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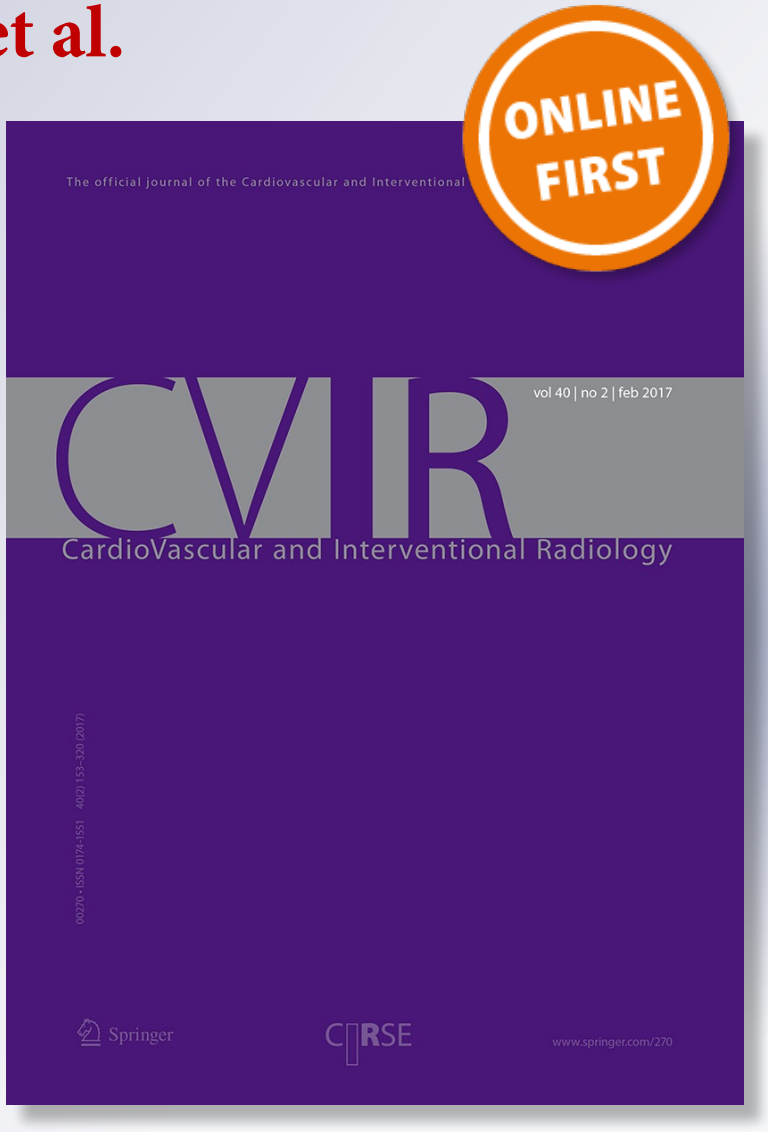

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CLINICAL INVESTIGATION

Recurrence of Lower Urinary Tract Symptoms Following Prostate Artery Embolization for Benign Hyperplasia: Single Center Experience Comparing Two Techniques

Francisco Cesar Carnevale[1] · Airton Mota Moreira[1] · Sardis Honoria Harward[3] · Shivank Bhatia[4] · Andre Moreira de Assis[1] · Miguel Srougi[2] · Giovanni Guido Cerri[1] · Alberto Azoubel Antunes[2]

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Abstract
Purpose To compare recurrence of lower urinary tract symptoms (LUTS) recurrence at 12 months following original prostate artery embolization (oPAE) or "proximal embolization first, then embolize distal" (PErFecTED) PAE for benign prostatic hyperplasia (BPH).
Materials and Methods 105 consecutive patients older than 45 years, with prostate size greater than 30 cm^3, International Prostate Symptom Score (IPSS) $\geq$ 8, quality of life (QoL) index $\geq$ 3, and refractory status or intolerance of medical management were prospectively enrolled between June 2008 and August 2013. The study was IRB-approved, and all patients provided informed consent. Patients underwent oPAE or PErFecTED PAE and were followed for at least 12 months. Technical success was defined as bilateral embolization and clinical success (non-recurrence) was defined as removal of the Foley catheter in patients with urinary retention, IPSS $<$ 8 and QoL index $<$ 3 at 12 months of follow-up. Nonparametric statistics were used to compare the study groups due to the size of the study population and distributions of clinical data.
Results 97 patients had 12-month data and were categorized as oPAE without recurrence (n = 46), oPAE with recurrence (n = 13), PErFecTED without recurrence (n = 36), or PErFecTED with recurrence (n = 2). Recurrence was significantly more common in oPAE patients (χ^2, p = 0.026). Unilateral embolization was significantly associated with recurrence among patients who underwent oPAE (χ^2, p = 0.032).
Conclusions Both oPAE and PErFecTED PAE are safe and effective methods for treatment of LUTS, but PErFecTED PAE is associated with a significantly lower rate of symptom recurrence.

Keywords Prostatic artery embolization · Benign prostatic hyperplasia · Lower urinary tract symptoms · International Prostate Symptom Score

Abbreviations

BPH	Benign prostatic hyperplasia
BCI	Bladder contractility index
BOO	Bladder outlet obstruction
BOOI	Bladder outlet obstruction index
CBCT	Cone beam computed tomography
DSA	Digital subtraction angiography
IPSS	International Prostate Symptom Score
LUTS	Lower urinary tract symptoms
MRI	Magnetic resonance imaging
oPAE	Original prostate artery embolization
PAE	Prostate artery embolization
PErFecTED	Proximal Embolization First Then Embolize Distal
QoL	Quality of life
TURP	Transurethral resection of the prostate
Q_{max}	Maximum flow rate

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Introduction

Prostate artery embolization (PAE) was first described as a therapy for BPH in 2010 [1, 2]. Several groups have since reported differing criteria for patient selection, technical success, and clinical benefit [3–6]. Variations in technique have resulted in inconsistent safety and efficacy outcomes, with LUTS recurrence at 12 months after PAE reported as high as 25% and as low as 0% [6, 7]. Examination of procedure techniques could improve PAE methods and patient outcomes.

The original method for PAE (oPAE), used in the earliest evaluations of PAE, has been optimized to the "Proximal Embolization First, Then Embolize Distal" (PErFecTED) technique [8, 9]. Recent investigations have indicated that the PErFecTED method is associated with a higher rate of prostatic infarction and symptom reduction than oPAE, but no analyses to date have compared the clinical success of these methods [8, 10]. In this article, we compare 12-month LUTS recurrence rates following original and PErFecTED PAE procedures in 97 patients.

Patients and Methods

Study Design

This investigation compared data from two prospective, single arm, phase II studies conducted by the Urology and Interventional Radiology Departments at a single institution between June 2008 and August 2014. Preliminary results from 66 of the earliest patients in these cohorts have been previously reported; the present study represents an expansion of the two investigations, with enrollment of additional patients and new global and subgroup analyses [1, 2, 10–13]. The institutional review board approved both protocols, and all patients provided written informed consent. Both investigations were registered in the Plataforma Brasil Registry under the identifiers CAAE #0985 5112.1.0000.0068 and CAAE #36089814.0.0000.0068. The primary endpoint in both investigations was reduction in International Prostate Symptom Score (IPSS), and secondary objectives included safety analyses and urodynamic improvements. All procedures were performed in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki declaration and its later amendments.

Patients

Both protocols enrolled patients older than 45 years, with prostate size greater than 30 cm^3, IPSS $\geq$ 8, quality of life (QoL) score $\geq$ 3, for whom medical management was contraindicated, not tolerated or refused, or whose symptoms were refractory to medical therapies. Exclusion criteria included biopsy-proven prostate cancer, active prostatitis or urinary tract infection, previous surgery or other invasive treatment for BPH, any disorder impacting bladder function, or inability to undergo magnetic resonance imaging (MRI).

Prostate volume was determined by MRI using the ellipsoid formula. Urodynamic testing assessed baseline bladder outlet obstruction (BOO) and bladder contractility. Due to the invasive nature of pressure-flow studies, patients were evaluated by uroflowmetry at 3 and 12 months following PAE unless complete urodynamic testing was clinically indicated [14–16].

Prostate Artery Embolization Methods

All patients received 400 mg of intravenous ciprofloxacin one hour prior to PAE procedures, followed by 500 mg twice daily for 7 days post PAE. All procedures were performed in an interventional radiology suite under local anesthesia by 3 interventional radiologists with a mean experience of 15 years (range 5–20 years). Each patient had a Foley catheter placed immediately before intervention, and the balloon inflated with 10 mL of a 10–30% contrast/saline solution. The Foley catheter was removed the same day in patients without urinary retention.

PAE was performed according to previously described techniques: between June 2008 and February 2013 all procedures were performed according to the original PAE (oPAE) method; after March 2013 all PAEs were performed according to the PErFecTED technique [8, 17]. Briefly (Fig. 1), oPAE was performed via superselective catheterization and embolization of the inferior vesicle arteries (IVAs) from a single position distal to any bladder or rectal branches, but proximal to individual prostatic branches. PErFecTED PAE was performed by embolization of the IVAs from two microcatheter positions: first from the proximal position used for oPAE, and then distally from individual branches to the prostate. For both techniques, embolization was performed using a 2.0 French microcatheter (Progreat; Terumo, Tokyo, Japan) and 100–300 μm or 300–500 μm tris-acryl gelatin microspheres (Embosphere Microspheres, Merit Medical Systems, South Jordan, Utah) to complete stasis. Digital subtraction angiography (DSA) was reviewed intraoperatively to assess risk of non-target embolization, patterns of enhancement suggestive of additional prostatic arteries, and confirmation of adequate prostatic parenchymal perfusion.

Patients were discharged home two to six hours post procedure. All patients received hydration, 500 mg

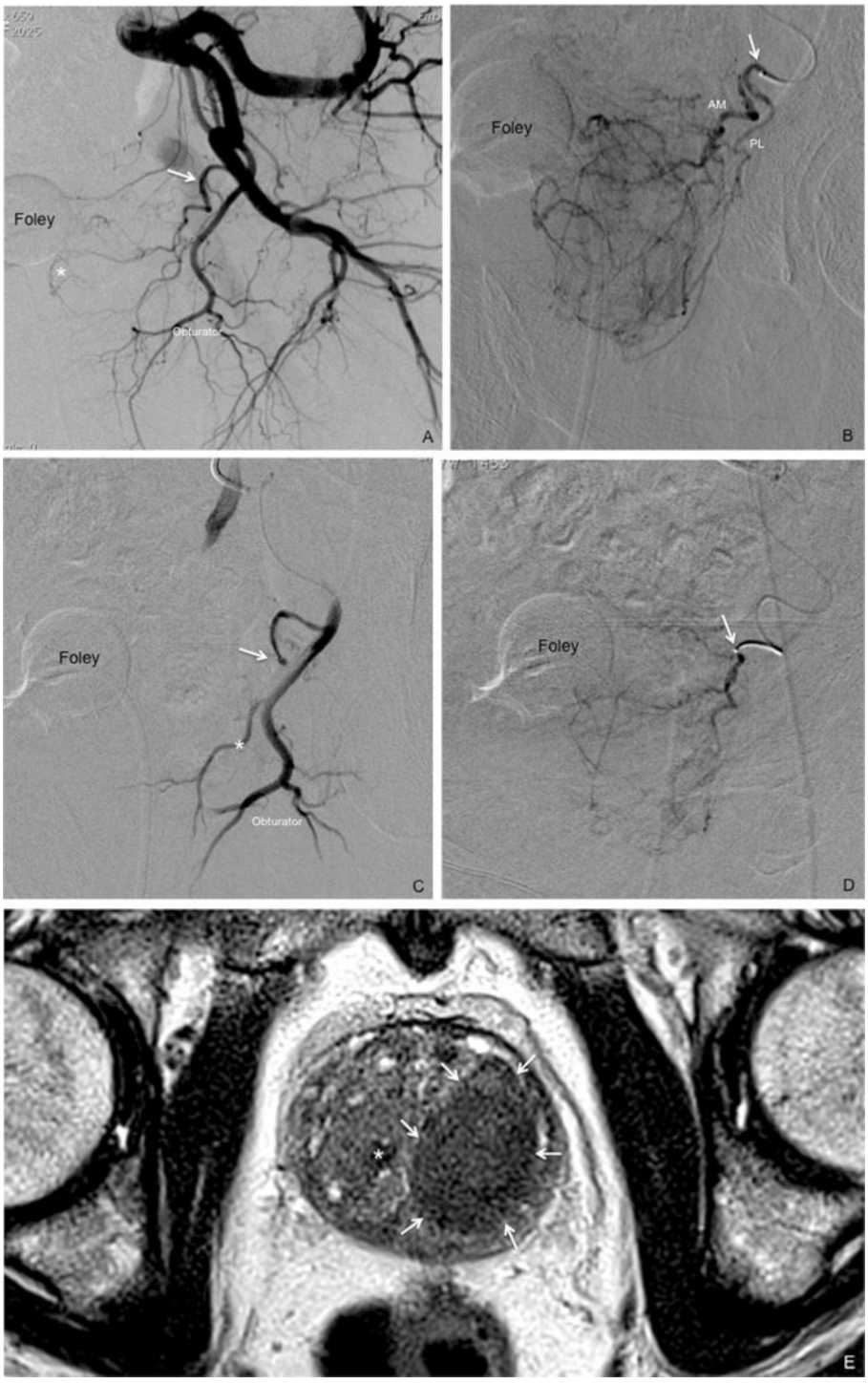

Fig. 1 **A** Left internal iliac arteriogram under ipsilateral oblique view showing the left prostatic artery (*arrow*) arising from the obturator artery. Intraprostatic branches (*asteristic*) are observed bellow the Foley balloon. **B** The tip of the microcatheter (*arrow*) was placed immediately before the bifurcation of the main intraprostatic branches (AM: antero-medial and PL: postero-lateral) for embolic agent injection. This is the exact position for the oPAE and for the first step of the PErFecTED techniques. **C** Digital subtraction arteriogram showing the occlusion (total stasis) of the left prostatic artery (*arrow*) with contrast media reflux into the obturator artery and its pelvic floor branch (*asteristic*). This is the endpoint for the oPAE technique and the moment when the microcatheter should be navigated deeply into the intraprostatic branches to perform the second step of the PErFecTED technique. **D** Observe the microcatheter tip placed distally into the AM branch (arrow) with additional branches opacification even after total stasis observed in the previous image. Additional amount of embolic agent is injected from this position. **E** 3-month axial-T2 weighted MRI control in a patient submitted to a prostate embolization using the PErFecTED technique on the *left side* (arrows - with large central gland ischemic area) and using the oPAE technique on the *right side* (asteristic - small ischemic areas)

ciprofloxacin, phenazopyridine, a non-opioid analgesic (dipyrone) and nonsteroidal anti-inflammatory drugs (cetoprofeno), if necessary. Those taking oral medications for LUTS continued them for one week post PAE. Patients with indwelling catheters due to urinary retention at baseline returned at one week for catheter removal if they were able to urinate spontaneously. Additional attempts to remove the Foley catheter were made every seven days for patients whose first attempt failed. All patients returned to the clinic for follow-up visits at 3 months and 12 months post PAE for prostate MRI, uroflowmetry, IPSS and QoL assessments.

Clinical success was defined as removal of the Foley catheter in patients with urinary retention, IPSS < 8 and

QoL < 3 at 12 months, with no relevant adverse events from the procedure. Recurrence was defined as IPSS ≥ 8 or QoL ≥ 3 at 12 months. Adverse events were evaluated using the National Cancer Institute's Common Toxicity Criteria for Adverse Events, version 4.0 [18].

Statistical Analyses

All statistical analyses were performed using Stata version 14.1 for Mac, and nonparametric methods were used for all analyses after Shapiro–Wilk W tests and quantile–quantile plots revealed that the majority of the continuous variables did not conform to a normal distribution.

Patients were categorized into groups based on their PAE treatment method and recurrence status: oPAE without recurrence, oPAE with recurrence, PErFecTED without recurrence and PErFecTED with recurrence. Continuous variables were compared between study groups at the same time point using the Mann–Whitney U test, and were compared within study groups between time points using the Paired-Sample Wilcoxon Signed Rank Test. Categorical variables were compared between recurrent and non-recurrent patients for each treatment method at each time point using the χ^2 test.

Results

Of 105 consecutive patients, 97 had 12-month IPSS and QoL data and were included in the final recurrence analyses. Of the patients treated with oPAE, 13 patients developed recurrent symptoms and 46 patients obtained durable symptom relief at 12 months of follow-up. Among patients treated with PErFecTED PAE, 2 patients experienced symptom recurrence and 36 obtained durable relief. Patient categorization into each group is summarized in Fig. 2.

Baseline patient characteristics are presented in Table 1. The only statistically significant differences between recurrent and non-recurrent patients were in the oPAE cohort: recurrent patients had significantly smaller mean prostate sizes (61.1 ± 24.7 cm^3 versus 93.7 ± 40.8 cm^3, U test $p = 0.0036$), higher mean IPSS (25.7 ± 3.7 versus 21.5 ± 4.7, U test $p = 0.0095$), and lower mean PSA values (2.7 ± 1.6 ng/mL versus 7.2 ± 5.4 ng/mL, U test $p = 0.0003$).

Procedure characteristics of all four patient groups are presented in Table 2. Unilateral PAE was significantly more common in patients treated with oPAE who experienced LUTS recurrence than those who did not (χ^2 test $p = 0.032$). Only one PErFecTED patient received unilateral PAE, and the two LUTS recurrences following PErFecTED PAE occurred in patients who had received bilateral PAE. The size of tris-acryl microspheres used for embolization had no significant effect on 12-month symptom recurrence in either group (χ^2 test $p = 0.106$ for oPAE, $p > 0.20$ for PErFecTED), nor did the volume of embolic suspension delivered (U test $p > 0.20$ for both groups). There were no significant differences between oPAE and PErFecTED PAE patients in mean procedure time ($p = 0.12$), fluoroscopy time ($p > 0.20$), or volume of embolic delivered ($p = 0.18$).

Post PAE outcomes at follow-up are presented in Table 3. Overall, oPAE resulted in a significantly higher rate of recurrence than PErFecTED PAE (22.0% compared to 5.3%, χ^2 test $p = 0.026$). Mean IPSS at one year (6.0 ± 6.4 among oPAE patients, 3.3 ± 2.8 among PErFecTED patients, U test $p = 0.095$) and mean IPSS reduction (72.5 ± 26.1% among oPAE patients, 83.1 ± 16.0% among PErFecTED patients, U test $p = 0.20$) were not significantly different between the two cohorts.

For both treatment groups, mean IPSS and QoL were significantly higher among recurrent patients at 12 months of follow-up. At 12 months post PAE, mean IPSS was 3.1 ± 2.2 among oPAE patients without recurrence, 16.3 ± 5.9 among oPAE patients with recurrence, 2.9 ± 3.9 among PErFecTED patients without recurrence, and 11.0 ± 2.8 among PErFecTED patients with recurrence. These IPSS values corresponded to mean IPSS reduction of 32.6 ± 17.4% and 84.7 ± 12.5% for oPAE patients with and without recurrence (U test $p < 0.0001$), and 37.9 ± 34.8% and 85.7 ± 10.4% for PErFecTED patients with and without recurrence (U test $p = 0.022$), respectively.

Post PAE PSA dynamics by treatment method and 12-month recurrence status is illustrated in Fig. 3. For both treatment methods, non-recurrent patients had significantly higher 24-hour post PAE PSA values than recurrent patients in their respective treatment cohort (U test $p = 0.042$ for oPAE patients, $p = 0.031$ for PErFecTED patients).

At one year of follow-up, oPAE patients without recurrence experienced a mean prostate volume reduction of 28.3 ± 17.3% compared to 8.5 ± 15.7% among oPAE patients with recurrence (U test $p = 0.0013$). Similarly, mean volume reduction was 24.3 ± 17.9% among PErFecTED patients without recurrence, while recurrent patients experienced a mean increase in prostate volume of 1.3 ± 12.9% (U test $p = 0.064$). Mean prostate volume was not significantly different between baseline and one year of follow-up among recurrent patients treated by either method.

Significant maximum flow rate (Q_{max}) improvements were evident in all treatment groups except the recurrent PErFecTED patients by three months of follow-up and were

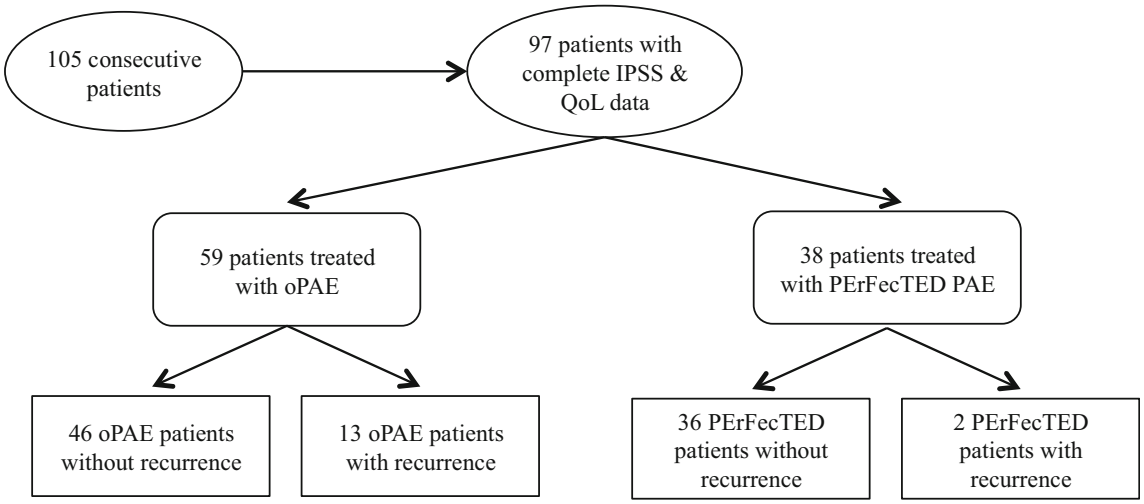

Fig. 2 Patient categorization based on PAE technique and 12 month recurrence status

Table 1 Baseline characteristics by PAE method and 12 month recurrence status

Variable	oPAE without recurrence ($n = 46$)	oPAE with recurrence ($n = 13$)	p value[a]	PErFecTED without recurrence ($n = 36$)	PErFecTED with recurrence ($n = 2$)	p value[a]
Age (years)	65.2 ± 6.9	62.7 ± 7.2	>0.20	62.5 ± 5.9	59.5 ± 2.1	>0.20
IPSS	21.5 ± 4.7	25.7 ± 3.7	0.0095	20.9 ± 5.1	19.5 ± 6.4	>0.20
QoL	5.1 ± 0.7	4.9 ± 0.6	>0.20	4.5 ± 0.7	4.5 ± 0.7	>0.20
Prostate size (cm^3)	93.7 ± 40.8	61.1 ± 24.7	0.0036	100.1 ± 54.3	72.0 ± 43.4	>0.20
PSA (ng/mL)	7.2 ± 5.4	2.7 ± 1.6	0.0003	5.4 ± 5.1	3.7 ± 2.3	>0.20
Q_{max} (mL/s)	5.9 ± 3.8	4.9 ± 2.3	>0.20	5.9 ± 3.7	9.3 ± 7.5	>0.20
Bladder contractility index	106.3 ± 21.4	104.8 ± 29.3	>0.20	109.3 ± 37.1	105.0 ± 46.7	>0.20
BCI < 100	10 (31.3%)	6 (46.1%)	>0.20	13 (36.1)	1 (50.0%)	>0.20
BCI 100–150	21 (65.6%)	7 (53.9%)		18 (50.0%)	1 (50.0%)	
BCI > 150	1 (3.1%)	0 (0%)		5 (13.9%)	0 (0%)	
Bladder outlet obstruction index	71.7 ± 28.8	70.7 ± 30.2	>0.20	67.7 ± 34.4	39.9 ± 5.8	0.16
BOOI < 20	0 (0%)	0 (0%)	>0.20	1 (2.8%)	0 (0%)	>0.20
BOOI 20–40	6 (18.7%)	3 (23.1%)		6 (16.7%)	1 (50.0%)	
BOOI > 40	26 (81.3%)	10 (76.9%)		29 (80.6%)	1 (50.0%)	
Indwelling urinary catheter	10 (21.7%)	2 (15.4%)	>0.20	1 (2.8%)	0 (0%)	>0.20
Hypertension	24 (52.2%)	7 (53.9%)	>0.20	18 (50.0%)	1 (50.0%)	>0.20
Diabetes	6 (13.0%)	1 (7.7%)	>0.20	7 (19.4%)	1 (50.0%)	>0.20
Dyslipidemia	14 (30.4%)	2 (15.4%)	>0.20	8 (22.2%)	0 (0%)	>0.20
Smoker	20 (43.5%)	6 (46.2%)	>0.20	14 (38.9%)	1 (50.0%)	>0.20
Obesity	10 (21.7%)	1 (7.7%)	>0.20	8 (22.2%)	0 (0%)	>0.20

[a] p values compare recurrent and non-recurrent patients within each treatment group; values for continuous variables obtained by Mann–Whitney U test and those for categorical variables obtained by χ-squared test

IPSS International Prostate Symptom Score, *QoL* quality of life, *PSA* prostate specific antigen, Q_{max} maximum urine flow rate, *oPAE* original prostate artery embolization technique, *PErFecTED* "proximal embolization first, then embolize distal" technique

Table 2 Procedure characteristics by PAE method and 12 month recurrence status

Variable	oPAE without recurrence ($n = 46$)	oPAE with recurrence ($n = 13$)	p value[a]	PErFecTED without recurrence ($n = 36$)	PErFecTED with recurrence ($n = 2$)	p value[a]
Embolization site						
Unilateral	2 (4.3%)	3 (23.1%)	0.032	1 (2.8%)	0 (0%)	>0.20
Bilateral	44 (95.7%)	10 (76.9%)		35 (97.2%)	2 (100%)	
Procedure time (m)	149.4 ± 56.6	160.3 ± 54.5	>0.20	158.6 ± 43.2	227.5 ± 102.5	>0.20
Fluoroscopy time (m)	55.7 ± 31.4	57.1 ± 20.1	>0.20	53.2 ± 22.5	95.5 ± 62.9	>0.20
Size of embolic						
300–500 μm	38 (82.6%)	8 (61.5%)	0.106	33 (91.7%)	2 (100%)	>0.20
100–300 μm	8 (17.4%)	5 (38.5%)		3 (8.3%)	0 (0%)	
Volume of embolic suspension delivered (cm^3)	14.7 ± 5.2	12.0 ± 5.7	>0.20	12.8 ± 4.4	11.0 ± 1.4	>0.20

[a] p values compare recurrent and non-recurrent patients within each treatment group; values for continuous variables obtained by Mann–Whitney U test and those for categorical variables obtained by χ^2 test

Table 3 Post PAE outcomes by PAE method and recurrence status

Variable	oPAE without recurrence ($n = 46$)	oPAE with recurrence ($n = 13$)	p value[a]	PErFecTED without recurrence ($n = 36$)	PErFecTED with recurrence ($n = 2$)	p value[a]
IPSS						
3 months	2.9 ± 2.5	4.7 ± 4.2	0.107	3.9 ± 3.9	8.5 ± 6.4*	0.12
12 months	3.1 ± 2.2	16.3 ± 5.9	<0.0001	2.9 ± 2.1	11.0 ± 2.8*	0.017
IPSS reduction (%)						
3 months	87.2 ± 10.0	81.8 ± 14.8	>0.20	78.8 ± 27.0	48.3 ± 49.5	0.18
12 months	84.7 ± 12.5	32.6 ± 17.4	<0.0001	85.7 ± 10.4	37.9 ± 34.8	0.022
QoL						
3 months	0.9 ± 0.7	1.5 ± 0.9	0.052	1.5 ± 0.8	3.0 ± 2.8*	>0.20
12 months	1.0 ± 0.6	3.0 ± 0.8	<0.0001	1.3 ± 0.6	3.5 ± 2.1*	0.040
Prostate size (cm^3)						
3 months	63.6 ± 25.2	51.3 ± 23.6	0.097	68.3 ± 34.2	58.6 ± 34.2*	>0.20
12 months	67.4 ± 31.1	57.0 ± 26.8*	>0.20	70.7 ± 32.3	70.1 ± 34.6*	>0.20
Prostate size reduction (%)						
3 months	28.5 ± 15.0	16.9 ± 10.7	0.0047	29.7 ± 13.3	14.5 ± 13.7	0.15
12 months	28.3 ± 17.3	8.5 ± 15.7	0.0013	24.3 ± 17.9	−1.3 ± 12.9	0.064
PSA (ng/mL)						
24 h	135.3 ± 108.9	78.5 ± 74.4	0.042	165.1 ± 111.3	39.4 ± 3.3*	0.031
3 months	2.5 ± 1.6	1.6 ± 0.8*	0.083	3.1 ± 2.1	3.2 ± 0.3*	>0.20
12 months	3.0 ± 1.9	2.8 ± 1.7*	>0.20	2.5 ± 1.7	6.0 ± 2.1*	0.04
Q_{max} (mL/s)						
3 months	14.4 ± 7.0	11.5 ± 4.9	>0.20	14.4 ± 7.7	29.1 ± 16.6*	0.12
12 months	15.8 ± 6.8	7.7 ± 3.4	0.0002	15.9 ± 7.9	20.2 ± 15.4*	>0.20

[a] p values compare recurrent and non-recurrent patients within each treatment group; all p values presented in table were obtained by Mann–Whitney U test

* Not significant compared to baseline by the Wilcoxon signed-rank test; all unmarked values are significant compared to baseline

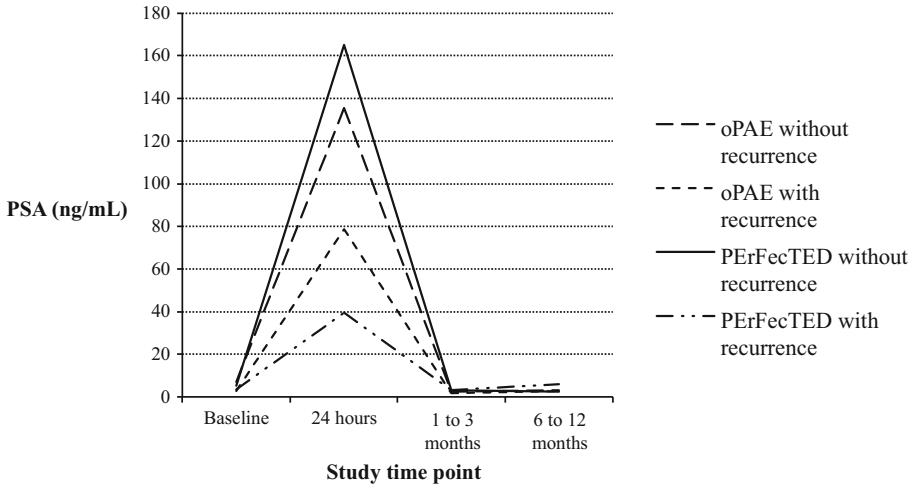

Fig. 3 PSA behavior post PAE by PAE method and recurrence status

sustained at one year. While recurrent oPAE patients maintained a significantly higher mean Q_{max} at one year than at baseline, mean values decreased significantly between follow-up time points (Signed Rank test $p = 0.042$).

Adverse events are presented by PAE method in Table 4. Urethral burning was the most common after both methods, but occurred in a significantly greater proportion of patients treated with PErFecTED PAE (97.4% compared to 74.6% treated with oPAE, χ^2 test $p = 0.003$). Retropubic pain and anal burning were significantly more common among patients treated with oPAE, both occurring in eight (13.6%) patients compared to no patients in the PErFecTED group (χ^2 test $p = 0.018$ for both).

Of the recurrent patients, one underwent a second PAE procedure with clinical success, one underwent a second PAE procedure but required subsequent transurethral resection of the prostate (TURP), four patients were managed with alpha-blocker medication, and nine required alpha-blockers and TURP.

Discussion

Relief of LUTS due to BPH following PAE was first reported as an incidental finding in 2000 [19]. Despite gaining increased attention as a primary therapy for LUTS associated with BPH, PAE remains a relatively new procedure and techniques are still evolving [20–23].

Bilateral embolization has been reported to have a significant and positive impact on 12-month clinical outcomes compared to unilateral embolization. In an ambispective cohort of 122 consecutive patients, Bilhim found a significantly higher rate of clinical failure ($p = 0.04$) among patients who received unilateral rather than bilateral PAE [24]. The present study reaffirms this conclusion, demonstrating a significant association between unilateral embolization and symptom recurrence following oPAE. As yet, no professional societies have endorsed PAE as a therapy for BPH, but the Society of Interventional Radiology position statement recommends bilateral

Table 4 Adverse events by PAE method

Event	oPAE ($n = 59$)	PErFecTED ($n = 38$)	p value[a]
Urethral burning	44 (74.6%)	37 (97.4%)	0.003
Decreased ejaculatory volume	10 (17.0%)	4 (10.5%)	>0.20
Retropubic pain	8 (13.6%)	0 (0%)	0.018
Anal burning	8 (13.6%)	0 (0%)	0.018
Transient hematochezia	8 (13.6%)	1 (2.6%)	0.070
Transient hematuria	5 (8.5%)	1 (2.6%)	>0.20
Fever	4 (6.8%)	0 (0%)	0.101
Transient hematospermia	3 (5.1%)	2 (5.3%)	>0.20
Diarrhea	2 (3.4%)	0 (0%)	>0.20
Trauma during Foley catheter placement	1 (1.7%)	1 (2.6%)	>0.20
Pubic bone ischemia	1 (1.7%)	0 (0%)	>0.20

[a] p value obtained by χ^2 test

embolization as the more rigorous definition of technical success [12, 21, 24].

The most significant predictor of recurrence among our 97 patients was the PAE method used: the PErFecTED technique resulted in a significantly lower proportion of recurrent patients ($p = 0.026$). Our results are consistent with those reported in the two other publications presenting clinical results of PErFecTED PAE, which report significant decreases in IPSS and prostate volume, and a significant increases in Q_{max} following treatment [9, 10]. PSA dynamics among recurrent and non-recurrent patients in our investigation also followed a previously reported pattern in both treatment groups, rising dramatically within 24 h of PAE then falling to a level significantly below that of baseline [12, 13].

Notably, oPAE and PErFecTED PAE differed in their adverse event profiles, with urethral burning significantly more common, and retropubic pain and anal burning significantly less common among patients receiving PErFecTED PAE. The increased incidence of urethral symptoms suggests that PErFecTED PAE results in more significant prostate ischemia and associated inflammation than oPAE, attributable to improved targeting of the prostatic arteries. This hypothesis is supported by the lower incidence of rectal adverse events when using the PErFecTED technique, likely as consequence of reduced non-target embolization, and the higher percentage of prostate infarction following PErFecTED PAE [8, 25]. No radiation-associated injuries were reported for patients in either group, but one such injury has been reported elsewhere and all patients should be monitored accordingly [26]. Additionally, while our cohort experienced a higher rate of technical success with PErFecTED PAE than oPAE (possibly due to the operator learning curve), it is worth noting that the distal embolization step of the PErFecTED method can be challenging to perform due to the small diameter and increased tortuosity of intra-prostatic arterial branches [8].

Although the current arsenal of surgical therapies for BPH is hardly lacking, the symptom relief and adverse event profile associated with PErFecTED PAE make the procedure a potential alternative therapy, particularly for poor surgical candidates. Previously published meta-analyses and randomized controlled trials indicate that transurethral interventions may reduce IPSS to a mean between 3.0 and 14.4 [27–29]. These procedures require general and/or spinal anesthesia, however, and are associated with numerous, potentially serious adverse events. Our results indicate that PAE may achieve comparable symptom reduction with lower sedation requirements and a more amenable safety profile. These outcomes make PAE a particularly appealing therapeutic option for fragile patients who have failed medical therapy but are ineligible for surgical intervention [30].

The present study has several limitations. Differing definitions of clinical and technical success prevented us from comparing our results with those of other research groups. Furthermore, while the small number of recurrences following PErFecTED PAE is optimistic for the future of PAE as a therapy, it detracted from this investigation's power to detect significant associations between symptom recurrence and patient or procedure characteristics. The consecutive selection of patients also introduces a potential source of confounding and bias, as the operator learning curve and optimization of technique may have contributed to better results obtained in patients treated later in the cohort.

Continued investigation into the safety and efficacy of various methods of PAE will be necessary to determine the most effective method, patient populations most likely to derive benefit from the procedure, and long-term outcomes. Our data indicate both oPAE and PErFecTED PAE are safe procedures with the potential to alleviate LUTS due to BPH, but that the PErFecTED technique for PAE has a lower incidence of symptom recurrence at 1 year than oPAE.

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Compliance with Ethical Standard

Conflict of interest FCC, SHH, and SB are research consultants to Merit Medical Systems, Inc. FCC receives patent royalties and SB has received research grants from Merit Medical Systems, neither of which were associated with this project.

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