CLINICAL STUDY

Prostate Artery Embolization via Transradial or Transulnar versus Transfemoral Arterial Access: Technical Results

Shivank Bhatia, MD, Sardis H. Harward, MPH, Vishal K. Sinha, BS, and Govindarajan Narayanan, MD

ABSTRACT

Purpose: To compare safety and feasibility of prostate artery embolization (PAE) via transradial/transulnar access (TR/UA) and transfemoral access (TFA).

Materials and Methods: A retrospective analysis was conducted for 3 cohorts: the first 32 consecutive PAE procedures performed via TFA (initial TFA, January 2014 to August 2015), the following 32 procedures performed via TFA (advanced TFA, August 2015 to February 2016), and the first 32 procedures performed via TR/UA (February 2016 to July 2016). Indications included lower urinary tract symptoms (n = 68), urinary retention (n = 24), and preoperative embolization before prostatectomy (n = 4). A single operator performed all procedures at a single institution.

Results: Technical success was achieved in 29/32 (90.6%) initial TFA procedures, 31/32 (96.9%) advanced TFA procedures, and 30/32 (93.8%) TR/UA procedures. Mean procedure time was 110.0 minutes in TR/UA group, 155.1 min in initial TFA group, and 131.3 minutes in advanced TFA group ($P < .01$ and $P = .03$ relative to TR/UA); mean fluoroscopy time was 38.8 minutes in TR/UA group, 56.5 minutes in initial TFA group, and 48.0 minutes in advanced TFA group ($P < .01$ and $P = .02$ relative to TR/UA). Access site–related and overall adverse events did not vary significantly among study cohorts ($P > .15$ and $P > .05$, respectively).

Conclusions: TR/UA represents a safe and feasible approach to PAE with a comparable safety profile to TFA. Reduced procedure and fluoroscopy times might be attributable to the learning curve or method of arterial access.

ABBREVIATIONS

DAP = dose area product, PAE = prostate artery embolization, TFA = transfemoral access, TRA = transradial access, TR/UA = transradial/transulnar access

Transradial access (TRA) is an increasingly common method of arterial access for interventional radiology procedures (1–3). A recent retrospective analysis of 1,500 patients who underwent diverse procedures, including chemoembolization and radioembolization, renal/visceral interventions, uterine artery embolization, and peripheral interventions, via TRA reported a major complication rate of 0.13% and concluded that TRA was safe and well tolerated in a heterogeneous patient population (3). Prostate artery embolization (PAE) is an emerging therapy for lower urinary tract symptoms attributable to benign prostatic obstruction (4–7). PAE procedures have previously been performed via transfemoral access (TFA) and require meticulous technical execution with special attention to tortuous or variant vascular anatomy (8,9). TRA has been investigated as a potential alternative to TFA for PAE

From the Department of Vascular and Interventional Radiology (S.B., G.N.), Jackson Memorial Hospital, University of Miami Miller School of Medicine (V.K.S.), R-109, PO Box 016960, Miami, FL 33101; and The Dartmouth Institute for Health Policy and Clinical Practice (S.H.H.), Geisel School of Medicine at Dartmouth, Hanover, New Hampshire. Received November 1, 2016; final revision received February 20, 2017; accepted February 21, 2017. **Address correspondence to** S.B.; E-mail: Sbhatia1@med.miami.edu

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Table 1. Characteristics of Study Cohorts before PAE

Variable	Initial TFA (n = 32)	Advanced TFA (n = 32)	TR/UA (n = 32)	*P* Value
Age, y	67.8 ± 9.9	70.5 ± 10.8	66.8 ± 6.8	> .20*
IPSS	24.1 ± 5.9	26.8 ± 5.3	23.4 ± 7.5	.13*
QOL score	4.9 ± 1.0	5.0 ± 0.8	4.8 ± 1.2	> .20*
Sexual Inventory in Men†	21.2 ± 9.9	20.6 ±15.8	13.1 ± 7.1	< .01*
Prostate size, g	120.0 ± 105.6	123.3 ± 85.4	107.7 ± 51.0	> .20*
Indwelling urinary catheter†	12 (37.5)	8 (25.0)	3 (9.4)	.03‡
Body mass index, kg/m^2	28.1 ± 5.3	26.7 ± 3.7	28.3 ± 4.5	> .20*
Obesity				> .20‡
BMI < 30	24 (75.0)	27 (84.4)	25 (78.1)	
BMI ≥ 30	8 (25.0)	5 (15.6)	7 (21.9)	
Indication for PAE†				< .01‡
LUTS due to BPO	17 (53.1)	22 (68.8)	29 (90.6)	
Urinary retention	12 (37.5)	9 (28.1)	3 (9.4)	
Prostate cancer	3 (9.4)	1 (3.1)	0 (0.0)	

Note–Values are presented as mean ± SD or n (%).
BMI = body mass index; BPO = benign prostatic obstruction; IPSS = International Prostate Symptom Score; LUTS = lower urinary tract symptoms; PAE = prostate artery embolization; QOL = quality-of-life; TFA = transfemoral access; TR/UA = transradial/transulnar access.
* *P* value obtained by Kruskal-Wallis H test.
† *P* value represents statistical significance ($P < .05$).
‡ *P* value obtained by Fisher exact test.

procedures in a case report and case series in which embolization was technically successful (bilateral) in all cases (10,11). The authors of both reports concluded that PAE via TRA was technically feasible and proposed advantages over PAE via TFA ranging from immediate ambulation to relief of lower back pain allowed by elevating patients' legs during prolonged procedures (10,11). However, these reports did not compare TRA with TFA. The present retrospective single-center study compared outcomes of PAE procedures performed via transradial/transulnar access (TR/UA) and TFA. To control for operator experience, patients treated via TFA were separated into 2 cohorts based on whether they were treated early or late in the operator's experience with PAE.

MATERIALS AND METHODS

Patients

An institutional review board–approved retrospective chart review was conducted for patients who underwent PAE at a single institution in 3 cohorts: initial experience with PAE procedures performed via TFA (treated between January 2014 and August 2015), advanced experience with PAE procedures performed via TFA (treated between August 2015 and February 2016), and PAE procedures performed via TR/UA (treated between February 2016 and July 2016). Initial experience with PAE via TFA was defined as the first 32 consecutive procedures, and advanced experience with PAE via TFA was defined as the following 32 consecutive procedures. The TR/UA cohort was defined as the first 32 patients to undergo PAE via TR/UA. The initial TFA procedures comprised the first PAE procedures the operator had ever performed, and the TR/UA procedures comprised the first procedures the operator had ever performed via TR/UA. At the time of treatment, 10 patients were enrolled in Investigational Device Exemption G120141, and 4 were enrolled in Investigational Device Exemption G130237.

Indications for PAE included lower urinary tract symptoms (n = 68), urinary retention (n = 24), and preoperative embolization before radical prostatectomy for prostate cancer (n = 4). Of the 68 patients treated for lower urinary tract symptoms, 3 patients presented with a history of recurrent urinary tract infection due to benign prostatic obstruction. This was not considered a contraindication for PAE. None of the patients had acute urinary tract infection at the time of the treatment. Mean baseline age was 67.8 years ± 9.9 among initial TFA patients, 70.5 years ± 10.8 among advanced TFA patients, and 66.8 years ± 6.8 among TR/UA patients ($P > .20$). The 3 study cohorts differed significantly in mean baseline Sexual Health Inventory for Men score, which varied across the 3 cohorts ($P < .01$) and was significantly lower among TR/UA patients than initial TFA patients (13.1 ± 7.1 vs 21.2 ± 9.9; $P < .01$) (12,13). Prevalence of urinary retention (37.5% of initial TFA patients, 25.0% of advanced TFA patients, and 9.4% of TR/UA patients; $P = .03$) and indication for PAE ($P < .01$) also differed significantly between cohorts. Baseline characteristics of the 3 study cohorts are presented in **Table 1**.

Transradial/Transulnar Arterial Access

Pulse oximetry and plethysmography were used to confirm normal ulnar arterial supply of the left hand (14). A eutectic mixture of local anesthetic cream (EMLA Cream; Akorn,

Inc, Lake Forest, Illinois), composed of lidocaine 2.5%, prilocaine 2.5%, and 2% nitroglycerin cream (NITRO-BID; Savage Laboratories, Melville, New York) was then applied to the left wrist (15). Local anesthesia consisting of a mixture of 1 mL of 100 μg of nitroglycerin and 9 mL of 1% lidocaine was delivered to the subcutaneous tissues around the left radial artery under ultrasound guidance. The left radial artery was accessed with a 4-cm 21-gauge needle (Merit Medical Systems, Inc, South Jordan, UT) using ultrasound guidance, and an 0.018-inch wire (Merit Medical Systems, Inc) was then inserted into the artery. A 5-F hydrophilic vascular sheath (Merit Medical Systems, Inc) was placed over the 0.018-inch wire and connected to a heparinized saline flush throughout the procedure. A mixture consisting of 2 mg of verapamil, 200 μg of nitroglycerin, and 2,000 IU of heparin was connected to the sheath; blood was aspirated to fill a 20-mL syringe and was then reinjected. Using a 125-cm 5-F Berenstein catheter (Merit Medical Systems, Inc) and 0.035-inch Glidewire (Terumo, Tokyo, Japan), either internal iliac artery was accessed under fluoroscopic guidance. In selected patients, the same catheter was used to obtain a pelvic angiogram before catheterizing the opposite side. In the 2 cases of ulnar artery access, arterial access was obtained via the same method as radial artery access.

Transfemoral Arterial Access

Right common femoral artery access was used for bilateral embolization in all cases. A 5-F vascular sheath (Terumo) was introduced into the common femoral artery and connected to a heparinized saline flush throughout the procedure. A 0.035-inch guide wire (Cook, Inc, Bloomington, Indiana) was used to guide a 5-F SOS Omni catheter (AngioDynamics, Inc, Latham, New York). This combination was coaxially advanced to the infrarenal abdominal aorta. In selected patients, pelvic angiography was performed using a pump injection (20 mL; 10 mL/s). After crossing the aortic bifurcation, selective digital subtraction arteriography of the internal iliac artery was performed with a 5-F Cobra 2 catheter (Boston Scientific, Marlborough, Massachusetts) or a 5-F Contra 2 catheter (Boston Scientific) to assess the blood supply to the prostate. After embolization was performed on 1 side, catheterization of the ipsilateral internal iliac artery was performed using a 5-F Contra 2 catheter (Boston Scientific) or Simmons I catheter (Boston Scientific).

PAE Procedure

All PAE procedures were performed by a single attending interventional radiologist (S.B.) at a single institution. All patients received a prophylactic 400-mg dose of intravenous ciprofloxacin and conscious sedation with intravenous midazolam (Hospira Inc, Lake Forest, Illinois) and fentanyl (West-Ward Pharmaceuticals, Eatontown, New Jersey) during the procedure. In both TR/UA and TFA procedures, the prostatic arteries were catheterized using a 1.8-F FINECROSS microcatheter (Terumo, Tokyo, Japan) and 0.014-inch Fathom guide wire (Boston Scientific). Cone-beam computed tomography was performed to confirm catheterization of the prostatic arteries before embolization on each pelvic side, and the decision of whether or not to perform pelvic angiography for each patient was based on operator discretion and learning curve, patient history of atherosclerotic disease, and patient age. Embolization was performed superselectively to avoid nontarget embolization and was attempted from 2 positions (first proximal, then distal) using 100–300 μm or 300–500 μm Embosphere Microspheres (Merit Medical Systems, Inc) according to operator discretion. Procedure time was calculated as the time from arterial access to closure, the same fluoroscopy frame rates were used for all patients, and PAE technical success was defined as bilateral embolization. Patients were discharged home within 24 hours of their procedure and were given a log form to report any adverse events. All procedures were evaluated for technical success, total procedure time, fluoroscopy time, dose area product (DAP), total radiation skin entry, contrast volume delivered, and length of hospital stay.

Adverse Events

Adverse events, including access site complications, were reviewed at 1-month follow-up evaluation, and severity was assessed according to the Society of Interventional Radiology (SIR) Clinical Practice Guidelines (16). Access site hematoma was assessed according to the Common Terminology Criteria of Adverse Events, version 4.03 (17). Hematoma was reported when access site swelling was observed; ecchymosis was reported when skin discoloration was observed (with or without hematoma). All patients who underwent the embolization procedure via TFA and TR/UA were assessed for arterial occlusion by physical examination at 1-month follow-up in the interventional radiology clinic. Assessment included palpation of arterial pulse at the access site and palpation of distal pulses. In equivocal cases, ultrasound was done to assess for arterial occlusion.

Statistical Analysis

Nonparametric methods were used for all analyses owing to statistically significant Shapiro-Wilk W tests and quantile-quantile plots that confirmed nonnormal data distributions of several continuous variables. All statistical analyses were performed using STATA version 14.2 (StataCorp LLC, College Station, Texas), and 2-sided P values $< .05$ were considered significant. Within the study groups, continuous variables were examined as means with SDs, and categorical variables were summarized as percentages. Comparisons of continuous variables between time points but within study groups were assessed with the paired samples Wilcoxon signed rank test, and comparisons between 2 study groups at a single time point were assessed with the Mann-Whitney U test. Assessments of a continuous variable at a single time point across all 3 study groups were made using the

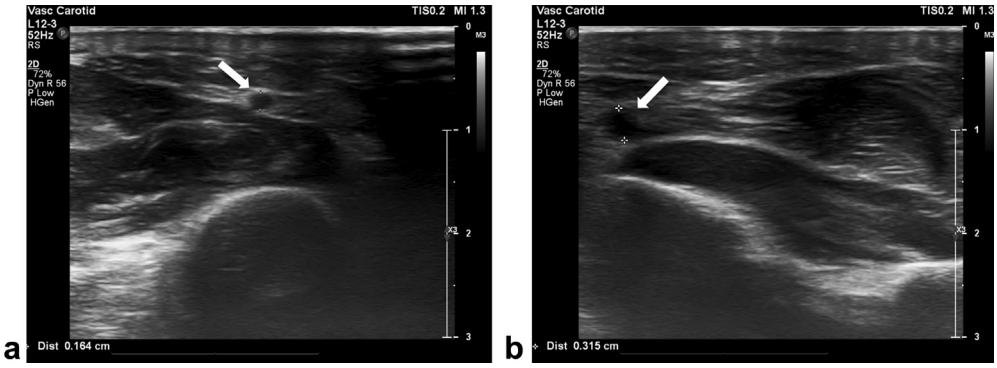

Figure 1. This 71-year-old patient had a baseline International Prostate Symptom Score of 25 and quality-of-life score of 4 (mostly dissatisfied). **(a)** Before the procedure, ultrasound depicted radial artery diameter of 1.6 mm (arrow). **(b)** For patients with radial artery diameters <2.0 mm, PAE via ulnar artery access was performed. Measurement of the ulnar artery in this patient via ultrasound showed a diameter of 3.1 mm (arrow). The patient was successfully treated without any access site complications. Follow-up is pending.

Kruskal-Wallis H test with correction for ties. Comparisons of categorical variables across study groups were made using Fisher exact test.

RESULTS

Among TR/UA patients, 17 (53.1%) had type A Barbeau waveforms, 13 (40.6%) had type B waveforms, and 2 (6.3%) had type C waveforms; mean radial artery diameter was 2.6 mm ± 0.4. Two patients (6.3%) were treated with ulnar artery access because they had radial artery diameters < 2.0 mm (Fig 1a, b).

Characteristics of PAE procedures are presented in Table 2. None of the TR/UA cases required conversion to femoral access, and technical success was achieved in 29 of 32 (90.6%) initial TFA patients, 31 of 32 (96.9%) advanced TFA patients, and 30 of 32 (93.8%) TR/UA patients. The 2 TR/UA technical failures, caused by the acute angles of the prostate artery origins, were not converted to TFA approaches, and unilateral embolization was performed. In the initial TFA cohort, 5 patients (15.6%) received 100–300 μm microspheres, and 26 (81.3%) received 300–500 μm microspheres; in the advanced TFA cohort, 7 patients (21.9%) received 100–300 μm microspheres, and 25 (78.1%) received 300–500 μm microspheres; and in the TR/UA cohort, 6 patients (18.7%) received 100–300 μm microspheres, and 26 (81.3%) received 300–500 μm microspheres ($P > .20$). Embolization data were unavailable for 1 patient in the initial TFA cohort. The volume of embolic agent delivered did not differ across the 3 cohorts for either pelvic side ($P > .20$).

Procedure time, fluoroscopy time, and contrast volume delivered were significantly lower among patients who underwent the procedure via TR/UA compared with either TFA cohort. Mean procedure time was 110.0 minutes ± 34.8 in the TR/UA cohort, 155.1 minutes ± 61.2 in the initial TFA cohort ($P < .01$ relative to TR/UA), and 131.3 minutes ± 42.9 in the advanced TFA cohort ($P = .03$ relative to TR/UA). Mean fluoroscopy time was 38.8 minutes ± 15.8 in the TR/UA cohort, 56.5 minutes ± 28.2 in the initial TFA cohort ($P < .01$ relative to TR/UA), and 48.0 minutes ± 17.0 in the advanced TFA cohort ($P = .02$ relative to TR/UA). Mean contrast volume was 112.2 mL ± 22.0 in the TR/UA cohort, 173.6 mL ± 88.5 in the initial TFA cohort ($P < .01$ relative to TR/UA), and 145.4 mL ± 50.3 in the advanced TFA cohort ($P < .01$). The differences in procedure time, fluoroscopy time, and contrast volume between initial and advanced TFA patients were not statistically significant ($P = .13$, $P > .20$, and $P > .20$).

DAP did not vary significantly across the 3 cohorts ($P = .12$) but was significantly lower among advanced TFA patients compared with initial TFA patients (49,795 mGy · cm^2 ± 17,777 vs 58,531 mGy · cm^2 ± 18,578; $P = .04$). Similarly, total radiation skin entry was significantly lower among TR/UA patients compared with initial TFA patients (4,008 mGy ± 1,827 vs 7,395 mGy ± 9,593; $P = .02$) but did not differ significantly across the 3 cohorts ($P = .07$) or between advanced TFA and TR/UA patients ($P > .20$).

Of the 64 patients in the 2 TFA cohorts, 56 (87.5%) patients (31/32 [96.9%] initial TFA patients; 25/32 [78.1%] advanced TFA patients) underwent intraprocedural pelvic angiography. In contrast, 5 (15.6%) patients in the TR/UA group underwent intraprocedural pelvic angiography ($P < .01$) (Fig 2a–c). Within the 3 cohorts, fluoroscopy time, total radiation skin entry, and DAP did not vary significantly between patients who underwent pelvic angiography and patients who did not ($P > .05$ for all). However, among patients who underwent pelvic angiography, fluoroscopy time was significantly lower among TR/UA patients compared with initial TFA ($P < .01$) and advanced TFA ($P = .02$) patients. Total radiation skin entry was significantly lower among TR/UA patients compared with initial TFA patients ($P = .01$) but not advanced TFA patients ($P = .09$) who underwent pelvic angiography. Fluoroscopy time and total radiation skin entry did not vary significantly between initial TFA and advanced TFA patients who underwent pelvic angiography ($P > .20$). DAP was significantly lower among advanced TFA patients compared with initial TFA patients who

Table 2. Characteristics of PAE Procedure in Study Cohorts

Variable	Initial TFA (n = 32)	Advanced TFA (n = 32)	TR/UA (n = 32)	*P* Value
Technical success	29 (90.6)	31 (96.9)	30 (93.8)	> .20*
Procedure time, min†	155.1 ± 61.2	131.3 ± 42.9	110.0 ± 34.8	< .01‡
Fluoroscopy time, min†	56.5 ± 28.2	48.0 ± 17.0	38.8 ± 15.8	< .01‡
DAP, mGy · cm^2	58,531 ± 18,578	49,795 ± 17,777	54,564 ± 18,994	.12‡
Radiation skin entry, mGy	7,395 ± 9,593	4,706 ± 2,284	4,008 ± 1,827	.07‡
Contrast volume, mL†	173.6 ± 88.5	145.4 ± 50.3	112.2 ± 22.0	< .01‡
Embolic agent size				> .20*
100–300 μm	5 (15.6)	7 (21.9)	6 (18.7)	
300–500 μm	26 (81.3)	25 (78.1)	26 (81.3)	
Embolic agent delivered, mL				
Left side	7.9 ± 4.4	7.5 ± 2.7	7.0 ± 2.4	> .20‡
Right side	6.5 ± 3.4	7.3 ± 3.3	6.8 ± 3.4	> .20‡
Pelvic angiogram required†	31 (96.9)	25 (78.1)	5 (15.6)	< .01*
Barbeau waveform				
A	—	—	17 (53.1)	
B	—	—	13 (40.6)	
C	—	—	2 (6.3)	
Conversion to ulnar access	—	—	2 (6.3)	
Vessel size, mm	—	—	2.6 ± 0.4	
Closure device				
Angio-Seal	18 (52.3)	19 (59.4)	0 (0.0)	
MYNX	8 (25.0)	8 (25.0)	0 (0.0)	
MYNX ACE	2 (6.3)	3 (9.4)	0 (0.0)	
Manual compression	4 (12.5)	2 (6.3)	0 (0.0)	
Safeguard Radial Compression Device	0 (0.0)	0 (0.0)	32 (100.0)	
Length of hospital stay, h	—§	23.4 ± 5.1	21.5 ± 3.8	.13‖

Note–Values are presented as mean ± SD or n (%).
DAP = dose area product, PAE = prostate artery embolization; TFA = transfemoral access; TR/UA = transradial/transulnar access.
* *P* value obtained by Fisher exact test.
† *P* value represents statistical significance ($P < .05$).
‡ *P* value obtained by Kruskal-Wallis H test.
§ Length of hospital stay was not recorded for initial TFA patients, but they were managed under the same protocol of 23-h observation.
‖ *P* value obtained by Mann-Whitney *U* test.

underwent pelvic angiography ($P = .02$) but did not differ significantly between the TR/UA cohort and the initial TFA or advanced TFA cohorts ($P > .20$ for both).

A Safeguard Radial Compression Device (Merit Medical Systems, Inc) was used to close all TR/UA access sites, and various methods, including Angio-Seal (St. Jude Medical, St. Paul, Minnesota), MYNX (Cardinal Health, Dublin, Ohio), MYNX ACE (Cardinal Health), and manual compression, were used to close TFA access sites. Standard times to ambulation were 30 minutes after PAE via TR/UA, 2 hours after PAE via TFA closed by a closure device, and 6 hours after PAE via TFA closed by manual compression. All patients were discharged within 23 hours of admission, and duration of hospitalization did not vary significantly between the advanced TFA and TR/UA cohorts ($P = .13$).

Access site–related adverse events did not vary significantly between study cohorts ($P > .15$ for all) and are presented in Table 3. Patients in all 3 cohorts experienced ecchymosis (initial TFA, 2 patients [6.3%]; advanced TFA, 3 patients [9.4%]; TR/UA, 2 patients [6.3%]), and patients in both the TR/UA and advanced TFA cohorts experienced hematoma (advanced TFA, 4 patients [12.5%]; TR/UA, 3 patients [9.4%]). All hematomas were classified as grade 1 in accordance with the Common Terminology Criteria for Adverse Events Version 4.03. No patients required aspiration, evacuation, or further interventions to treat hematoma. None of the patients were on oral anticoagulant medication and all patients had a normal coagulation profile before PAE. The seven patients with access site hematomas had access site closures with the following devices: Angio-Seal, 2 of 7 (28.6%); MYNX, 1 of 7 (14.3%); MYNX ACE, 1 of 7 (14.3%); and Safeguard Radial Compression Device, 3 of 7 (42.9%). There was no significant relationship between closure devices and hematoma incidence ($P > .20$). Patients in both the initial TFA and advanced TFA cohorts experienced pain (3 patients each [9.4%]). There were no cases of radial or ulnar arterial occlusion in the TR/UA cohort.

Table 4 presents all other adverse events, none of which differed significantly between study cohorts. The most

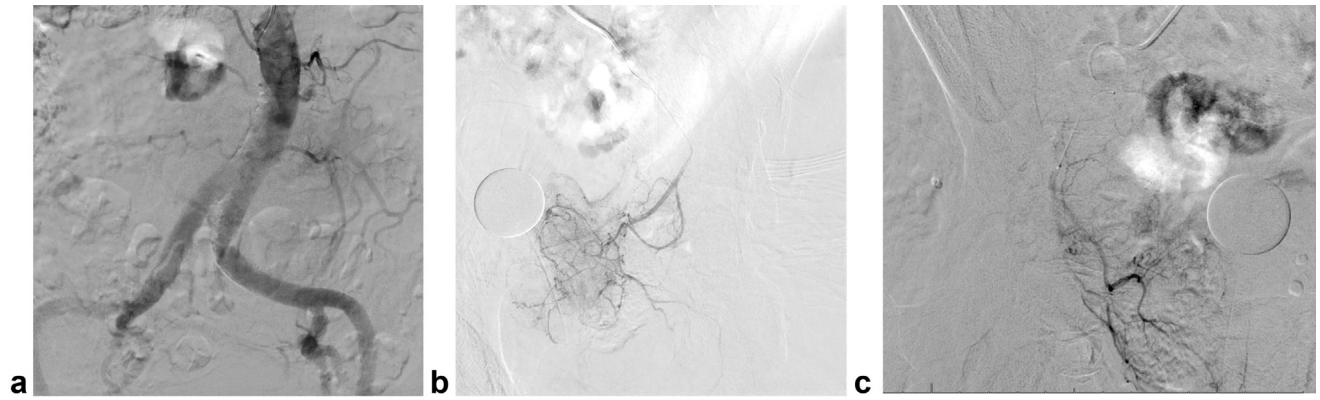

Figure 2. This 80-year-old patient with an International Prostate Symptom Score (IPSS) of 27 and quality-of-life score of 5 (unhappy) was treated with PAE via radial artery access. He experienced no access site complications. At 3-month follow-up, the patient's IPSS improved to 8, and his quality-of-life score was 0 (delighted). **(a)** Pelvic aortography revealed severe aortic tortuosity, which is challenging to navigate via TFA. **(b)** The left prostate artery was a branch of the left obturator artery. Injection of 8 mL of a mixture of 300–500 μm Embosphere microspheres was followed by subselective catheterization. **(c)** The right prostatic artery was a branch from the right inferior vesical artery. Embolization of this artery was performed with 5 mL of the 300–500 μm Embosphere microspheres mixture.

Table 3. Access Site Adverse Events by Study Cohort

Variable	Initial TFA (n = 32)	Advanced TFA (n = 32)	TR/UA (n = 32)	*P* Value*
Ecchymosis	2 (6.3)	3 (9.4)	2 (6.3)	> .20
Pain	3 (9.4)	3 (9.4)	0 (0.0)	> .20
Hematoma	0 (0.0)	4 (12.5)	3 (9.4)	.16

Note–Values are presented as n (%).
TFA = transfemoral access; TR/UA = transradial/transulnar access.
* *P* values obtained from Fisher exact test.

common adverse event in all 3 groups was dysuria, which occurred in 12 initial TFA patients (37.5%), 16 advanced TFA patients (50.0%), and 21 TR/UA patients (65.6%) ($P = .09$). Other common events included urgency (in 18.7%, 3.1%, and 15.6% of initial TFA, advanced TFA, and TR/UA patients; $P = .14$), hematuria (12.5% of initial TFA and advanced TFA patients and 9.4% of TR/UA patients; $P > .20$), and urine leakage (3.2% of initial TFA patients, 18.7% of advanced TFA patients, and 12.5% of TR/UA patients; $P = .17$). Urine leakage and incontinence, which occurred in 1 initial TFA patient (3.1%) and 1 TR/UA patient (3.1%), occurred as urge incontinence and resolved completely within 1 week of PAE.

The only major complication associated with PAE occurred in an initial TFA patient who developed urosepsis. The patient was admitted for 2 days and initially treated with vancomycin, gentamicin, and meropenem. On the second day, the patient was stable and was discharged home with a peripherally inserted central catheter. He was treated successfully with 10 days of intravenous ertapenem. One minor ischemic complication occurred in the advanced TFA group. The patient presented 2 weeks after PAE with 2–3 areas of patchy white discoloration on the glans penis that caused mild discomfort. He was successfully treated with Collagenase Santyl Ointment (Smith & Nephew, Inc, Hull, United Kingdom) for 3 weeks without further intervention.

DISCUSSION

PAE is a technically demanding and often lengthy intervention typically performed via TFA (18). Two prior reports of PAE via TRA have been published, both of which reported successful bilateral embolization in all treated patients and radiation doses and procedure times similar to those reported for PAE via TFA (10,11). Neither of these reports compared PAE procedures completed via TRA and TFA, and neither accounted for the learning curve associated with PAE. The present study addresses both of these concerns, examining consecutive PAE procedures performed via TR/UA and TFA at a single institution and by a single operator. This study concluded that PAE via TR/UA was associated with shorter procedure and fluoroscopy times and lower contrast volumes than either initial TFA or advanced TFA. Moreover, far fewer patients undergoing PAE via TR/UA required pelvic angiography, which may have contributed to lower total radiation skin entry; however, it should not have a significant impact on the fluoroscopy times.

PAE has been associated with rare but clinically significant radiation-related injuries, and minimizing radiation exposure to the patient is an important consideration during the procedure (19). The current data indicate the potential for improved procedure characteristics with TR/UA, including significantly reduced procedure and fluoroscopy times, among patients treated later in a single operator's experience. The presence of a PAE learning curve has been hypothesized but never demonstrated, and these results lend support to calls for caution and appropriate training for this procedure (20). Although the consecutive nature of the

Table 4. Overall Adverse Events by Study Cohort

Variable	Initial TFA (n = 32)	Advanced TFA (n = 32)	TR/UA (n = 32)	*P* Value*
Dysuria	12 (37.5)	16 (50.0)	21 (65.6)	.09
Urgency	6 (18.7)	1 (3.1)	5 (15.6)	.14
Hematuria	4 (12.5)	4 (12.5)	3 (9.4)	> .20
Urine leakage	1 (3.2)	6 (18.7)	4 (12.5)	.17
Hematospermia	2 (6.3)	5 (15.6)	2 (6.3)	> .20
Fever	1 (3.1)	4 (12.5)	3 (9.4)	> .20
Lower abdominal spasm	3 (9.4)	2 (6.3)	2 (6.3)	> .20
Fatigue	2 (6.3)	2 (6.3)	2 (6.3)	> .20
Frequency	2 (6.3)	1 (3.1)	2 (6.3)	> .20
Acute urinary retention	1 (3.1)	2 (6.3)	0 (0.0)	> .20
Hematochezia	0 (0.0)	2 (6.3)	1 (3.1)	> .20
Constipation	1 (3.1)	1 (3.1)	0 (0.0)	> .20
Incontinence	1 (3.1)	0 (0.0)	1 (3.1)	> .20
Urinary spasm	0 (0.0)	0 (0.0)	2 (6.3)	> .20
Discoloration of penis	0 (0.0)	1 (3.1)	0 (0.0)	> .20
Dizziness	0 (0.0)	0 (0.0)	1 (3.1)	> .20
Leg swelling	1 (3.1)	0 (0.0)	0 (0.0)	> .20
Nausea	1 (3.1)	0 (0.0)	0 (0.0)	> .20
Nocturia	1 (3.1)	0 (0.0)	0 (0.0)	> .20
Pelvic pain	0 (0.0)	1 (3.2)	0 (0.0)	> .20
Perineal pain	0 (0.0)	1 (3.1)	0 (0.0)	> .20
Rectal pain	1 (3.12)	0 (0.0)	0 (0.0)	> .20
Retroperitoneal pain	0 (0.0)	0 (0.0)	1 (3.2)	> .20
Scrotal pain	0 (0.0)	0 (0.0)	1 (0.0)	> .20
Scrotal swelling	0 (0.0)	0 (0.0)	1 (3.1)	> .20
Urinary tract infection	1 (3.1)	0 (0.0)	1 (3.1)	> .20
Urosepsis	1 (3.1)	0 (0.0)	0 (0.0)	> .20
Urethral pain	0 (0.0)	1 (3.1)	0 (0.0)	> .20
Vasovagal episode	0 (0.0)	1 (3.1)	0 (0.0)	> .20

Note–Values are presented as n (%).
TFA = transfemoral access; TR/UA = transradial/transulnar access.
* *P* values obtained from Fisher exact test.

advanced TFA and TR/UA cohorts does not allow the effects of method of arterial access and increasing operator experience to be examined separately, the improved technical results associated with both cohorts relative to the initial TFA cohort indicates that experience is necessary to optimize technique. The statistically insignificant decrease in DAP with TR/UA despite significantly shorter fluoroscopy times compared with both TFA cohorts and significantly lower radiation skin entry than the initial TFA cohort cannot be explained by patient body habitus, as mean baseline body mass index was not significantly different among the 3 groups evaluated.

One potential challenge in the adoption of TR/UA is the small diameter of the radial and ulnar arteries relative to the diameter of the femoral artery. Previous reports of peripheral interventions via TRA have limited eligibility to patients with radial artery diameters > 2 or 3 mm (2,3,15). Radial artery diameter < 2 mm is considered a contraindication for TRA at the single institution involved in this study, and the 2 TRA cases that were found to have radial arteries below this minimum were converted to ulnar artery access and performed successfully. Transulnar access may be a potential alternative for patients with radial artery diameters < 2 mm, but additional studies are required to examine this method more carefully. All cases were performed with a 5-F sheath, and no occlusion events or conversions to TFA occurred.

Adverse events in all 3 cohorts were reflective of the complication profiles reported from other investigations of PAE, and PAE via TR/UA was not associated with any previously unreported complications (21–24). Access site complications are potentially avoidable adverse events in any transarterial procedure, and inguinal hematoma has been reported as a complication of PAE, occurring in 1%–8% of cases (25,26). In the present study, the incidence of access site complications across the 3 groups was similar, but the minor access site complications associated with TR/UA were more tolerable and did not lead to delayed ambulation. In contrast, TFA access site complications represent significant procedure-related morbidity that results in delayed ambulation and persists for a longer duration.

The similar lengths of hospitalization across the 3 cohorts are largely attributable to the treatment protocol at the single institution, which includes 23 hours of observation after PAE and does not reflect the shorter time to ambulation in TR/UA patients compared with TFA patients. Same-day discharges could easily be achieved in patients undergoing PAE via TR/UA; patients were held for a 23-hour observation period with the intent of obtaining 24-hour prostate-specific antigen consistently for all patients. The rate of technical success did not vary significantly across the 3 study groups, implying that TR/UA may be an attractive alternative method of arterial access for a relatively complex procedure.

The present study has some limitations, including its retrospective nature, its nonrandomized design, and the heterogeneity of indications and baseline characteristics of the study cohorts. Although several procedural variables suggest improved performance later in a single operator's experience, these differences were found to be statistically insignificant—possibly this was due to the small size of the study cohorts. Although advanced TR/UA procedures were not included in this study, it is possible that increased experience with TR/UA may be associated with a similar evolution of procedure and fluoroscopy times and adverse event incidence. Furthermore, the consecutive nature of the advanced TFA and TR/UA cohorts may have resulted in progression along the learning curve, such that the TR/UA cases were performed with greater experience than the advanced TFA cases. Prospective, randomized investigations will be necessary to more thoroughly evaluate the effect of arterial access method on technical and clinical outcomes.

To conclude, TR/UA represents a safe and feasible method for performing PAE. Although our results may be associated with progression along the procedure learning curve, the potential for decreased PAE procedure times, fluoroscopy times, and radiation skin entry is promising.

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