Radiology

Benign Prostatic Hyperplasia: Prostatic Arterial Embolization versus Transurethral Resection of the Prostate—A Prospective, Randomized, and Controlled Clinical Trial[1]

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Purpose: To compare prostatic arterial embolization (PAE) and transurethral resection of the prostate (TURP) in the care of patients with benign prostatic hyperplasia (BPH).

Materials and Methods: This prospective randomized clinical trial was approved by the institutional review board. A total of 114 patients provided written informed consent and were randomly assigned to undergo PAE (n = 57) or TURP (n = 57). The groups were compared regarding relevant adverse events and complications. Functional results—including improvement of International Prostate Symptom Score (IPSS), quality of life (QOL), peak urinary flow, postvoiding residual urine volume, prostate-specific antigen (PSA) level, and prostate volume—were assessed at 1-, 3-, 6-, 12-, and 24-month follow-up between January 20, 2007, and January 31, 2012. Student t test, χ^2 test, Fisher exact test, and repeated measures analysis of variance were used, as appropriate.

Results: Overall technical success rates for TURP and PAE were 100% and 94.7%, respectively; the clinical failure rates were 3.9% and 9.4%, respectively. The six functional results showed improvements after TURP and PAE at all follow-up time points when compared with preoperative values (P = .001). However, the TURP group showed greater degrees of improvement in the IPSS, QOL, peak urinary flow, and postvoiding residual urine volume at 1 and 3 months, as well as greater reductions in the PSA level and prostate volume at all follow-up time points, when compared with the PAE group ($P < .05$). The PAE group showed more overall adverse events and complications (P = .029), mostly related to acute urinary retention (25.9%), postembolization syndrome (11.1%), and treatment failures (5.3% technical; 9.4% clinical).

Conclusion: Both procedures resulted in significant clinical improvements in the treatment of BPH. However, the advantages of the PAE procedure must be weighed against the potential for technical and clinical failures in a minority of patients.

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Prostatectomy via open surgery or transurethral resection of the prostate (TURP) is the standard treatment for benign prostatic hyperplasia (BPH) (1). However, individuals older than 60 years are at high risk for surgical complications (2), including urinary tract infection, strictures, postoperative pain, incontinence or urinary retention, sexual dysfunction, and blood loss (2). As a growing trend for the clinical management of BPH, several minimally invasive treatments have been proposed (3–6). In the 1970s, prostatic arterial embolization (PAE) was introduced as a method to control massive hemorrhage after prostatectomy or prostate biopsy (7,8). In 2000, DeMeritt et al (9) reported a case study of a patient with BPH who underwent PAE for severe gross hematuria. DeMeritt et al incidentally discovered that PAE could successfully induce shrinkage of the enlarged prostate, thereby relieving the clinical symptoms.

Relatively recently, authors have reported on the treatment of BPH with PAE in experimental animals and human patients (10–17). Some of these reports have identified PAE as a safe and effective method with which to treat lower urinary tract symptoms (LUTS) caused by BPH (10–14). However, the follow-up periods of these series were too short (1–6 months) to ensure the real effectiveness of PAE (9–12). To compare the effectiveness of PAE with the reference standard of TURP in patients with LUTS related to BPH, a prospective randomized controlled clinical trial has been needed. In this article, we report results from a prospective randomized controlled trial in which we compared PAE with TURP in the treatment of BPH.

Advances in Knowledge

- Prostatic arterial embolization (PAE) is an effective treatment in patients with lower urinary tract symptoms (LUTS) due to benign prostatic hyperplasia (BPH), especially in patents with BPH who have predominant prostatic arteries and a rich vasculature.
- Compared with transurethral resection of the prostate (TURP), PAE brings less rapid relief from symptoms, typically within 3 months after the procedure; however, late symptom improvements are almost comparable to those achieved with TURP.
- Compared with TURP, PAE treatment of BPH is associated with shorter hospital stays but higher technical and clinical failure rates.

Materials and Methods

Study Population

From January 2007 to January 2012, a total of 120 patients with LUTS due to BPH were assessed for study eligibility. Inclusion criteria were an International Prostate Symptom Score (IPSS) greater than 7 after failed medical therapy with a washout period of 2 or more weeks, prostate volume of 20–100 mL on transrectal ultrasonographic (US) or magnetic resonance (MR) images, peak urinary flow of less than 15 mL/sec, and patient understanding and written informed consent. Exclusion criteria were detrusor hyperactivity or hypocontractility at urodynamic study, urethral stricture, prostate cancer, diabetes mellitus, and previous prostate, bladder neck, or urethral surgery. Patients who had a prostate-specific antigen (PSA) value greater than 4 ng/mL or an abnormal finding at digital rectal examination underwent US-guided prostate biopsy prior to study inclusion. These patients were included in the study if the biopsy result was negative. After we applied inclusion and exclusion criteria, we excluded six patients for various reasons. Thus, 114 patients were included in the study (Fig 1).

Implications for Patient Care

- PAE can be considered a treatment option for relief of LUTS secondary to BPH, especially in the care of patients at high risk who are not candidates for surgery.
- Advantages of PAE must be weighed against the risk of technical and clinical failures requiring a second intervention.

Study Design

Protocols for this prospective, parallel randomized controlled trial were approved by the Health Ethics and Research Committee of the authors' hospitals. Prior to their appointment for treatment, patients were contacted by telephone (Y.H.). They were informed of the details and intent of the study and were invited to participate. Interested patients were scheduled to meet with the radiologist on the day before their treatment to undergo baseline testing. Eligible patients were randomly assigned to one of two treatment groups, as described by Zelen (18), and asked to provide informed consent. If the patient refused the assigned treatment, he was offered other treatment or treatments; however, the results were not included for analysis.

Randomization was performed by using computer-generated simple random tables in a 1:1 ratio. A standard deviation of six for the IPSS of either group was assumed; the sample size was estimated by using the two-mean comparison sample size formula, with type I error $\alpha < .05$ and 80% power (type II error $\beta < 20\%$) to detect a difference in IPSS score of three points (19). The minimum sample size to detect significant differences was 50

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Abbreviations:
BPH = benign prostatic hyperplasia
IPSS = International Prostate Symptom Score
LUTS = lower urinary tract symptoms
PAE = prostatic arterial embolization
PSA = prostate-specific antigen
QOL = quality of life
TURP = transurethral resection of the prostate

Author contributions:
Guarantors of integrity of entire study, Y.G., Y.W.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, Y.W.; clinical studies, all authors; statistical analysis, Y.H., R.Z.; and manuscript editing, Y.G., Y.W.

Conflicts of interest are listed at the end of this article.

Figure 1

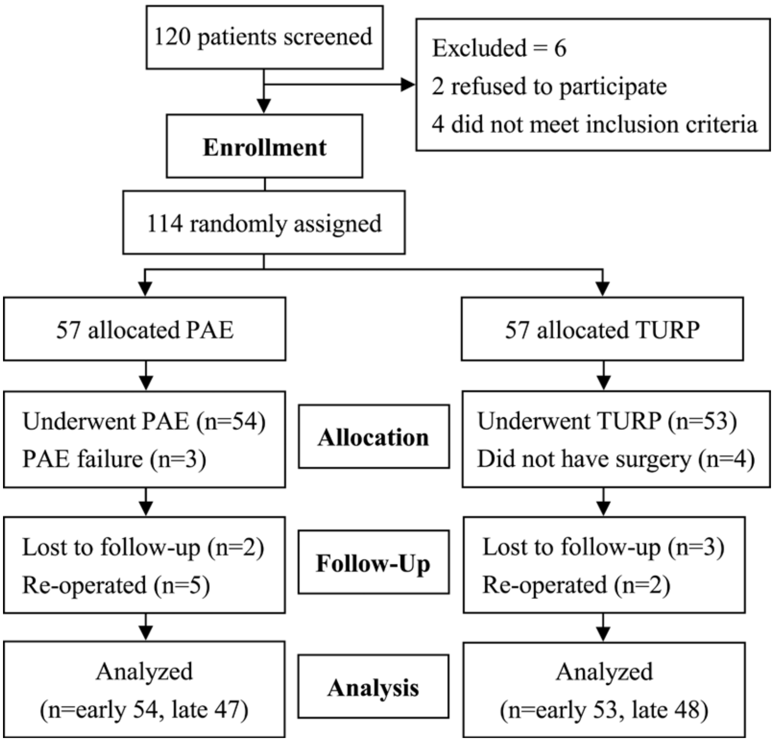


Figure 1: Flow chart shows the random assignment of patients to treatment groups.

patients per group. To account for noncompliance and loss to follow-up, 120 patients were recruited (Fig 1).

TURP Technique

TURP was performed by two urologists (Y.Y., Q.Z.; 12 and 9 years of experience, respectively) with use of epidural anesthesia. Patients underwent bipolar TURP (PlasmaKinetic System; Gyrus Medical System, Minneapolis, Minn) with a 26-F continuous flow resectoscope. A three-way 22-F Foley catheter was inserted after surgery; this was followed by continuous irrigation with saline. Before this study, all attending urologists had performed at least six bipolar TURP procedures.

PAE Technique

PAE was performed by two interventional radiologists (Y.G., Y.H.; 11 and 7 years of experience, respectively) using a digital subtraction angiographic unit (Integris CV12; Philips Medical Systems, Amsterdam, the Netherlands) with nonionic visipaque contrast medium (320 mg of iodine per milliliter, Iodixanol; GE Healthcare, Cork, Ireland). PAE was performed bilaterally or unilaterally depending on whether a catheter could be inserted in the prostatic arteries. The patients received local anesthesia, and vascular access was obtained with a right femoral approach. For most patients, pelvic angiography initially was used to evaluate the iliac and prostatic vessels. Selective arteriography of the right and left internal iliac arteries was performed by using a 4-F Cobra-shaped catheter to assess blood supply to the prostate. Superselective catheterization of the right and left inferior vesicle arteries was performed by using a 3-F microcatheter (Microferret; Cook, Bloomington, Ind). Angiography was performed by manually injecting 3–5 mL of contrast medium to ensure that the tip of the microcatheter was inside or at the ostium of the prostatic arteries.

Polyvinyl alcohol microspheres (355–500 μm in diameter, Ivalon; Cook) were used for embolization. A 2.0-mL vial of microparticles was diluted in 20 mL of 50% contrast medium and 50% normal saline solution. The mixture was slowly injected with fluoroscopic control. Embolization was immediately terminated when complete stasis was achieved, without reflux of the mixture to undesired arteries (Fig 2a–2c). Fluoroscopy time and radiation exposure were obtained from the angiography machine at the end of the procedure. If any complications occurred or if a postoperative urethral catheter was required, the patient was admitted to the hospital.

Outcome Assessment

Safety and adverse events were evaluated with intra- and perioperative data (operative time, fluoroscopy time, radiation dose, changes in hemoglobin and serum sodium levels within 24 hours after the procedure, transfusion requirements), postoperative data (hospital stay, catheter requirements), and peri- and postoperative complications. Adverse events and complications were graded with the modified Clavien classification system (20), with grades I and II considered minor complications and grades III and IV considered major complications.

Functional results were assessed with clinical observation at 1, 3, 6, 12, and 24 months. Functional results included improvement of *(a)* IPSS, which ranged from 0 (best) to 35 (worst); *(b)* quality of life (QOL) score, which ranged from 0 (delighted) to 6 (terrible); *(c)* peak urinary flow, which was measured with uroflowmetry; *(d)* postvoiding residual urine volume, which was measured with transabdominal US except in patients with an indwelling catheter; *(e)* prostate volume, which was measured with transrectal US by using the ellipsoid formula (length × width × depth × 0.5233); and *(f)* PSA level (Fig 2d–2f). Pre- and postoperative functional results were compared to evaluate clinical improvement.

Cases of persisting severe symptoms (decrease in IPSS of ≤25%, IPSS ≥18, decrease of QOL score by ≤1, and QOL score ≥4) and/or peak urinary flow increase of less than 2.5 mL and peak urinary flow of 7 mL/sec or lower

Figure 2

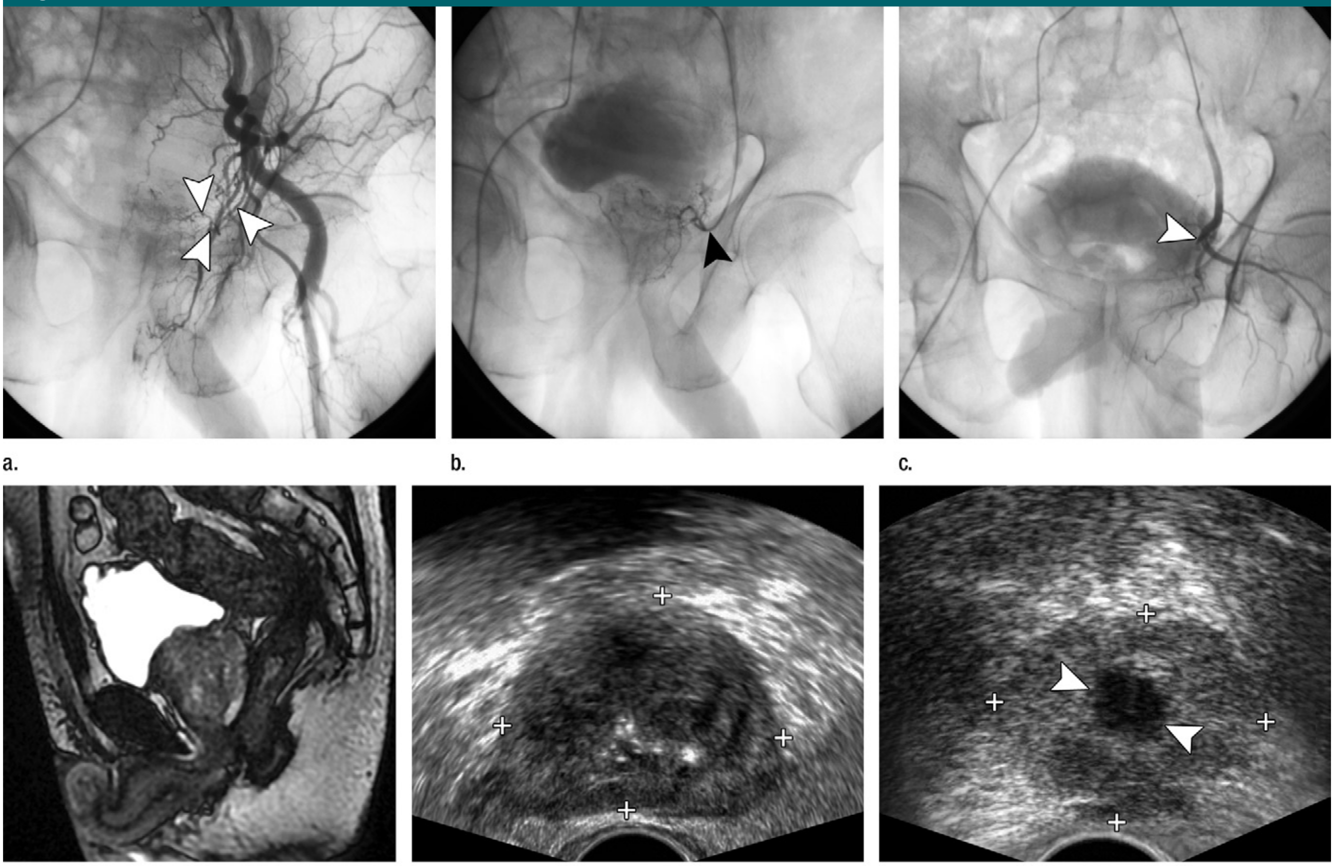


Figure 2: Prostatic arteriography and embolization techniques for BPH. **(a)** Internal iliac arteriogram shows a prostatic artery (arrowheads) supplying an enlarged prostate. **(b)** Selective PAE with polyvinyl alcohol particles administered via a microcatheter system (arrowhead) shows some vascular staining in the enlarged prostate. **(c)** Postembolization internal iliac arteriogram shows absent flow (arrowhead) to the enlarged prostate. **(d)** Pelvic MR image obtained before PAE shows prostate dimensions of 56.6 × 49.3 × 53.2 mm and a volume of 77.7 mL. **(e)** Transrectal US image before PAE shows prostate dimensions of 57.2 × 51.5 × 52.1 mm and prostate volume of 80.4 mL. **(f)** Transrectal US image 6 months after PAE shows prostate dimensions of 48.3 × 44.5 × 39.2 mm and prostate volume of 44.1 mL. Cystic necrosis (arrowheads) in the center of the prostate results in a volume decrease of 45.1%.

after the procedure were considered clinical failures. (12,21). In the case of clinical failure, the TURP was repeated 6 months after the initial procedure. A PAE procedure was considered technically successful if selective prostatic arterial catheterization and embolization were achieved on at least one side of the pelvis. Rich vasculature or hypervascularity were defined as marked vascular staining in the prostate during selective prostatic arteriography (13,14,22). A predominant prostatic artery was defined as only one independent prostatic artery with a diameter of approximately 2 mm on at least one side of the pelvis (13,14,22).

Statistical Analysis

Results are given as mean ± standard deviation. Statistical analysis was performed by using the SPSS, version 18.0 statistical software package (SPSS, Chicago, Ill). The estimated power was 95%, with the assumption of a two-sided significance test with a significance level of $\alpha = .05$ and a sample size of 57 cases per group. Continuous variables were tested for normality and equality of variances by using the Kolmogorov-Smirnov-test and the Levene F test, respectively. The Student t test, Pearson χ^2 test, and Fisher exact test were used, when appropriate. Repeated measures analysis of variance was performed to compare the functional results between groups over time. All randomly assigned patients who did not withdraw from the study were included on a modified intention-to-treat basis. Results for patients lost to final follow-up (at 24 months) or who underwent repeat procedures were included in the analysis, when available. Results after the repeat procedure were not included.

Results

Patients were followed for at least 24 months, with a mean follow-up of 22.5 months. Three patients were lost to

follow-up at 6 months (one in the PAE group, two in the TURP group), and two patients were lost to follow-up at 12 months (one in each group). No clinically relevant or significant differences were detected between the two groups for any baseline characteristic (Table 1).

Operation and Treatment Success Rates

In the PAE group, the procedure was technically successful in 54 of 57 patients (94.7%). In three patients (5.3%), PAE was impossible due to tortuosity and atherosclerotic changes of the bilateral iliac arteries. Because of similar changes, PAE was performed unilaterally in six patients (10.5%). PAE was bilateral in 48 patients (84.2%). Five patients (9.4%) were considered to have clinical failure (four in patients with bilateral PAE, one in a patient with unilateral PAE), and the prostate in all five of these patients showed a hypovascular or complicated blood supply pattern without a predominant prostatic artery (Figs 3, 4).

In the TURP group, the procedure was technically successful in all 53 patients (100%) who underwent treatment. Clinical failure was reported in two patients (3.8%).

Intraoperative and Early Postoperative Outcomes

The intraoperative and early postoperative outcomes are summarized in Table 2. The mean procedure time was insignificantly shorter in patients who underwent TURP. Fewer patients required postoperative urethral catheterization after PAE than after TURP ($P < .001$). High-flow bladder irrigation was maintained for at least the first 24 hours in all patients after TURP, but it was not maintained in patients after PAE ($P < .001$). Hemoglobin and serum sodium levels after PAE were similar to those before PAE; however, both hemoglobin and serum sodium levels were significantly reduced after TURP. Significantly more patients were admitted to the hospital after TURP than after PAE, and their average hospital stay was longer.

Table 1

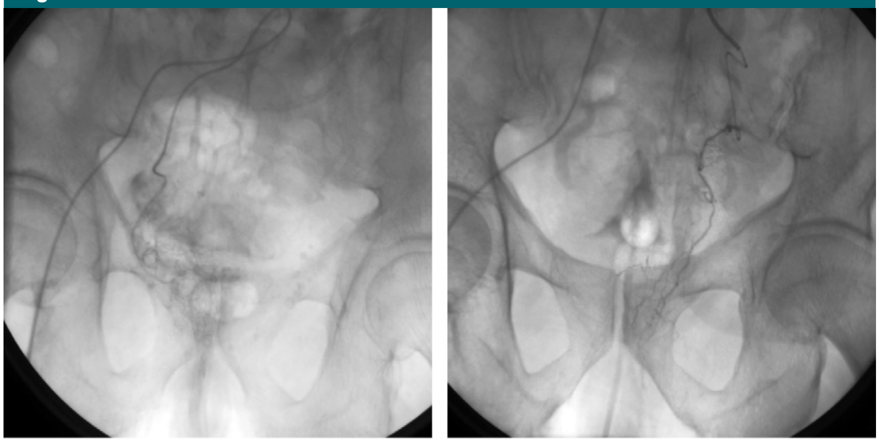
Baseline Characteristics of Patients of Both Groups

Characteristic	PAE Group ($n = 57$)	TURP Group ($n = 57$)	P Value
Age (y)	67.7 ± 8.7	66.4 ± 7.8	.397
ASA classification*			.544
I	15 (26.3)	18 (31.6)	…
II	29 (50.9)	31 (54.4)	…
III	12 (21.1)	8 (14.0)	…
IV	1 (1.8)	0	…
Prostate volume (mL)	64.7 ± 19.7	63.5 ± 18.6	.744
PSA level (ng/mL)	3.7 ± 2.0	3.6 ± 1.9	.285
IPSS	22.8 ± 5.9	23.1 ± 5.8	.823
Peak urinary flow (mL/s)	7.8 ± 2.5	7.3 ± 2.3	.355
Postvoiding residual urine volume (mL)	126.9 ± 68.8	115.4 ± 69.1	.401
QOL	4.8 ± 0.8	4.6 ± 0.7	.136
Preoperative catheterization*	5 (8.8)	6 (10.5)	.751

Note.—Unless otherwise indicated, data are mean ± standard deviation. ASA = American Society of Anesthesiology.

* Data are number of patients, and data in parentheses are percentages.

Figure 3



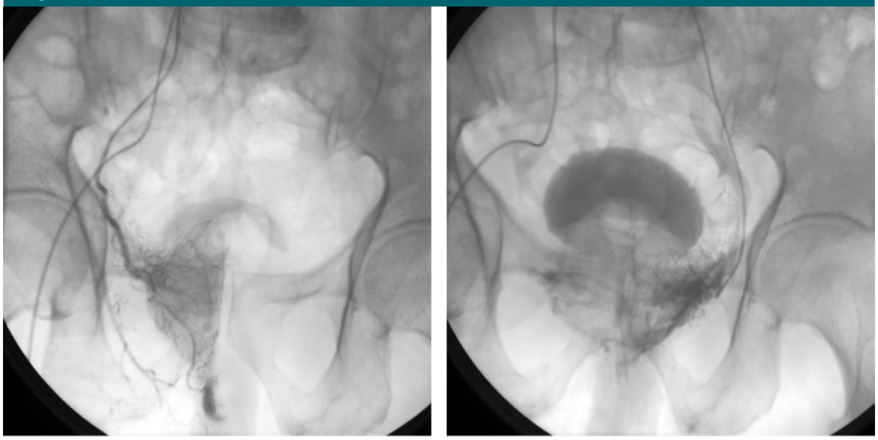
a. b.

Figure 3: Images in a 64-year-old man with BPH who was moved to the TURP group because of inadequate LUTS control due to a hypovascular prostate 6 months after bilateral PAE. **(a)** Selective right prostatic arteriogram shows slight vascular staining in the prostate. **(b)** Selective left prostatic arteriogram shows a small prostatic artery supplying the prostate.

Adverse Events and Complications

Table 3 shows the results for the adverse events and complications in both groups. Overall, a significantly higher percentage of patients in the PAE group had complications compared with the TURP group. Of the 54 patients in the PAE group, 22 reported minor complications mostly related to postembolization syndrome and acute urinary retention. Of the 53 patients in the TURP group, 13 reported minor complications mostly related to blood transfusion, acute urinary retention, hematuria, and urinary tract infection. In the PAE group, eight patients reported major adverse events, including technical and clinical treatment failures. In the TURP group, four patients reported major adverse events, including transurethral resection syndrome, clinical failures, and bladder neck stenosis.

Figure 4



a. b.

Figure 4: Images in a 73-year-old man with BPH showed a satisfactory effect after bilateral PAE. **(a)** Selective right prostatic arteriogram shows an enlarged prostatic artery and marked vascular staining in the prostate. **(b)** Selective left prostatic arteriogram shows marked vascular staining in the prostate. A hypervascular prostate implies a better response to PAE.

Table 2

Intraoperative and Early Postoperative Outcomes in Both Groups

Outcome	PAE Group (*n* = 54)	TURP Group (*n* = 53)	*P* Value
Procedure time (min)	89.7 ± 17.1	83.5 ± 17.5	.066
Fluoroscopy time (min)	33.2 ± 6.7	0	<.001
Radiation dose (cGy/cm^2)	11 305.1 ± 2671.5	0	<.001
Serum sodium level (mmol/L)			
Preoperative	138.8 ± 3.2	139.2 ± 3.1	.560
Postoperative	137.5 ± 4.8	136.5 ± 4.9	.273
P value	.086	.001	…
Mean change	1.4 ± 1.2	2.7 ± 2.2	<.001
Hemoglobin level (g/L)			
Preoperative	13.8 ± 1.1	13.9 ± 1.0	.393
Intraoperative	13.5 ± 1.1	11.8 ± 1.7	<.001
P value	.197	<.001	…
Mean change	0.3 ± 0.2	2.1 ± 0.7	<.001
Patients with urethral catheter*	19 (35.2)	53 (100)	<.001
Patients with hospital stay*	26 (48.1)	53 (100)	<.001
Hospital stay duration (d)	2.9 ± 1.6	4.8 ± 1.8	<.001

Note.—Unless otherwise indicated, data are mean ± standard deviation.

* Data are numbers of patients, and data in parentheses are percentages.

Functional Results

Postoperative IPSS, QOL, peak urinary flow, and postvoiding residual urine volume were improved compared with the preoperative values (*P* = .001), with a comparable degree of improvement in both groups at 12 and 24 months. However, the degrees of improvement at 1 and 3 months were significantly higher in the TURP group than in the PAE group (Fig 5a–5d). Both procedures reduced the PSA level and prostate volume compared with preoperative levels (*P* = .001); however, significantly greater reduction was observed in the TURP group at all time points (Fig 6a, 6b).

Discussion

In this article, we report the results from a prospective randomized controlled trial of patients with LUTS due to BPH that was designed to compare the efficiency and safety of PAE with the efficiency and safety of TURP. All six of the monitored functional results were improved after either procedure. IPSS, QOL, peak urinary flow, and postvoiding residual urine volume showed similar improvements in both groups at 12- and 24-month follow-up. These findings indicate that PAE is an effective treatment in patients with LUTS due to BPH.

The TURP group showed superior improvements in IPSS, QOL, peak urinary flow, and postvoiding residual urine volume at 1 and 3 months and greater reduction of PSA at all time points compared with the PAE group. These findings may be explained by the fact that PAE is not an immediate ablative technique. PAE destroys the prostate vasculature, and several months are needed for the prostate to complete its complicated histopathologic changes (15,16). In addition, a greater portion of the transitional zone may have been resected in the TURP group than in the PAE group because of the different degrees of experience between the urologists and the interventional radiologists.

Pisco et al (11) recently studied 15 patients with BPH who underwent PAE. Their data were considerably less promising than our own, with IPSS improvements in the range of 6.5 points and peak urinary flow improvement of 3.85 mL/sec. They used follow-up times of 3 and 6 months, which might have been too short to ensure the real effectiveness of PAE. However, DeMeritt et al (9) reported that the IPSS decreased from 24 to 13 after 12 months. At 5 months, the prostatic volume was reduced by 40%, and the PSA level had decreased from 40 ng/mL to 4 ng/mL.

Overall, within the 24-month follow-up period, the PAE group had a greater percentage of patients with complications and adverse events than did the TURP group (52.6% vs 29.8%, *P* = .029) (Table 3). All eight of the major adverse events in the PAE group were due to

Table 3

Intraoperative, Early, and Late Postoperative Adverse Events and Complications in Patients of Both Groups

Adverse Event or Complication/Clavien grade	PAE Group	TURP Group	Management	*P* Value
Intraoperative				
Technical failure/IIIb	3 (5.3%)	0	TURP	.268
Blood transfusion/II	0	2 (3.8)	Transfusion	.444
Transurethral resection syndrome/IVb	0	1 (1.9)	Admission to intensive care unit	.971
Early (<30 days)				
Postembolization syndrome/I	6 (11.1)	0	Symptomatic treatment	.038
Severe pelvic pain/II	1 (1.9)	0	Narcotics and antibiotics	>.99
Acute urinary retention/I	14 (25.9)	3 (5.7)	Bedside recatheterization	.004
Hematuria/I	0	4 (7.5)	Bladder irrigation	.122
Urinary tract infection/II	1 (1.9)	2 (3.8)	Antibiotics	.987
Clot retention/I	0	1 (1.9)	Bedside catheter change	.993
Late (≤24 months)				
Clinical failure/IIIb	5 (9.4)	2 (3.9)	TURP	.262
Urethral stricture/II	0	1 (2.1)	Dilatation	>.99
Bladder neck stenosis/IIIb	0	1 (2.1)	Bladder neck incision	>.99
Overall adverse events or complications				
Minor (grades I and II)	22 (38.6)	13 (22.8)		.113
Major (grades III and IV)	8 (14)	4 (7)		.275
Total	30 (52.6)	17 (29.8)		.029

technical and clinical failures. The three technical failures (5.3%) were caused by tortuosity and atherosclerotic changes of the iliac arteries. Preprocedural evaluation of the anatomic details and variations of the prostatic and iliac arteries with CT or MR angiography may be useful for improving the procedural success rate and shortening the procedure time. The five clinical failures (9.4%) were attributable to prostate hypovascularity or a complicated blood supply pattern, without a predominant prostatic artery. This condition may have made sufficient and successful embolization difficult. A relatively recent study from Portugal yielded a clinical failure rate for PAE of 28.6% at 1 year (11). Thus, future studies of PAE should focus on ways to improve the technique, increase experience, and identify indications to lower the treatment failure rate.

Commonly observed minor complications in the PAE group included postembolization syndrome (11.1%) and acute urinary retention (25.9%). The latter might have been due to urethra compression by the prostate due to ischemic edema after PAE. These complications generally disappeared within 3 postoperative days, were without clinical consequence, and occurred with a sufficiently high frequency such that they might be considered expected side effects rather than complications.

In the TURP group, two patients (3.8%) developed substantial bleeding, which enabled us to confirm the previous observation that bleeding is a major complication after TURP (23). Bleeding may lead to clot retention and necessitate premature termination of the procedure (2). One patient in the TURP group experienced transurethral resection syndrome. The frequency observed in this study (1.9%) is similar to the 2% proportion reported by Mamoulakis et al (24).

None of the patients in the PAE group developed significant changes in their hemoglobin or sodium levels compared with their preoperative levels; this was an advantage of PAE over TURP. PAE uses an endovascular procedure instead of a transurethral procedure, without causing urethral injury or necessitating bladder irrigation. Thus, the risks of transurethral resection syndrome, bleeding, urethral stricture, and bladder neck contracture are eliminated. Another advantage of PAE was its faster postoperative recovery time. Fewer patients were admitted to the hospital after PAE, and their average hospital stay was shorter compared with the TURP group.

The procedural time in the PAE and TURP groups was similar (89.7 min ± 17.1 and 83.5 min ± 17.5, respectively), and the PAE procedural and fluoroscopy times were similar to those in a relatively recent report (11). However, the time for PAE was longer than the time for uterine artery embolization (25); this was likely due to the highly variable origins, complicated blood supply pattern, and smaller caliber of the prostatic arteries compared with the uterine arteries (13,14). The mean radiation dose in the PAE group (11305.1 cGy/cm^2) was slightly larger than that of a gastrointestinal barium meal used to examine the esophagus, stomach, and small intestine and was within an acceptable range of radiation dose (26).

Our study had some limitations. First, a relatively small sample size was used. Second, PAE was performed by interventional radiologists with differing amounts of experience, which may explain the relatively high postembolization syndrome and treatment failure rates. Third, data from the modified intention-to-treat population were subjected to statistical analysis, and observers were not blinded to group assignment, which may have slightly biased our results. Thus, the highly significant statistical differences between the two groups should be interpreted with caution.

In conclusion, the results of our prospective randomized controlled trial showed that PAE is an effective treatment in patients with LUTS due to BPH, especially BPH with predominant prostatic arteries and a rich vasculature. PAE can be used without limits on prostate size, urethral stricture, or bladder capacity. PAE was associated with shorter hospital stays compared with TURP. This technique may be important in the care of patients at high risk who are not

Figure 5

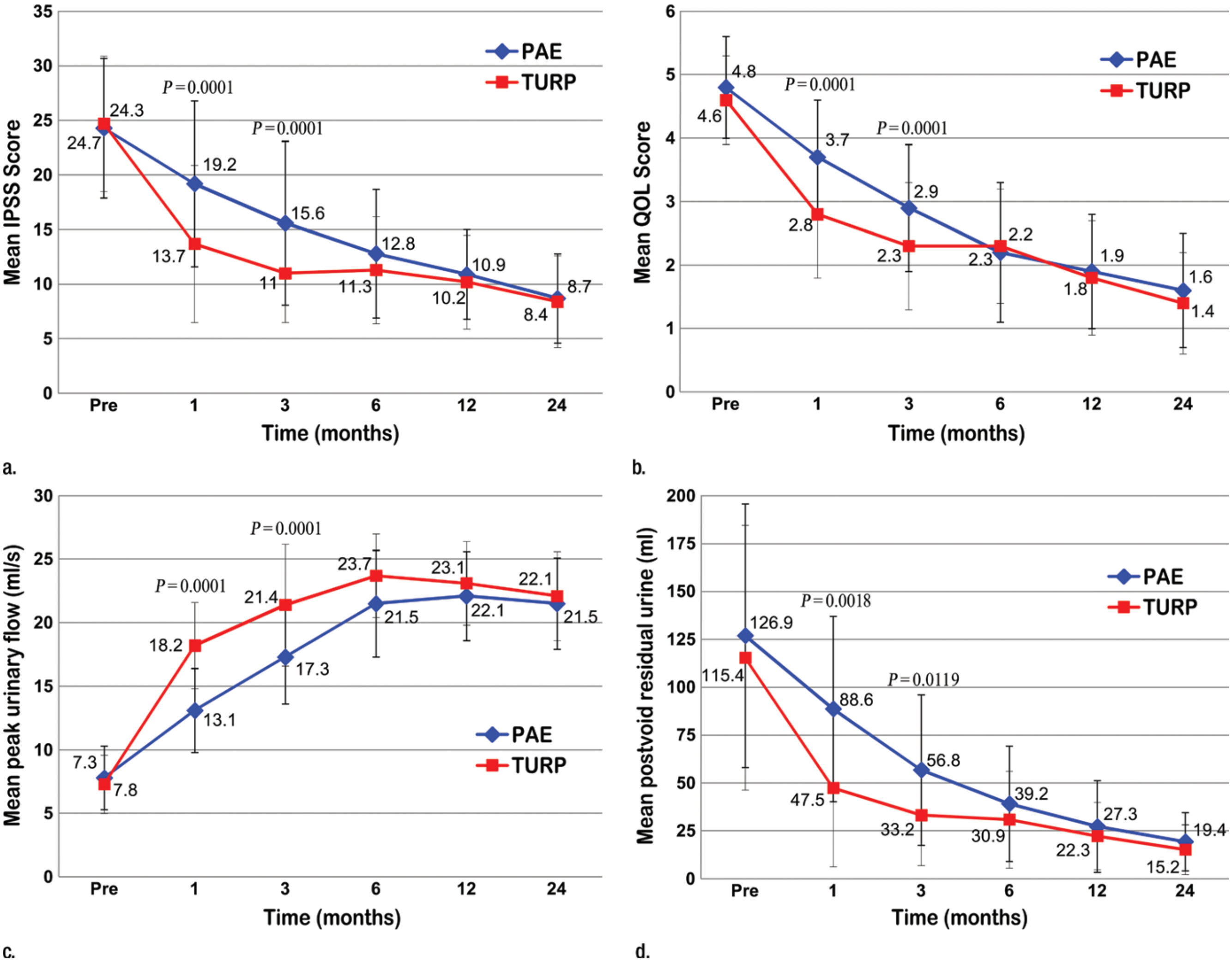


Figure 5: Graphs show functional results in both groups with respect to **(a)** IPSS, **(b)** QOL, **(c)** peak urinary flow, and **(d)** postvoiding residual urine volume. Repeated measures analysis of variance was used to compare the mean of each parameter from baseline over time between PAE and TURP groups.

candidates for surgery. However, the advantages of PAE must be weighed against the risk of technical and clinical failures. Future studies with larger sample sizes and longer follow-up periods should focus on technical improvement and identification of indications for PAE.

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References

1. Bachmann A, Muir GH, Wyler SF, Rieken M. Surgical benign prostatic hyperplasia trials: the future is now! Eur Urol 2013;63(4):677–679; discussion 679–680.
2. Rassweiler J, Teber D, Kuntz R, Hofmann R. Complications of transurethral resection of the prostate (TURP): incidence, management, and prevention. Eur Urol 2006;50(5):969–979; discussion 980.
3. Oesterling JE. Benign prostatic hyperplasia: medical and minimally invasive treatment options. N Engl J Med 1995;332(2):99–109.
4. Herrmann TRW, Gross AJ, Schultheiss D, Kaufmann PM, Jonas U, Burchardt M. Transurethral microwave thermotherapy for the treatment of BPH: still a challenger? World J Urol 2006;24(4):389–396.
5. Yu X, Elliott SP, Wilt TJ, McBean AM. Practice patterns in benign prostatic hyperplasia surgical therapy: the dramatic increase in minimally invasive technologies. J Urol 2008;180(1):241–245; discussion 245.
6. Thangasamy IA, Chalasani V, Bachmann A, Woo HH. Photoselective vaporisation of the prostate using 80-W and 120-W laser versus transurethral resection of the prostate for benign prostatic hyperplasia: a systematic review with meta-analysis from 2002 to 2012. Eur Urol 2012;62(2):315–323.

Figure 6

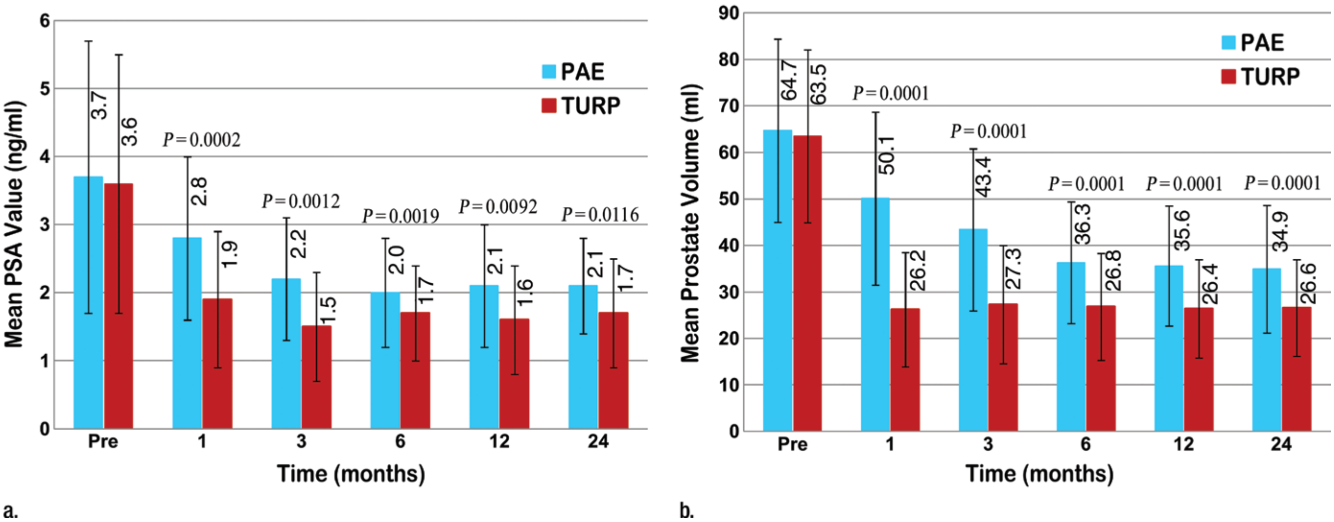

Figure 6: Graphs show **(a)** PSA levels and **(b)** prostate volume over time in both groups. Repeated measures analysis of variance was used to compare the mean of each parameter from baseline over time between PAE and TURP groups.

7. Mitchell ME, Waltman AC, Athanasoulis CA, Kerr WS Jr, Dretler SP. Control of massive prostatic bleeding with angiographic techniques. J Urol 1976;115(6):692–695.
8. Michel F, Dubruille T, Cercueil JP, Paparel P, Cognet F, Krause D. Arterial embolization for massive hematuria following transurethral prostatectomy. J Urol 2002;168(6):2550–2551.
9. DeMeritt JS, Elmasri FF, Esposito MP, Rosenberg GS. Relief of benign prostatic hyperplasia-related bladder outlet obstruction after transarterial polyvinyl alcohol prostate embolization. J Vasc Interv Radiol 2000;11(6):767–770.
10. Carnevale FC, Antunes AA, da Motta Leal Filho JM, et al. Prostatic artery embolization as a primary treatment for benign prostatic hyperplasia: preliminary results in two patients. Cardiovasc Intervent Radiol 2010;33(2):355–361.
11. Pisco JM, Pinheiro LC, Bilhim T, Duarte M, Mendes JR, Oliveira AG. Prostatic arterial embolization to treat benign prostatic hyperplasia. J Vasc Interv Radiol 2011;22(1):11–19; quiz 20.
12. Pisco J, Campos Pinheiro L, Bilhim T, et al. Prostatic arterial embolization for benign prostatic hyperplasia: short- and intermediate-term results. Radiology 2013;266(2):668–677.
13. Bilhim T, Pisco JM, Furtado A, et al. Prostatic arterial supply: demonstration by multirow detector angio CT and catheter angiography. Eur Radiol 2011;21(5):1119–1126.
14. Bilhim T, Pisco JM, Rio Tinto H, et al. Prostatic arterial supply: anatomic and imaging findings relevant for selective arterial embolization. J Vasc Interv Radiol 2012;23(11):1403–1415.
15. Sun F, Sánchez FM, Crisóstomo V, et al. Transarterial prostatic embolization: initial experience in a canine model. AJR Am J Roentgenol 2011;197(2):495–501.
16. Sun F, Sánchez FM, Crisóstomo V, et al. Benign prostatic hyperplasia: transcatheter arterial embolization as potential treatment—preliminary study in pigs. Radiology 2008;246(3):783–789.
17. Jeon GS, Won JH, Lee BM, et al. The effect of transarterial prostate embolization in hormone-induced benign prostatic hyperplasia in dogs: a pilot study. J Vasc Interv Radiol 2009;20(3):384–390.
18. Zelen M. A new design for randomized clinical trials. N Engl J Med 1979;300(22):1242–1245.
19. Capitán C, Blázquez C, Martin MD, Hernández V, de la Peña E, Llorente C. GreenLight HPS 120-W laser vaporization versus transurethral resection of the prostate for the treatment of lower urinary tract symptoms due to benign prostatic hyperplasia: a randomized clinical trial with 2-year follow-up. Eur Urol 2011;60(4):734–739.
20. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240(2):205–213.
21. Homma Y, Kawabe K, Tsukamoto T, et al. Estimate criteria for efficacy of treatment in benign prostatic hyperplasia. Int J Urol 1996;3(4):267–273.
22. Bilhim T, Tinto HR, Fernandes L, Martins Pisco J. Radiological anatomy of prostatic arteries. Tech Vasc Interv Radiol 2012;15(4):276–285.
23. Geavlete B, Georgescu D, Multescu R, Stanescu F, Jecu M, Geavlete P. Bipolar plasma vaporization vs monopolar and bipolar TURP: a prospective, randomized, long-term comparison. Urology 2011;78(4):930–935.
24. Mamoulakis C, Ubbink DT, de la Rosette JJ. Bipolar versus monopolar transurethral resection of the prostate: a systematic review and meta-analysis of randomized controlled trials. Eur Urol 2009;56(5):798–809.
25. Costantino M, Lee J, McCullough M, Nsouli-Maktabi H, Spies JB. Bilateral versus unilateral femoral access for uterine artery embolization: results of a randomized comparative trial. J Vasc Interv Radiol 2010;21(6):829–835; quiz 835.
26. Sulieman A, Elzaki M, Kappas C, Theodorou K. Radiation dose measurement in gastrointestinal studies. Radiat Prot Dosimetry 2011;147(1-2):118–121.