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CLINICAL INVESTIGATION

Transurethral Resection of the Prostate (TURP) Versus Original and PErFecTED Prostate Artery Embolization (PAE) Due to Benign Prostatic Hyperplasia (BPH): Preliminary Results of a Single Center, Prospective, Urodynamic-Controlled Analysis

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Abstract
Purpose To compare clinical and urodynamic results of transurethral resection of the prostate (TURP) to original and PErFecTED prostate artery embolization (PAE) methods for benign prostatic hyperplasia.
Methods We prospectively randomized 30 patients to receive TURP or original PAE (oPAE) and compared them to a cohort of patients treated by PErFecTED PAE, with a minimum of 1-year follow-up. Patients were assessed for urodynamic parameters, prostate volume, international prostate symptom score (IPSS), and quality of life (QoL).
Results All groups were comparable for all pre-treatment parameters except bladder contractility and peak urine flow rate (Q_{max}), both of which were significantly better in the TURP group, and IIEF score, which was significantly higher among PErFecTED PAE patients than TURP patients. All groups experienced significant improvement in IPSS, QoL, prostate volume, and Q_{max}. TURP and PErFecTED PAE both resulted in significantly lower IPSS than oPAE but were not significantly different from one another. TURP resulted in significantly higher Q_{max} and significantly smaller prostate volume than either original or PErFecTED PAE but required spinal anesthesia and hospitalization. Two patients in the oPAE group with hypocontractile bladders experienced recurrence of symptoms and were treated with TURP. In the TURP group, urinary incontinence occurred in 4/15 patients (26.7 %), rupture of the prostatic capsule in 1/15 (6.7 %), retrograde ejaculation in all patients (100 %), and one patient was readmitted for temporary bladder irrigation due to hematuria.
Conclusions TURP and PAE are both safe and effective treatments. TURP and PErFecTED PAE yield similar symptom improvement, but TURP is associated with both better urodynamic results and more adverse events.

Keywords Embolization/embolisation/embolotherapy · Therapy · Prostate · Urinary tract

Abbreviations

BPH	Benign prostatic hyperplasia
BCI	Bladder contractility index
BOO	Bladder outlet obstruction
BOOI	Bladder outlet obstruction index
CT	Computed tomography
P_{det}	Detrusor muscle pressure
DRE	Digital rectal examination
DSA	Digital subtraction angiography

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ED	Erectile dysfunction
IVA	Inferior vesical artery
IVO	Infravesical obstruction
IRB	Institutional review board
IIEF-5	International index of erectile function
IPSS	International prostate symptom score
LUTS	Lower urinary tract symptoms
MRI	Magnetic resonance imaging
Q_{max}	Maximum urinary flow rate
oPAE	Original PAE method
PVR	Post-void residual urine volume
PAE	Prostate artery embolization
PSA	Prostate specific antigen
PErFecTED	Proximal embolization first then embolize distal method of PAE
QoL	Quality of life
TRUS	Transrectal ultrasound
TURP	Transurethral resection of the prostate

Introduction

Benign prostatic hyperplasia (BPH) is the most frequent cause of lower urinary tract symptoms (LUTS) in the aging male. Moderate to severe LUTS will occur in about one quarter of men in their 50 s, and in about half of all men aged 80 years or older [1]. For more than 80 years, transurethral resection of the prostate (TURP) has been considered as the gold standard surgical treatment for BPH [1, 2].

Prostate artery embolization (PAE) has recently been described as a promising, minimally invasive alternative treatment for LUTS due to BPH [3–5]. Previously published analyses have demonstrated that the original PAE method (oPAE) may reduce prostate volume by about 30 %, improve obstructive symptoms and quality of life (QoL) scores, increase urinary flow rate, and relieve urinary retention in patients using indwelling urinary catheters [6–9]. Results of PAE improved with the introduction of the Proximal Embolization First, Then Embolize Distal technique (PErFecTED), which is associated with greater prostate infarction rates [10].

To date, only one clinical trial has published data comparing PAE to TURP, and found that the two procedures yield similar short-term results [11]. These authors did not use urodynamic evaluations to assess patients for bladder dysfunction, however. The purpose of our prospective investigation is to compare the clinical and urodynamic results of TURP, oPAE, and PErFecTED PAE for the treatment of LUTS due to BPH.

Materials and Methods

Study Design

A randomized, controlled trial to compare the results of TURP and oPAE in 30 patients was conducted by the Urology and Interventional Radiology Departments between November 2010 and December 2012. An additional 15 patients were enrolled in a separate arm to assess the outcomes of the PErFecTED technique for PAE between January 2013 and April 2014. Informed consent was obtained from all individual participants included in the study, and all procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Patients

Fifteen patients were enrolled in each arm of the randomized study, and an additional 15 patients were enrolled in a separate investigation of the PErFecTED technique. All patients were on the waiting list for TURP, and those meeting protocol inclusion/exclusion criteria were offered the option of study participation. Inclusion criteria for all patients included: age >45 years; International Prostate Symptom Score (IPSS) >19; symptoms refractory to medical treatment for at least 6 months; negative screening for prostate cancer; prostate volume between 30 and 90 cm^3 on magnetic resonance imaging (MRI); and bladder outlet obstruction (BOO) confirmed by urodynamic examination. Patients with renal failure, bladder calculi or diverticula, suspected prostate cancer, urethral stenosis, or neurogenic bladder disorders were excluded.

Before and after intervention, all patients underwent a medical review focused on urinary symptoms and past medical history, including digital rectal examination (DRE), prostate specific antigen (PSA) measurement, transrectal ultrasound (TRUS), MRI, and urodynamic evaluation. Detrusor muscle function was assessed using the bladder contractility index, a function of detrusor muscle pressure (P_{det}) at maximal urinary flow rate (Q_{max}) (BCI = P_{det} @ Q_{max} + 5 Q_{max}). Patients were classified as hypocontractile when BCI was <100, borderline hypocontractile when BCI was between 100 and 150, and normal bladder contractility when BCI was >150 [12, 13]. The Bladder Outlet Obstruction Index (BOOI) was used to assess infravesical obstruction (IVO) and was calculated as BOOI = P_{det} @ Q_{max} − 2 Q_{max}. Patients were classified as unobstructed when BOOI was <20, equivocal when BOOI was between 20 and 40, and obstructed when BOOI was >40 [12, 13].

Study Interventions

TURP procedures were performed according to institutional standards. A 1 g intravenous dose of Cefazolin was given prior and 24 h after surgery. Patients also received Cefadroxil 500 mg for 7 days, phenazopyridine, non-opioid analgesic (dipyrone), and non-steroidal anti-inflammatory (cetoprofeno) medications after TURP. All procedures were performed under spinal anesthesia, using a 24-French resectoscope and monopolar generator (Valleylab, Covidien, USA) and 3 % manitol solution irrigation fluid. All tissue samples were sent for histopathology.

Our techniques for original [14] and PErFecTED [10] PAE have been described previously. Procedures were performed under local anesthesia through a unilateral femoral artery approach on an outpatient basis. A 400 mg intravenous dose of ciprofloxacin was given prior to the PAE procedures followed by 500 mg orally twice a day for 7 days after PAE. Patients received similar analgesic medications as after TURP. When additional pain management was necessary, opioids (tramadol or codeine) were given. An initial pelvic arteriogram was obtained to evaluate the iliac vessels and the prostatic arteries during the arterial and late phases. Selective digital subtraction angiography (DSA) of the right and left internal iliac arteries using non-iodinated contrast medium (iodixanol 320 mgI/mL; Visipaque; GE Healthcare, Princeton, New Jersey) was performed with a 5-French Cobra 2 or Vertebral catheter (Cordis, Johnson and Johnson, USA) to better assess the blood supply to the prostate. Superselective catheterization of the right and left inferior vesical arteries (IVAs) was then performed using a microcatheter (Embocath 2.8; Merit Medical, USA or Progreat 2.8; Terumo, Japan for oPAE patients, and Progreat 2.0 (Terumo, Japan for PErFecTED patients), and angiography was performed by manual injection using 3–5 mL of contrast medium to ensure that the tip of the microcatheter was inside or at the ostium of the prostatic arteries. A Foley balloon, inflated with a 50 % contrast and saline solution, was used as a landmark for all PAE patients; cone-beam computed tomography (CT) (Innova 3D CT; GE Healthcare) was also used to assess prostatic vasculature in patients receiving PErFecTED PAE. Calibrated 300–500 μm tris-acryl gelatin microspheres (Embosphere Microspheres; Merit Medical, USA) were used for embolization. Each 2-mL vial of microspheres was diluted in a solution of 50 % non-iodinated contrast medium and 50 % normal saline, and slowly injected under fluoroscopic guidance. Embolization of the prostatic arteries arising from the IVAs was performed to stasis without reflux of the mixture to undesired arteries. Follow-up angiography was performed manually with the microcatheter at the IVA, and with the use of a pump with the 5-French catheter at the anterior branch of the internal iliac artery to assess for any further blood supply to the prostate. Embolization was then performed on the contralateral side using the same technique.

IPSS, QoL, International Index of Erectile Function (IIEF-5), PSA, prostate volume by MRI, and urodynamic testing were used to assess outcomes in all patients. Standard scoring was used for each questionnaire, as follows: IPSS 0–7 = mildly symptomatic, 8–19 = moderately symptomatic, 20–35 = severely symptomatic; QoL 0 = delighted, 1 = pleased, 2 = mostly satisfied, 3 = equally satisfied and dissatisfied, 4 = mostly dissatisfied, 5 = unhappy, and 6 = terrible [15]; IIEF-5 1–7 = severe erectile dysfunction (ED), 8–11 = moderate ED, 12–16 = mild to moderate ED, 17–21 = mild ED, and 22–25 no ED [16]. The three questionnaires, urodynamic assessment, post-void residual urine volume (PVR), TRUS, and MRI were compared between baseline and 1 year post-study treatment for all patients. Urodynamic evaluations were consistent with the Good Urodynamic Practice Standards of the International Continence Society [17] and included non-invasive uroflowmetry, PVR, invasive pressure flow, and urethral function tests. Due to the risks associated with invasive urodynamic studies, complete urodynamic testing was performed at baseline only; follow-up assessments of Q_{max} and PVR were obtained by non-invasive uroflowmetry.

All adverse events were evaluated for severity based on the National Cancer Institute Common Toxicity Criteria for Adverse Events, version 4.0 [18].

Statistical Analyses

Within each study group, all continuous variables were described using means, standard deviations, and ranges. Categorical variables were summarized as percentages. Baseline and 12-month follow-up values for each continuous variable were compared using the Paired-Sample Wilcoxon Signed Rank Test. Continuous variables were compared among all three study groups using the Kruskal–Wallis H test with correction for ties; analyses of continuous variables comparing one study group directly to another were performed using the Mann–Whitney U test. Categorical variables were compared between study groups using the Chi-squared (χ^2) test. A two-sided p value <0.05 was considered significant for all analyses, and all analyses were performed using STATA® version 14.0 for Mac.

Results

Fifteen patients were randomized to each arm of the TURP versus oPAE study; additional 15 patients treated with the PErFecTED method of PAE were enrolled in a separate

arm. Pre-intervention baseline parameters for each study group are presented in Table 1. Baseline characteristics were similar across all study groups except for IIEF, Q_{max}, and bladder contractility: patients in the PErFecTED group had significantly higher IIEF scores than those in the TURP group ($p = 0.0150$), but there were no significant differences in IIEF scores between the oPAE and TURP or PErFecTED groups. Patients in the oPAE and PErFecTED groups had significantly lower baseline Q_{max} than patients in the TURP arm ($p = 0.05$ and $p = 0.0011$, respectively; $p = 0.004$ across all three groups by the Kruskal–Wallis H test). All patients in the TURP group had normal bladder contractility, but the prevalence of hypocontractile and borderline bladders were 5/15 (33.3 %) and 10/15 (66.7 %) in the oPAE group and 8/15 (53.3 %) and 6/15 (40.0 %) in the PErFecTED group, respectively ($p = 0.0001$ by the Kruskal–Wallis H test and $p < 0.0001$ by the Chi-squared test for analysis as a continuous and categorical variable, respectively).

Study treatment procedure data are presented in Table 2. Mean procedure duration was 61.7 ± 17.0, 144.8 ± 50.1 and 147.5 ± 30.4 min for the TURP, oPAE and PErFecTED groups, respectively (anesthesia time for TURP and femoral compression for access puncture hemostasis for PAE were not included in the procedure durations); mean fluoroscopy time for the oPAE and PErFecTED groups was 49.2 ± 17.2 and 45.8 ± 14.6, respectively, and was not significantly different ($p > 0.20$). Mean hospital stay was 2.1 days (2–3 days) after TURP and 6 h after original and PErFecTED PAE ($p < 0.0001$). Mean resection weight among TURP patients was 27.7 cm^3 (4–57 cm^3), and no patients required blood transfusion. Technically successful PAE, defined as bilateral embolization, was achieved in 13 of 15 (86.7 %) oPAE patients and all PErFecTED patients. Two patients (13.3 %) in the oPAE group received unilateral embolization due to severe atherosclerosis or occlusion of the IVA on one side.

Table 3 presents post-treatment outcomes at 12 months of follow-up. In comparison to baseline, all groups experienced significant improvement in mean IPSS, QoL, and Q_{max}, and all had significant decreases in mean prostate volume; both PErFecTED PAE and TURP patients demonstrated a significant decrease in PSA. Clinical success, defined as IPSS ≤8 and/or QoL ≤3 at 12 months of follow-up, was achieved in all patients in the TURP and PErFecTED groups, and 13/15 (86.7 %) in the oPAE group.

Among the three study treatment groups, mean post-treatment IPSS was significantly lower among TURP and PErFecTED patients than among oPAE patients ($p = 0.012$ and $p = 0.0007$, respectively), but not significantly different between TURP and PErFecTED patients ($p > 0.20$). Mean QoL score at 12 months of follow-up

Table 1 Mean pre-intervention clinical and urodynamic characteristics

Variable	Study group			p value
	TURP ($n = 15$)	OPAE ($n = 15$)	PErFecTED ($n = 15$)	
Age (years)	66.4 ± 5.6 (55–78)	63.5 ± 8.7 (46–75)	60.4 ± 5.2 (53–68)	0.06[a]
IPSS	27.6 ± 3.2 (20–34)	25.3 ± 3.6 (19–30)	24.6 ± 3.6 (18–29)	0.08[a]
QoL	4.6 ± 0.8 (4–6)	4.7 ± 0.6 (4–6)	4.7 ± 0.6 (4–6)	>0.20[a]
IIEF	12.5 ± 6.6 (0–21)	14.3 ± 6.8 (0–21)	17.3 ± 5.3 (0–22)	0.05[a]
Prostate volume (cm^3)	56.6 ± 21.5 (32–89)	63.0 ± 17.8 (34–97)	66.2 ± 12.7 (42–82)	>0.20[a]
PSA (ng/mL)	3.2 ± 2.5 (0.6–9.2)	3.4 ± 2.2 (1.6–8.1)	3.7 ± 2.1 (1.0–7.3)	>0.20[a]
PVR (mL)	78.3 ± 73.3 (0–200)	127.0 ± 99.9 (20–320)	74.2 ± 49.3 (5–161)	>0.20[a]
Q_{max} (mL/s)	9.7 ± 3.8 (5.0–18.0)	7.0 ± 3.6 (2.9–13.7)	5.1 ± 3.0 (1.0–12.8)	0.004[a]
BCI	416 ± 138 (227–671)	103 ± 19 (59–131)	96 ± 31 (42–161)	0.0001[a]
BCI <100	0 (0 %)	5 (33.3 %)	8 (53.3 %)	<0.0001[b]
BCI 100–150	0 (0 %)	10 (66.7 %)	6 (40 %)	
BCI >150	15 (100 %)	0 (0 %)	1 (6.7 %)	
BOOI	65.1 ± 30.6 (23–121)	58.9 ± 21.7 (24–96)	60.8 ± 23.5 (34–125)	>0.20[a]
BOOI <20	0 (0 %)	0 (0 %)	0 (0 %)	>0.20[b]
BOOI 20–40	3 (20 %)	4 (26.7 %)	2 (13.3 %)	
BOOI >40	12 (80 %)	11 (73.3 %)	13 (86.7 %)	

[a] p value obtained by Kruskal–Wallis H test

[b] p value obtained by Chi-squared (χ^2) test

Table 2 TURP, oPAE, and PErFecTED PAE procedure characteristics

Procedure	Mean procedure time (min)	Mean fluoroscopy time (min)
TURP	61.7 ± 17.0 (30–90)	N/A
Original PAE	144.8 ± 50.1 (67–278)	49.2 ± 17.2 (24–85)
PErFecTED PAE	147.5 ± 30.4 (110–203)	45.8 ± 14.6 (29–76)

Table 3 Mean post-intervention clinical and urodynamic characteristics at 12-month follow-up

Variable	Study group		
	TURP	oPAE	PErFecTED
IPSS	6.1 ± 8.6 (0–27)[a]	12.8 ± 8.0 (2–27)[a]	3.6 ± 2.9 (0–11)[a]
QoL	0.9 ± 1.4 (0–4)[a]	2.2 ± 1.2 (1–4)[a]	1.6 ± 0.7 (0–3)[a]
IIEF	16.1 ± 5.7 (5–21)[a]	12.6 ± 7.7 (0–21)	18.7 ± 3.2 (14–24)
Prostate volume (cm^3)	32.0 ± 11.4 (21–60)[a]	50.9 ± 19.0 (25–92)[a]	50.0 ± 13.8 (24–70)[a]
PSA (ng/mL)	1.6 ± 0.9 (0.4–3.2)[a]	2.2 ± 1.1 (0.8–4)	1.7 ± 1.2 (0.7–5.2)[a]
PVR (mL)	8.3 ± 11.9 (0–30)[a]	62.3 ± 71.0 (0–250)[a]	48.6 ± 65.7 (0–224)
Q_{max} (mL/sec)	27.1 ± 8.7 (12–45)[a]	10.1 ± 6.5 (2–25)[a]	16.7 ± 8.4 (4–31)[a]

[a] Statistically significant change from baseline

was significantly better among TURP patients than oPAE or PErFecTED patients ($p = 0.0041$ and $p = 0.0095$, respectively), but not significantly different between oPAE and PErFecTED patients ($p = 0.1916$). Similarly, mean prostate volume at 12 months post-procedure was significantly lower among TURP patients than oPAE and PErFecTED patients ($p = 0.0026$ and $p = 0.0010$, respectively), but it was not significantly different between the oPAE and PErFecTED groups ($p > 0.20$). There were no significant differences in post-treatment PSA among the treatment groups.

Urodynamic evaluations showed that TURP resulted in significantly lower mean PVR than oPAE ($p = 0.0062$), but the post-treatment difference between mean PVR after TURP was only marginally significantly different compared to that post-PErFecTED PAE ($p = 0.0517$). The difference in PVR post-oPAE and PErFecTED PAE was not significantly different ($p > 0.20$). Mean Q_{max} was significantly higher among both TURP and PErFecTED than oPAE patients ($p < 0.0001$ and $p = 0.0223$, respectively), and significantly higher in the TURP group than in the PErFecTED group ($p = 0.0054$). BOOI and BCI calculations were not possible with the available follow-up data due to the use of non-invasive uroflowmetry for post-treatment evaluations.

Patients receiving PAE (original and PErFecTED) reported local pain at the prostate site, mild to moderate urethral burning during voiding, and urinary frequency for 3–4 days post-procedure. Other adverse events occurring in both PAE groups included transient minimal rectal bleeding (1/15, 6.7 % in each group), hematospermia (1/15, 6.7 % in each group), and reduction in ejaculate volume (2/15, 13.3 % in oPAE group, 1/15, 6.7 % in PErFecTED group). One incident (6.7 %) of transient pubic bone ischemia and 2 cases (13.3 %) of hematuria occurred in the oPAE group. No adverse events related to radiation exposure during original or PErFecTED PAE were observed.

All TURP patients complained of pollakuria, dysuria, and hematuria for up to 2 weeks after TURP. The only serious adverse events occurred among TURP patients: one patient (6.7 %) suffered intra-operative damage to the left venous sinus and rupture of the prostatic capsule which was treated successfully with Foley balloon traction for 2 h after resection to stop bleeding. One other (6.7 %) TURP patient was readmitted to the hospital for bladder catheterization and temporary irrigation 24 h post-discharge due to hematuria. Early urinary incontinence was seen in 4/15 (26.7 %), and retrograde ejaculation occurred in all (100 %) TURP patients. Prostate cancer was identified incidentally in one patient (6.7 %) in the TURP group during histopathological examination of resected tissue.

No recurrence of LUTS occurred in the TURP and PErFecTED cohorts. Two patients (13.3 %) in the oPAE group experienced recurrence of LUTS, one at 6 and one at 12 months post-PAE. The first patient had bladder hypocontractility (BCI = 91) and the second was borderline hypocontractile (BCI = 107) at baseline, and both were subsequently treated with TURP with relief of symptoms.

Discussion

All treatments obtained statistically significant symptom, imaging, and urodynamic improvements. Mean procedure time was significantly longer for both original and

PErFecTED PAE than for TURP, but PAE procedures were all performed on an outpatient basis with only local anesthesia. Per protocol, no closure devices were used, so patients remained in the hospital for 6 h post-embolization to avoid puncture site bleeding complications. All TURP patients required hospital admission for an average of 2.1 days, with continuous bladder irrigation for 1 day post-resection and eventual removal of the Foley catheter.

Similar procedure and fluoroscopy times were observed between the PAE treatment groups. Longer procedure duration was often due to difficult anatomy, including tortuous vessels and atherosclerosis. In particular, identifying the prostatic artery in the oPAE patient with total occlusion of the left IVA and navigating the tight stenosis at the origin of the right IVA in the patients who ultimately received unilateral embolization resulted in longer procedure times. Additionally, some original and PErFecTED PAE cases were performed during teaching sessions, with extra time allowed to narrate each step of the procedure. No complications related to radiation exposure were observed, but the length of fluoroscopy time during PAE should be limited to the extent possible. Laborda and colleagues have described a case of radiodermatitis in an obese patient following 72 min and 8,023,949 mGy cm^2 of fluoroscopy exposure during a PAE procedure [19].

Mean resection weight during TURP was 27.7 cm^3 (4–57 cm^3), and all tissue samples were sent to histopathology for examination. One case of prostate adenocarcinoma, classified as Gleason 7, was identified in 10 % of removed tissue. No patient presented with signs of cancer during the follow-up period after original or PErFecTED PAE, and the effect of PAE on prostate cancer is not yet known.

All PAE patients presented with mild to moderate burning during urination and frequency during the first 3–4 days following embolization, likely related to ischemia of the prostate. Two cases of transient hematuria were observed in the oPAE arm. One patient experienced a single episode of hematuria during the first week after PAE, and the other case was related to urethral trauma during Foley catheter placement prior to PAE. Hematospermia and hematochezia were each reported in one patient in the oPAE and PErFecTED treatment groups. Bagla et al. reported 16 % hematospermia even with the use of cone-beam CT [8]. Hematospermia following PAE may be related to seminal vesicle or focal prostate ischemia and hematochezia related to transient ischemic rectitis [20]. During the 3-month MRI, an image of a pubic bone ischemia was observed in one patient (6.7 %) of the oPAE group. The patient was asymptomatic, and the lesion had disappeared at the next MRI control. The finding was probably related to non-target embolization and was identified only because MRI was used. The use of cone-beam CT has improved procedure safety and can help to avoid non-target embolization. All of these events were transient, required no additional treatment, and resolved spontaneously. Two patients in the oPAE group and one patient in the PErFecTED group observed reduced ejaculate volume, likely the result of reduced prostate volume following embolization (and therefore less seminal fluid production). There were no serious adverse events in either PAE cohort, and no patients in either PAE group reported urinary incontinence or retrograde ejaculation.

Hematuria, dysuria, and pollakuria were observed in all patients in the TURP group during the first 2 weeks following the procedure. Hematuria is an important consideration the first day after resection, and all patients required hospitalization for bladder catheterization and continuous irrigation to avoid urinary obstruction due to blood clots. One of the serious events in the TURP cohort occurred when a patient was readmitted to the hospital for bladder catheterization and temporary irrigation 1 day post-discharge due to hematuria. Another TURP patient experienced an intra-operative lesion of the left venous sinus with capsular rupture during resection and required Foley balloon traction to stop the bleeding. Bleeding is the main intra-operative complication of TURP, resulting in a transfusion rate of 2.9 % in the literature [2]. Additionally, early urinary incontinence was observed in 4/15 patients (26.7 %) in this group. All cases of urinary incontinence were transitory, and all patients recovered by 6 months post-TURP. If the bladder neck sphincter is damaged during TURP, this can lead to permanent urinary incontinence [21]. All TURP patients (100 %) reported retrograde ejaculation. The sperm cells are produced in the testis and accumulate in the epididymis, and then pass through the vas deferens and ejaculatory duct to enter the urethra and exit the penis during ejaculation. The ejaculatory duct delivers sperm into the urethra, adding secretions from the prostate necessary for sperm function, while providing an interface between the reproductive and urinary systems in men. We believe that the main causal mechanism of retrograde ejaculation is related to the resection of the bladder neck (internal sphincter) that occurs during TURP. However, recent data have described that preservation of the prostatic tissue just beside and proximal to the verumontanum may spare ejaculation [22]. More studies are needed to clarify these questions.

Figure 1 shows MRI findings after TURP and PAE. Ischemic areas of coagulative necrosis called “black hole sign” in the central gland with prostate size reduction are observed after PAE, and a wide channel is created in the center of the gland after TURP. These findings may explain higher urinary flow and the risk of urinary incontinence and retrograde ejaculation after TURP.

Two patients (13.3 %) in the oPAE group had recurrence of LUTS, one after 6 months and the other after 12 months. Re-embolization was not offered to these

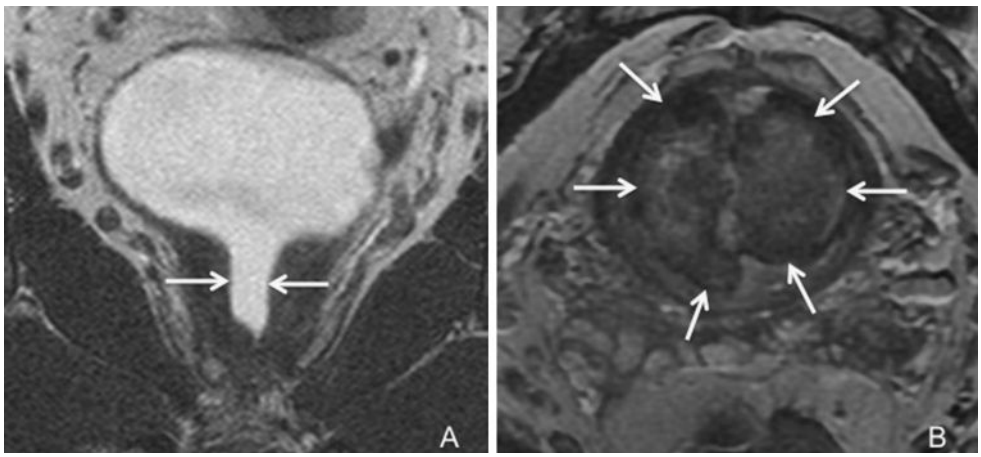

Fig. 1 **A** T2-weighted MRI coronal image showing the intraprostatic channel (*white arrows*) after TURP and **B** axial image with bilateral infarcted areas (*black hole sign*) in the central gland after PAE (*white arrows*)

patients because both had known bladder hypocontractility and one had severe atherosclerosis. Both patients experienced improvement compared to their baseline status, but did not meet the pre-defined protocol criteria for clinical success (IPSS $\leq$8, and/or QoL $\leq$3). Both patients were successfully treated with subsequent TURP.

Several short-term, non-controlled trials have described the results of PAE for treatment of LUTS due to BPH. Pisco and colleagues described their outcomes from a group of 255 patients diagnosed with BPH and moderate to severe LUTS after failure of medical treatment for at least 6 months [9]. Follow-up ranged from 1 to 36 months, and clinical success was defined only as improvement of symptoms and QoL compared to baseline status. With a mean follow-up of 10 months, 72 % of patients met the authors' criteria for clinical success. A case of severe complication (bladder ischaemia) was observed. Patients in this study did not undergo urodynamic evaluation as a component of baseline or follow-up evaluations.

To date, only one other prospective and randomized trial comparing TURP and PAE has been published [11]. The authors analyzed 114 patients followed for 24 months and observed clinical failure rates of 3.9 and 9.4 % in TURP and PAE patients, respectively. Compared to baseline values, both treatments showed improvements at all time points. The TURP group showed greater improvement in IPSS, QoL, Q_{max}, and PVR at 1 and 3 months compared to the PAE group. After 12 months, results of PAE were similar to those of TURP, but TURP continued to result in greater PSA and prostate volume reductions at all follow-up time points. The PAE group experienced more adverse events and overall complications in that study, mostly related to acute urinary retention and post-embolization syndrome. As only uroflowmetry and not urodynamic assessments were performed, the role of bladder hypocontractility in symptom improvement or lack thereof in that study is unknown.

Our group has previously published an analysis of 11 patients with indwelling catheters to manage acute urinary retention due to BPH who underwent PAE and had a minimum follow-up of 1 year [6, 23]. Following embolization, 10 of 11 patients were able to void spontaneously with mean time to catheter removal of 12.1 days. Prior to PAE, BOOI was >40 in all patients, but after embolization 30 % of patients were unobstructed (BOOI $\leq$20), 40 % were equivocal (BOOI between 20 and 40), and 30 % remained obstructed (BOOI >40). These figures suggest that PAE may offer relief or improvement of BOO in approximately 70 % of patients with severe obstruction. However, those data were obtained using the oPAE technique. PAE may offer even better results in less advanced cases that have not yet progressed to complete obstruction. The current investigation also suggests that patients with neurogenic or non-neurogenic bladder dysfunctions resulting in hypocontractility may not be optimal candidates for PAE. Further studies are needed to identify appropriate candidates based on clinical and urodynamic characteristics.

In this study, the two patients with symptom recurrence were in the oPAE group. One suffered from bladder hypocontractility and the other had a borderline BCI (BCI = 102) at baseline. Despite randomization, all 15 patients (100 %) in the TURP group had normal bladder function as assessed by the BCI (BCI >150), while prevalence of hypocontractility (BCI <100) and borderline hypocontractility (BCI between 100 and 150) were 5/15 (33.3 %) and 10/15 (66.7 %) in the oPAE and 8/15 (53.3 %) and 6/15 (40 %) in the PErFecTED group. Longer duration of follow-up will be necessary to evaluate these patients for recurrence of LUTS.

The small number of patients in each treatment cohort and the better baseline bladder function in the TURP arm may explain the difference in outcomes between the three study groups. It is notable that although almost all the patients in the PAE treatment arms (29/30) had reduced

bladder contractility compared to those in the TURP group at baseline, they still experienced improvement in all parameters after embolization except IIEF, which remained unchanged.

This is the first prospective, randomized study comparing TURP and PAE that includes urodynamic evaluations instead of only uroflowmetry. Our investigation revealed that while TURP results in significantly higher Q_{max} and significantly smaller prostate volume post-procedure than original or PErFecTED PAE, there was no significant difference between post-procedure IPSS among patients who received TURP and those who received PErFecTED PAE. Furthermore, both original and PErFecTED PAE produced significant improvements in IPSS compared to baseline without inpatient hospitalization, spinal or general anesthesia, or major complications.

Since these early cases were performed, we have developed technical modifications and procedural improvements for PAE [10, 14]. This study is the first statistical comparison of outcomes from the PErFecTED technique compared to oPAE, and the PErFecTED method resulted in significantly better IPSS scores in follow-up. Results obtained in this study support our idea of performing the PErFecTED technique, however, a larger, multicenter study that includes urodynamic evaluation and MRI will be required to properly evaluate outcomes following various techniques for PAE.

As with any treatment, PAE has advantages and disadvantages. PAE can be performed on an outpatient basis with local anesthesia as an alternative to medication and surgery. It may be an appropriate option for elderly patients, poor surgical candidates, and patients who do not want to risk potential adverse effects from TURP such as retrograde ejaculation, urinary incontinence, or transfusion. The disadvantages of PAE include contrast medium and radiation exposure, and the lack of tissue sampling for histopathologic analysis. In this study, TURP resulted in similar IPSS to PErFecTED PAE and significantly better urinary flow in follow-up but required 2–3 days of post-operative hospitalization, urinary catheterization, spinal anesthesia, and was associated with a high incidence of early urinary incontinence and retrograde ejaculation.

The present study was prospective, included randomization to TURP and oPAE, and all patients were evaluated with MRI and complete urodynamic studies before study treatment and at 1 year of follow-up. Our study does have limitations, however. The study population was small and from a single center. Randomization allocated patients to the TURP and oPAE groups only, because the PErFecTED technique was developed after the randomized study was initiated. Furthermore, although a number of studies have published outcomes of PAE in various populations, there is not yet a consensus on the definition of clinical success.

Both PAE and TURP are safe and effective treatments for improving LUTS, QoL, urinary flow, PSA elevation, and large prostate size due to BPH. Symptom recurrence in the oPAE group was observed only in patients with hypocontractile bladders. In this small study, TURP and PErFecTED PAE resulted in similar symptom relief as measured by the IPSS questionnaire, but TURP resulted in significantly greater urine urinary flow than original or PErFecTED PAE. This improvement in urodynamic performance came at the expense of inpatient hospitalization and a greater number and severity of adverse events, however. A rigorous, multicenter, controlled study will be required to compare objective long-term outcomes after PAE and TURP.

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Compliance with Ethical Standards

Conflict of interest Authors declare they have no financial disclosure.

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