not reach significance; prostate volume measurements were performed with transabdominal ultrasound). Objective urine flow measurements and quantitative erectile function assessments were not made.

Prostatic artery embolization (PAE) has been shown to successfully treat lower urinary tract symptoms (LUTS) in benign prostatic hyperplasia (BPH) patients by causing infarction and necrosis of hyperplastic adenomatous tissue, which decompresses urethral impingement and improves obstructive symptoms (1–9). To date, no consensus exists regarding the type and size of embolic particles that deliver optimal efficacy and safety. In PAE studies that have described results using polyvinyl alcohol (PVA) particles (3,7), there is indication that smaller particles (50 μm vs 100 μm) might improve outcomes without compromising safety (10). Many authors have performed PAE with trisacryl gelatin spherical particles (1,2,5,6,8,9). Their decreased size variability and aggregation have reportedly led to more predictable target occlusion (11–13). The 100–300-μm version of these particles could potentially penetrate prostate tissue better and cause superior infarction than larger particles. However, most PAE studies published with trisacryl gelatin spherical particles have used the larger 300–500-μm particles, citing concerns that smaller particles might lead to increased nontarget embolization-related adverse events (14,15). One retrospective study by Goncalves et al (14) comparing small PAE cohorts using 100–300-μm and 300–500-μm particles showed similar outcomes and adverse events, whereas a larger randomized trial by Torres et al (15) comparing both sizes showed similar outcomes with more minor adverse events in the 100–300-μm particle group. However, procedures in the latter study were performed using digital subtraction angiography combined with a diagnostic computed tomography (CT) angiogram, but not with cone-beam CT, which may provide additional information about target prostatic and nontarget pelvic arterial perfusion.

Cone-beam CT imaging also enables delineation of median lobe enlargement (MLE) anatomy and perfusion, as well as time-of-procedure prostate gland volume (PGV), which can be calculated using cone-beam CT image segmentation. MLE and PGV >100 mL are key prohibitive factors that can exclude patients from transurethral procedural therapies (16). However, PAE studies examining PGV as a predictor of outcomes have done so using magnetic resonance scans acquired at unspecified pre-procedure time intervals, using ellipsoid volume estimation without detailed evaluation of MLE (4,17). Correlating post-procedure outcomes with MLE and PGV information derived from time-of-procedure cone-beam CT could provide novel insight as to how these factors affect such outcomes.

Accordingly, this study sought to address these issues by reporting medium-term outcomes in a cohort of BPH patients who underwent PAE performed with 100–300-μm spherical particles for treatment of LUTS and by evaluating how patient factors that determine prostatic surgical candidacy (PGV, MLE, age, and medical comorbidities) affect these results.

MATERIALS AND METHODS

Patients

At a single center, data from 74 consecutive patients with LUTS attributable to BPH who underwent PAE with 100–300-μm trisacryl gelatin spherical particles (Embosphere; Merit Medical Systems, South Jordan, Utah) from April 2014 through September 2018 were retrospectively reviewed under an institutional review board-approved protocol. All patients underwent evaluations by both a urologist and the performing interventional radiologist, with completion of International Prostate Symptoms Score (IPSS) and Quality of Life (QoL) index questionnaires, as well as calculation of Charlson Comorbidity Index (CCI) (18). International Index of Erection Function (IIEF)-5 questionnaires were not completed in most cases. Pre-procedure post-void residual volumes (PVRs) (n = 50) and PGVs (n = 34) measured by trans-abdominal ultrasound were obtained. Pre-procedure urinary flow rates were not available. All patients were older than 45 years of age and had BPH-associated LUTS contraindicated for or refractory to 3 or more months of medical therapy, with IPSS >12, QoL score >2, and PGV >40 mL, and thus were

Table 1. Baseline Characteristics for All 74 Patients Undergoing PAE for LUTS Who Were Initially Included for Study

Characteristic	Mean ± SD	Median	Range
Age (years)	71.8 ± 9.3	71.0	48.4–92.2
Charlson Comorbidity Index	3.5 ± 1.7	3.0	0–9
IPSS	22.4 ± 5.6	22.0	13–35
QoL	4.4 ± 0.9	4.0	3–6
PVR	172 ± 144 mL	126.5 mL	1–535 mL
PGV (measured by cone-beam CT)	174 ± 110 mL	145 mL	54–698 mL
PSA (ng/mL)	6.4 ± 7.4	3.5	0.5–38.2
Ethnicity	Caucasian 94%, Hispanic 3%, African-American 3%		

Patient BPH Medications at Time of PAE	
Medication	**# Patients**
5-α-Reductase Inhibitor	6/62 (10%)
α-Blocker	17/62 (27%)
Both	29/62 (47%)
None	10/62 (16%)

Patient BPH Procedures prior to PAE	
Procedure	**# Patients**
TURP	7 (11%)
Photovaporization	3 (5%)
Microwave Thermotherapy	2 (3%)

BPH = benign prostatic hyperplasia; IPSS = International Prostate Symptom Score; PAE = prostatic artery embolization; PGV = prostate gland volume; PSA = prostate-specific antigen; PVR = post-void residual; QoL = Quality of Life; SD = standard deviation; TURP = transurethral resection of the prostate.

considered to be index BPH patients according to American Urological Association procedural treatment guidelines (16). All patients with gross hematuria underwent cystoscopy, and any prostate-specific antigen level >4.0 ng/mL was also evaluated by a urologist. Baseline characteristics for all 74 patients are summarized in **Table 1**. Patients with histories of prior transurethral surgical procedures for BPH were included for analysis because the severity of their recurrent symptoms was sufficient to merit further intervention. Patients who underwent embolization and who had preexisting bladder cancer (n = 3), prostate cancer (n = 4), or bladder stone (n = 5) were excluded from analysis due to the potential for confounding symptoms and adverse events. Thus, the final outcomes analysis cohort included 62 patients. Of note, this cohort of LUTS patients was part of a separate larger study (also including urinary retention patients) by the same authors that compared procedural metrics and clinical improvements for PAE when performed with a balloon-occlusion versus an endhole microcatheter (19).

Procedure

Patients were prescribed antibiotic (ciprofloxacin 500 mg PO BID), anti-inflammatory (ibuprofen 400 mg PO QID), proton-pump inhibitor (esomeprazole 40 mg PO QD), and stool softener (docusate sodium 200 mg PO BID) medications for 2 days prior to PAE. All procedures were performed by a single operator (8 years of experience) using moderate sedation (midazolam IV, fentanyl IV) and ketorolac 30mg IV. A 6-Fr radial or femoral arterial sheath was introduced, followed by selection of one of the internal iliac arteries with a 5-Fr angiographic catheter. Digital subtraction angiography delineated branches of the internal iliac artery.

The prostatic artery was sub-selected with a 0.016" Fathom guidewire (Boston Scientific, Marlborough, Massachusetts) and either an endhole microcatheter (2.4-F Renegade STC; Boston Scientific, or 2.1-Fr Maestro or 2.4-Fr Swift Ninja; Merit Medical Systems) (n = 34) or a balloon-occlusion microcatheter (2.2-F Sniper; Embolx, Sunnyvale, California) (n = 28) at the discretion of the operator (19). Sub-selective angiography delineated prostatic arterial supply and any nontarget branch vessels. Then, 200 mcg of nitroglycerin were injected into each prostatic artery (even in patients with more than 1 prostatic artery per side), followed by cone-beam CT (GE Healthcare, Chicago, Illinois) to confirm arterial anatomy, assess prostate perfusion, and measure PGV. Any nontarget branches not bypassed or excluded by balloon occlusion were protectively coil embolized (Medtronic, Minneapolis, Minnesota, or Cook Medical, Bloomington, Indiana). The microcatheter was then advanced further into the prostatic artery, where embolization was performed to stasis with 100–300-μm spherical particles, confirmed by follow-up contrast injection. Identical technique was then employed on the contralateral side, with the same type of microcatheter used on

both sides in all but 3 patients (in these, a balloon-occlusion microcatheter was used on the first side, but its straight tip could not be advanced into a tortuous prostatic artery origin on the other side). Finally, vascular access was removed, and hemostasis was achieved. Patients were observed for 2 hours and were discharged home after successful urination. Use of the described approach was confirmed by review of all included procedures.

Post-Procedural Follow-Up

Post-procedure medications included continued ibuprofen as needed for pain, solifenacin succinate (5 mg PO BID) as needed for bladder spasm, phenazopyridine (200 mg PO TID) for 5 days, and continuation of the antibiotic, proton-pump inhibitor, and stool softener medications for 7 days. No new BPH medications were started or doses increased after embolization. Patients maintained their pre-procedure BPH medication doses until their first follow-up appointment. Thereafter, such medications were discontinued if symptomatic improvement into the mild range was reported, and were restarted only for recurrence of symptoms into the moderate range. Patients followed-up with the interventional radiologist at 1, 3, 6, 12, and 24 months after PAE, completing IPSS and QoL assessments at each visit. PVR and PGV measurements were obtained from 3 months onward. Patients also followed-up with their urologists within 6 months after PAE. To address potential responder bias stemming from missing follow-up data points, phone follow-up was attempted in all instances of missed clinic follow-up. Any new hematuria or worsening of LUTS into the medium range was evaluated by a urologist. Adverse events within 90 days were tabulated using Clavien-Dindo classification (20).

Image Processing and Statistical Analysis

Volumetric measurements of PGV were calculated using segmented regions of interest drawn around prostate tissue on source cone-beam CT procedural images (Fig 1) (GE Advantage Workstation, Release 4.5; GE Healthcare). MLE was defined as any intravesical protrusion of prostatic tissue that was seen on axial and sagittal cone-beam CT images to emanate from the median lobe and not from lateral lobe regions of the gland. Statistical analysis was performed using R (R Foundation for Statistical Computing, Version 3.3.2, 2016). IPSS and QoL scores were compared to baseline (paired Wilcoxon signed-rank tests), as were PGV and PVR (2-tailed paired Student *t*-tests) using measurements obtained by pre- and post-procedure transabdominal ultrasound. Simple linear regression models evaluated associations between IPSS, QoL, or PVR improvements and patient age, CCI, or PGV (using segmented volumetric PGV measurements obtained from procedural cone-beam CT). Student *t*-tests evaluated differences in IPSS, QoL, and PVR improvement associated with MLE. *P* values less than .05 were considered statistically significant.

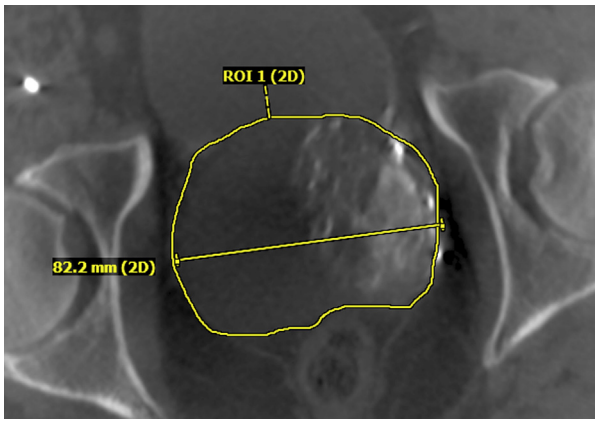

Figure 1. Axial cone-beam CT image of prostate gland used to confirm appropriate target vessel(s) for embolization and for measurement of PGV. Image was obtained during left prostatic artery contrast injection, with the entirety of the left hemi-prostate perfused.

RESULTS

Procedural Metrics

Technical success, defined as bilateral embolization with 100–300-μm spherical particles, was achieved in 58/62 (94%) patients. Small tortuous prostatic arteries resulted in unilateral embolization in 3/62 (4.5%) patients and no embolization in 1 (1.5%) patient. Protective coiling of collaterals was performed in 33/62 (53%) patients, with a mean of 1.4 ± 0.6 separate vessels coiled among these patients. Mean procedure time was 179 ± 68 minutes (range, 66–332 minutes). Mean fluoroscopy time was 46.4 ± 20.4 minutes (range, 21.5–119.8 minutes). Cumulative dose and dose-area product data were unavailable for reporting.

Follow-up and Clinical Outcomes

Of the 58 patients who underwent technically successful PAE, 60%–80% of patients eligible for follow-up at each timepoint were evaluated in clinic: 37/57 (65%) at 1 month; 32/53 (60%) at 3 months; 35/49 (71%) at 6 months; 26/40 (65%) at 12 months; and 8/10 (80%) at 24 months. One patient died within 30 days of PAE and was not included in outcomes analysis. Although not every eligible patient returned at each follow-up timepoint, 53/58 (91%) patients had returned for their latest eligible follow-up at time of submission. For instances when patients did not return to clinic, phone follow-up was available in 5%–20% of patients at each timepoint, with subjective improvement from pre-procedure baseline or subjective stability of previously quantified post-procedure improvement recorded but not included in quantitative statistical analyses. By definition, the number of patients eligible for follow-up was lower at each successive timepoint due to the ongoing nature of patient accrual.

Baseline and follow-up data for improvements in IPSS, QoL, PVR, and PGV at 1-, 3-, 6-, 12-, and 24-month timepoints for the 57 patients who underwent technically

Table 2. Clinical Outcomes through 24 Months of Follow-up for the 58 Patients Who Underwent Technically Successful PAE Procedures

Clinical Outcome	n	Mean ± SD	Median	Median Score Change or Mean % Volume Change	*P* Value
IPSS					
Baseline	58	22.4 ± 5.6	22.0	-	-
1 month	37	7.6 ± 5.2	7.0	-15.0	< .0001
3 months	32	6.4 ± 5.1	5.5	-17.0	< .0001
6 months	35	6.4 ± 4.1	6.0	-16.0	< .0001
12 months	26	7.3 ± 5.5	6.5	-16.0	< .0001
24 months	6	8.0 ± 5.4	8.5	-14.0	< .0001
QoL					
Baseline	58	4.4 ± 0.9	4.0	-	-
1 month	37	1.7 ± 1.4	2.0	-2.0	< .0001
3 months	32	1.2 ± 1.2	1.0	-3.0	< .0001
6 months	35	1.2 ± 1.2	1.0	-3.0	< .0001
12 months	26	1.2 ± 0.8	1.0	-3.0	< .0001
24 months	6	0.7 ± 0.5	1.0	-3.5	< .0001
PVR					
Baseline	50	172 ± 144 mL	127 mL	-	-
3 months	23	53 ± 41mL	39 mL	-61%	< .001
6 months	30	68 ± 80 mL	43 ml	-65%	< .0001
12 months	23	89 ± 117 mL	35 mL	-57%	< .0001
24 months	8	91 ± 99 mL	73 mL	-53%	NS
PGV					
Baseline	34	120 ± 54 mL	116 mL	-	-
3 months	12	73 ± 38 mL	67 mL	-46%	< .0001
6 months	12	60 ± 19 mL	63 mL	-43%	< .001
12 months	10	60 ± 48 mL	57 mL	-47%	< .01
24 months	3	30 ± 5 mL	31 mL	-71%	NS

Note–Data are not included for the 4 technical failure patients.
IPSS = International Prostate Symptom Score; PGV = prostate gland volume; PVR = post-void residual; QoL = Quality of Life; SD = standard deviation.

successful PAE procedures and have available follow-up data are summarized in Table 2 and depicted in Figure 2 and Figure 3. Patients had statistically significant reduction in subjective symptom burden after PAE performed with 100–300-μm spherical particles at 3 months (IPSS reduction of 72%, QoL reduction of 76%) and maintained through 2 years of follow-up (IPSS reduction of 69%, QoL reduction of 84%) (Table 2, Fig 2). Improvements in bladder emptying and gland shrinkage were likewise substantial and sustained (Fig 3). Mean follow-up interval was 316.5 ± 224.2 days (median, 309.5 days). Of patients taking BPH medications before PAE, 35/46 (76%) discontinued them, and no patients started new BPH medications as of their latest follow-up (mean follow-up duration, 270 ± 216 days).

Linear regression analyses assessed for significant relationships between baseline patient characteristics (PGV, age, and CCI) and improvement in clinical parameters after PAE. At 3, 6, or 12 months after PAE, baseline PGV had no significant effect on improvements in IPSS ($P = .70, .81, .91$), QoL ($P = .96, .27, .30$), or PVR ($P = .22, .30, .83$) (Fig 4a–c). The same held true for age and IPSS ($P = .06, .38, .27$), QoL ($P = .31, .43, .42$), and PVR ($P = .59, .40, .09$) (Fig 4d–f). CCI also had no effect on improvements in IPSS ($P = .07, .30, .53$), QoL ($P = .09, .24, .30$), or PVR ($P = .53, .87, .63$) (Fig 4g–i). Similarly, the presence of MLE had no effect on improvements in IPSS ($P = .43, 1.00, .41$), QoL ($P = .78, .75, .26$), or PVR ($P = .61, .97, 1.00$) at 3, 6, or 12 months after PAE.

Clinical Non-Responders

At 1-month follow-up, 8/57 (14%) patients still had moderate-range symptoms (IPSS >12). Of these, 6 (10.5%) went on to have sustained improvement into the mild range at all subsequent follow-ups. The 2 (3.5%) patients who did not improve were referred back for urologic evaluation. One of them had developed newly diagnosed bladder cancer, and the other was treated for overactive bladder. At 6 months, 4 (7%) additional patients developed worsening LUTS into the moderate range and were initially managed medically. However, 2 of these patients went on to have transurethral surgical procedures due to unsatisfactory improvement of

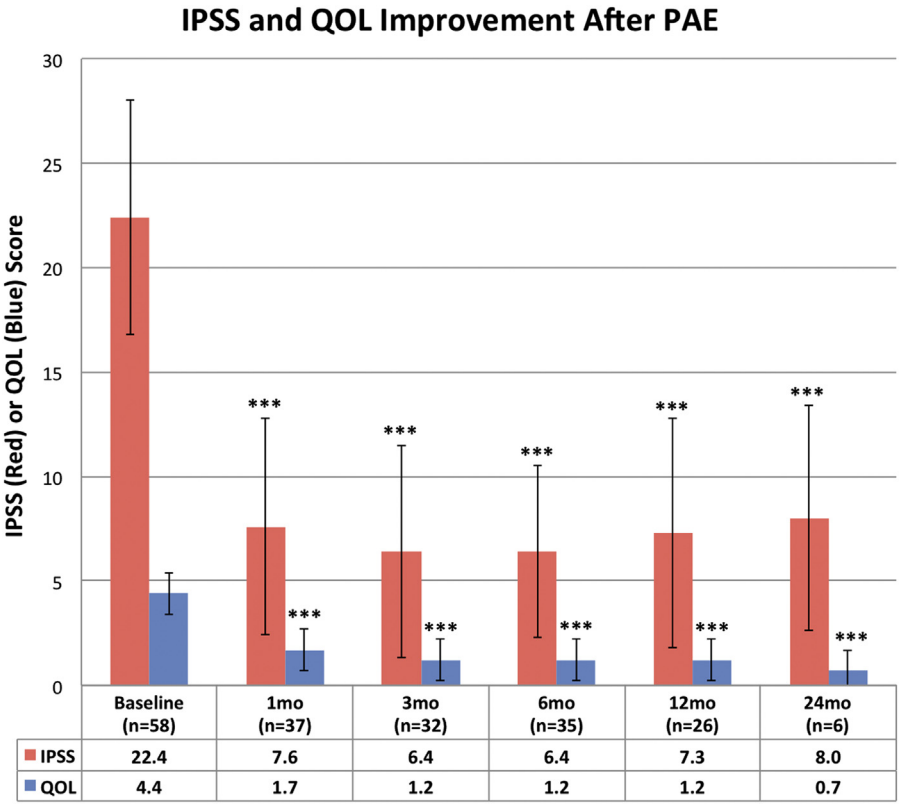

Figure 2. Mean IPSS and QoL score improvement with time after PAE (*** $P < .0001$).

symptoms, between 6 and 12 months after PAE. Two additional patients (3.5%) underwent limited transurethral resection of sloughing necrotic tissue that was causing pain or intermittent obstruction, 8 and 11 months after PAE, respectively. No other patients had worsening of symptoms beyond the mild range (IPSS >12) at 12 or 24 months. Thus, 8/57 (14%) patients had persistent or recurrent LUTS in the medium severity range after PAE or sloughing tissue that required limited transurethral resection. Six of these patients were among the 11/46 (24%) patients who had been on BPH medications prior to PAE and remained on them afterwards. The remaining 5/46 patients who remained on BPH medications did so either because they noticed transient mild worsening of symptoms when they tried to stop them or because their referring urologists advised them to stay on their medications indefinitely despite their symptomatic improvement after PAE.

Adverse Events

Adverse events were tabulated using Clavien-Dindo classification, as summarized in **Table 3**. Sixteen grade I events occurred, along with 2 grade II urinary tract infections requiring treatment. One of these patients was an immunocompromised stage IV cancer patient who developed fungemia during an inpatient hospital stay and died from sepsis within 30 days of PAE. This death was deemed unrelated to PAE. One patient noticed subjectively decreased erectile function 1 month after PAE, coinciding with new onset myasthenia gravis. Another described subjective decrease in erectile function throughout the year after PAE.

DISCUSSION

In this study, patients experienced a 67% reduction in IPSS and a 73% reduction in QOL score at 12 months after PAE with 100–300-μm Embosphere particles. Improvements in PVR and PGV were likewise substantial and sustained. These results were found to be independent of PGV, MLE, patient age, and CCI. There was a total 90-day adverse event rate of 29% (26% minor grade I events and 3% grade II urinary tract infections) and no lasting procedure-related side effects. These results demonstrate efficacy and safety with 100–300-μm spherical particles, similar to results from previously published PAE studies that used larger 300–500-μm Embosphere particles (1,2,5,6,8,9) or PVA particles (3,7). Such studies reported IPSS and QoL score improvements ranging from 42% to 76% (1–9). For example, Bhatia et al (2) reported improvements in IPSS of 67% and QoL score of 70% at 12 months (n = 93, 84 procedures using 300–500-μm Embospheres). Salem et al (1) reported improvements in IPSS of 47% and QoL score of 46% at 12 months (n = 45, 300–500-μm Embospheres). Additionally, DeAssis et al (5) reported improvements in IPSS of 85% and QoL score of 81% at 3 months (n = 35, 300–500-μm Embospheres).

Results with smaller embolization particles for PAE have been mixed. One study directly comparing different sizes of

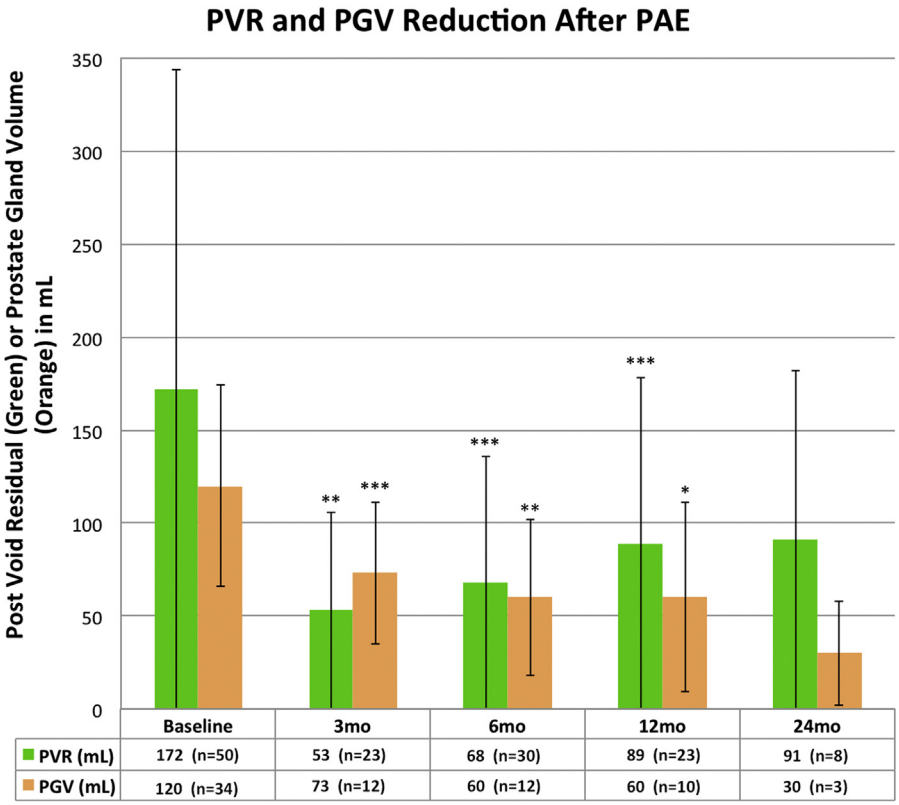

Figure 3. Mean PVR and PGV improvement with time after PAE (*** $P < .0001$, ** $P < .001$, * $P < .01$).

PVA particles in PAE found that patients who were treated with a combination of 50-μm and 100-μm particles had improved clinical and imaging outcomes with no increase in adverse events, compared to embolization with 100-μm particles alone (10). Another study retrospectively compared 2 groups who underwent PAE with either 100–300-μm or 300–500-μm Embosphere particles (n = 15 each) and showed no statistically significant differences in symptomatic improvements or adverse events; however, cohort sizes were small (14). Torres et al (15) reported a randomized trial comparing PAE performed with 100–300-μm Embospheres, 300–500-μm Embospheres, or a combination of both. Again, no statistically significant differences in symptomatic improvements were seen, although they described significantly increased minor adverse events in the 100–300-μm particle group. However, cone-beam CT was not used in these procedures, nor was a balloon-occlusion microcatheter used. The symptomatic improvements and adverse events with PAE using 100–300-μm Embospheres in the current study compared favorably with those from this randomized trial. In the current study, cone-beam CT was used in all procedures, and a balloon-occlusion microcatheter was used in 45% of procedures. These measures may have contributed to the decreased adverse events observed, although a separately reported analysis of this same cohort did not demonstrate any improvement in outcomes related to balloon-occlusion microcatheter use (19). A replication of Torres et al's trial with cone-beam CT use and balloon-occlusion microcatheter availability could reconcile the differences in adverse events with 100–300-μm Embospheres observed between the current study and that of Torres et al, as well as the differences in efficacy observed between the 100–300-μm Embospheres in the current study and the 300–500-μm Embospheres in other studies mentioned above.

Prior published analyses of the effect of PGV on symptomatic improvements after PAE showed no relationship or improved response with larger gland size (4,17,21,22). However, these relied on ellipsoid approximations of gland volume, using diagnostic magnetic resonance imaging or CT scans obtained prior to PAE that may not have accounted for interval pre-procedural gland growth. Furthermore, these studies did not examine the effect of MLE, which is a key determinant of a patient's transurethral procedural candidacy (16,23). In the current study, volumetric PGV measurements obtained using cone-beam CT at the time of embolization enabled a quantitative evaluation of the relationship between PGV (obtained at the time of treatment) and post-procedure improvements in IPSS, QOL, and PVR, with no statistically significant associations found. Additionally, procedural cone-beam CT allowed for delineation of MLE, a potentially prohibitive factor for transurethral procedures, versus lateral lobe enlargement, which does not pose such a challenge. With this anatomical delineation, it was determined that MLE also had no effect on post-procedure symptomatic improvements. These findings, combined with the lack of associations found between symptomatic improvements and patient age or

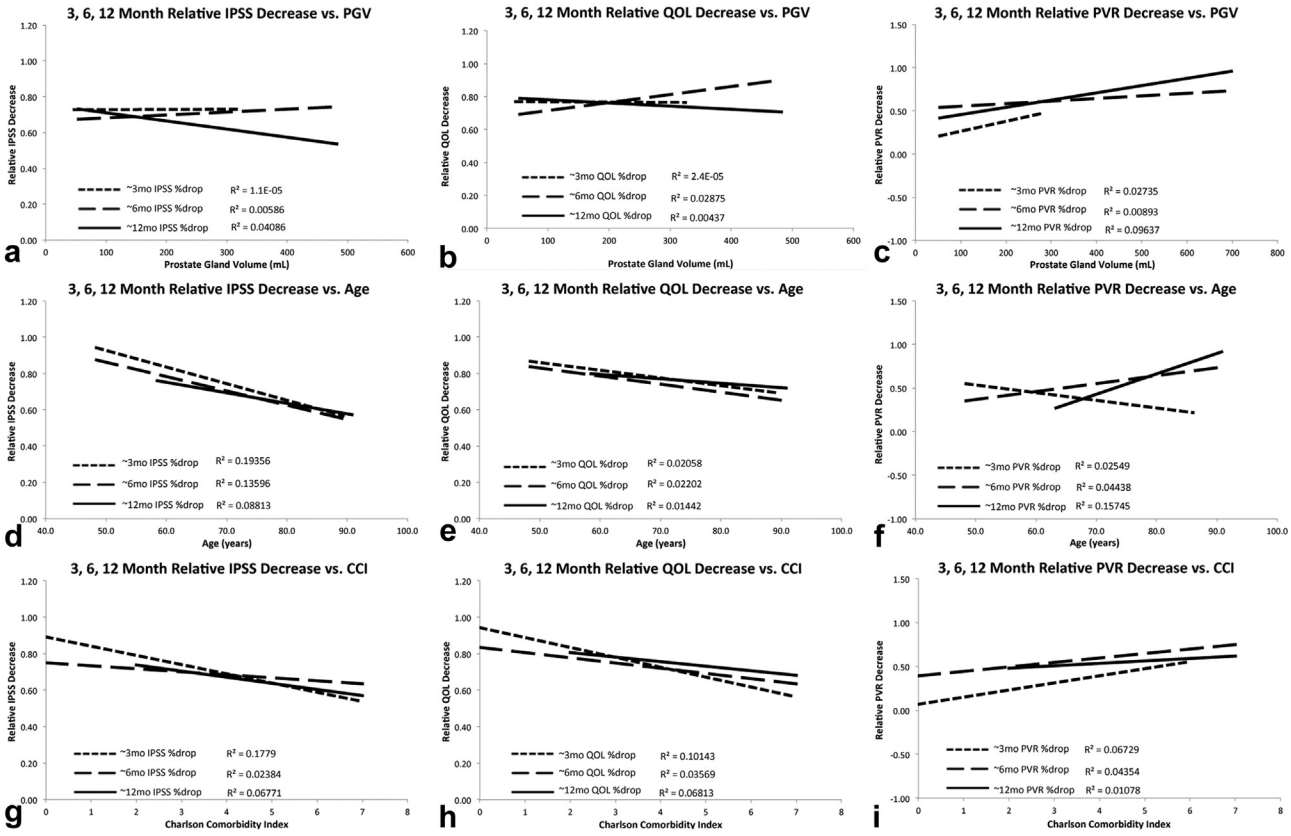

Figure 4. (**a–c**) Pre-procedure PGV versus post-procedure IPSS, QoL score, and PVR plotted for 3-, 6-, and 12-month timepoints. (**d–f**) Pre-procedure age versus post-procedure IPSS, QoL score, and PVR plotted for 3-, 6-, and 12-month timepoints. (**g–i**) Pre-procedure CCI versus post-procedure IPSS, QoL score, and PVR plotted for 3-, 6-, and 12-month timepoints. No significant association was found between pre-procedure PGV, age, or CCI and post-procedure IPSS, QoL score, or PVR at any timepoint.

CCI, further support the utility of PAE in patients who are poor candidates for surgical BPH therapies.

This study's main limitations included its single-arm retrospective design and its lack of objective urine flow measurements and quantitative erectile function assessments. Responder bias may be present, stemming from incomplete follow-up data for patients who may have experienced poor outcomes or adverse events. Although PGV was measured with cone-beam CT during each procedure, post-procedure PGV could only feasibly be measured with transabdominal ultrasound. Therefore, changes in PGV could only be assessed in patients who had pre-procedure ultrasound measurements available. Follow-up compliance was limited by the elderly nature of patients. Finally, placebo effects could not be accounted for in this retrospective study.

Overall, patients in this study were referred for PAE because of prostate glands too large, median lobes too prominent, or comorbidities too severe for standard transurethral procedures or prostatectomies. Although they likely had more severe voiding dysfunction than index BPH patients, the symptomatic improvements after PAE seen in this cohort were similar to results obtained with surgical procedures, allowing most patients to discontinue BPH medications (24). Also, the rate of clinical failure prompting surgical intervention was low. Furthermore, the safety profile of PAE in this study was superior to reported safety profiles of transurethral and open surgical treatments for BPH (24,25). The 1 death of an immunocompromised cancer patient within 30 days of PAE, although deemed unrelated to the procedure, highlights the increased comorbidities of this study's patient population compared to index BPH patients and the need for careful patient selection for PAE.

Table 3. Adverse Events Reported within 90 Days after PAE, Tabulated Using the Clavien-Dindo Classification

90-day grade I adverse events (n = 16)	
Dysuria >1 week	n = 4
Hematuria	n = 2
Hematochezia	n = 1
Hematospermia	n = 2
Urinary retention requiring Foley for <1 week	n = 3
Urinary retention requiring Foley <2 weeks	n = 1
Delirium from anticholinergic medication	n = 1
Access site ecchymosis	n = 2
90-day grade II adverse events (n = 2)	
Urinary infection requiring treatment	n = 2

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