Prostatic Artery Embolization for Benign Prostatic Hyperplasia: Patient Evaluation, Anatomy, and Technique for Successful Treatment

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Abbreviations: IIA = internal iliac artery, IPA = internal pudendal artery, IPSS = International Prostate Symptom Score, PA = prostatic artery, PAE = prostatic artery embolization, PERFECTED = proximal embolization first, then embolize distal, PSA = prostate-specific antigen, PVR = postvoid residual, Q_{max} = maximal urinary flow rate, TURP = transurethral resection of the prostate

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Describe the clinical evaluation of and treatment options for benign prostatic hyperplasia.
- Identify the pelvic arterial anatomy relevant to PAE.
- Discuss the published outcomes after PAE.

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Symptomatic benign prostatic hyperplasia is a common condition in the aging population that results in bothersome lower urinary tract symptoms and decreased quality of life. Patients often are treated with medication and offered surgery for persistent symptoms. Transurethral resection of the prostate is considered the traditional standard of care, but several minimally invasive surgical treatments also are offered. Prostatic artery embolization (PAE) is emerging as an effective treatment option with few reported adverse effects, minimal blood loss, and infrequent overnight hospitalization. The procedure is offered to patients with moderate to severe lower urinary tract symptoms and depressed urinary flow due to bladder outlet obstruction. Proper patient selection and meticulous embolization are critical to optimize results. To perform PAE safely and avoid nontarget embolization, interventional radiologists must have a detailed understanding of the pelvic arterial anatomy. Although the prostatic arteries often arise from the internal pudendal arteries, several anatomic variants and pelvic anastomoses are encountered. Prospective cohort studies, small randomized controlled trials, and meta-analyses have shown improved symptoms after treatment, with serious adverse effects occurring rarely. This article reviews the basic principles of PAE that must be understood to develop a thriving PAE practice. These principles include patient evaluation, review of surgical therapies, details of pelvic arterial anatomy, basic principles of embolization, and an overview of published results.

Online supplemental material is available for this article.

Introduction

Prostatic artery (PA) embolization (PAE) is emerging as an effective minimally invasive treatment for lower urinary tract symptoms caused by benign prostatic hyperplasia. Benign prostatic hyperplasia affects more than 50% of men by the age of 60 years and up to 80% of men older than 70 years, and its prevalence is increasing as the population ages. Lower urinary tract symptoms are associated with decreased quality of life and an estimated annual cost of $3.9 billion for treatment of benign prostatic hyperplasia (1).

Medical and surgical therapies may be associated with complications, hospitalization, and high procedure-related costs (2,3). PAE is a minimally invasive treatment that is safe and effective. Several studies (4–7) have shown clinical improvement, with good short- and midterm outcomes. Patients avoid the risks of retrograde ejaculation, erectile dysfunction, and sphincter injury associated with surgical treatment. The procedure is performed in the interventional radiology suite with the patient under conscious sedation, and overnight hospitalization rarely is required. PAE is technically

TEACHING POINTS

- The International Prostate Symptom Score (IPSS) is determined on the basis of answers to a common validated questionnaire that is used to screen and monitor patients with benign prostatic hyperplasia and is the most commonly reported symptom score in the PAE literature. The IPSS consists of seven symptom-related questions and one quality-of-life question. A total score of 0–7 represents mild disease, 8–19 indicates moderate disease, and 20–35 is considered severe disease.
- TURP is considered the surgical standard of care for medium-sized prostates, while prostates larger than 100 mL may require simple prostatectomy.
- The vascular supply of the prostate gland consists of vessels that supply the central gland and branches that supply the periphery. These branches may arise from a common trunk or from different parent arteries. When they arise from a common trunk, the PA often originates from the inferior vesical artery and, after it supplies the inferior bladder and seminal vesicles, it bifurcates into the central and capsular divisions.
- De Assis et al evaluated 286 pelvic sides and classified 267 (93.3%) of them into four main types. The most common origin was the IPA in 31.1%, and the second most common was a common trunk with the superior vesical artery in 28.7% of the classified pelvic sides.
- The PAs have anastomoses with other pelvic arteries in up to 57% of pelvic sides. The most common anastomoses involve the IPA (43.3%), the contralateral PA (17.6%), and the vesical arteries (11.3%). The risk of nontarget embolization is reduced with a supraselective microcatheter position or with proximal coil embolization of anastomoses to prevent particulate flow.

demanding, and successful outcomes require detailed knowledge of the benign prostatic hyperplasia disease process, patient evaluation, and the pelvic arterial anatomy.

This article reviews the clinical evaluation of patients with benign prostatic hyperplasia and the indications for PAE. We demonstrate the anatomy of the internal iliac artery (IIA) and the PA, which is important for safe embolization, and discuss anatomic variants and vascular anastomoses that must be understood to avoid complications from nontarget embolization. We review the procedure, show techniques to optimize outcomes, and discuss published clinical results.

Patient Evaluation

Use and understanding of the proper nomenclature is important during patient evaluation. Benign prostatic hyperplasia is a histologic diagnosis of smooth muscle and epithelial proliferation in the transitional zone of the prostate (2). The terms *benign prostatic enlargement*, *benign prostatic obstruction*, and *bladder outlet obstruction* accurately describe the disease process (8). Although it is not technically correct, the histologic term *benign prostatic hyperplasia* is used as a generic descriptor of these conditions. Static and dynamic components contribute to bladder outlet obstruction.

Table 1: Classification of Lower Urinary Tract Symptoms

Storage symptoms (irritative)
Frequency
Urgency
Nocturia
Urge incontinence
Voiding symptoms (obstructive)
Weak stream
Hesitancy
Straining
Intermittent stream and dribbling
Overflow incontinence
Chronic urinary retention

The static component is related to the size of the enlarged prostate, and the dynamic component is related to abnormal smooth muscle tone.

Men with bladder outlet obstruction often present with lower urinary tract symptoms, which may be classified as storage or voiding symptoms (Table 1). Lower urinary tract symptoms result in decreased quality of life for many patients seeking therapy. The cause of lower urinary tract symptoms is multifactorial and not specific to benign prostatic obstruction. Lower urinary tract symptoms also may be caused by an overactive bladder; detrusor dysfunction; and bladder neck, urethral, or neurologic abnormalities (8). Cardiovascular, respiratory, or renal disease and weight gain also may be contributing factors. The differential diagnosis for bladder outlet obstruction includes evaluation for prostate cancer, bladder carcinoma, urethral stricture, bladder neck contracture, urinary tract infection, prostatitis, overactive bladder, and neurogenic bladder. In severe cases, bladder outlet obstruction can result in acute urinary retention, recurrent urinary tract infections, and renal failure.

Patients should undergo complete urologic evaluation before considering PAE. This includes a detailed history, a physical, review of prior medications and treatments, and discussion of treatment alternatives. Antidepressants, antihistamines, anticholinergics, bronchodilators, and sympathomimetics may affect detrusor and sphincter function and worsen lower urinary tract symptoms. A frequency and volume record may be completed to assess for nocturnal polyuria. Patients should be screened for prostate cancer with digital rectal examination and a serum prostate-specific antigen (PSA) test. Collaboration with urologists is important to optimize patient selection and develop a comprehensive treatment program to best treat these patients.

Preprocedural Testing

The International Prostate Symptom Score (IPSS) is determined on the basis of answers to a common validated questionnaire that is used to screen and monitor patients with benign prostatic hyperplasia and is the most commonly reported symptom score in the PAE literature (9). The IPSS consists of seven symptom-related questions and one quality-of-life question. A total score of 0–7 represents mild disease, 8–19 indicates moderate disease, and 20–35 is considered severe disease. The quality-of-life question asks patients to rate how they would feel on a scale of 0 (delighted) to 6 (terrible) if they had to live the rest of their lives with their current symptoms. An additional questionnaire, the International Index of Erectile Function (IIEF-5) is used frequently to assess the effect of treatment on erectile function (Fig E1) (10).

Uroflowmetry and measurement of postvoid residual (PVR) volume can provide objective assessment before intervention. A flowmeter measures maximal urinary flow (Q_{max}) rate, average flow rate, voided volume, flow time, and time to maximum flow. The volume voided should be greater than 150 mL for an accurate study. Patients with bladder outlet obstruction typically have a flattening of the normal bell-shaped flow curve, and 90% of men with a Q_{max} rate of less than 10 mL/sec show bladder outlet obstruction at uroflowmetry (11). The PVR volume is measured with catheterization or US of the bladder. A PVR volume of greater than 300 mL often is used to indicate chronic urinary retention.

If the flow rate does not suggest obstruction, there is a higher rate of procedure failure. In this instance, urodynamic evaluation, which provides measurements of storage and voiding pressures and pelvic floor electromyographic activity, can be performed to confirm the diagnosis and improve patient selection (2). Invasive urodynamic testing can help to distinguish obstruction from detrusor over- or underactivity, which can mimic symptoms of bladder outlet obstruction and would not be expected to improve with embolization (8,11).

Before treatment options are offered to the patient, the prostate volume is measured by means of transrectal US, CT, or MRI. Different urologic procedures may be recommended on the basis of prostate size. Although PAE has been shown to be successful in a wide range of prostate sizes, a prostate volume greater than 40 mL generally is recommended for treatment.

The guidelines for treatment of benign prostatic hyperplasia do not require prostate cancer screening as part of the initial evaluation; however, radical prostatectomy can be considerably more challenging and has a higher complication rate after transurethral resection of the prostate (TURP) performed for benign prostatic hyperplasia (12). There is a paucity of data that indicate how embolization may change the landscape for future evaluation and treatment of prostate cancer; thus, it generally is accepted that patients should be screened for prostate cancer. Although recommendations vary, a PSA value of greater than 2.5–3 ng/mL (2.5–3 μg/L) or abnormal digital rectal examination findings should be investigated further with additional testing or biopsy, as directed by a urologist (13).

Treatment of Lower Urinary Tract Symptoms

First-line therapy consists of lifestyle modifications such as fluid restriction for nocturia and polyuria and avoidance of α-agonists. The primary medical therapy consists of α-adrenergic blockers (alfuzosin, doxazosin, tamsulosin, terazosin, and silodosin), 5-α-reductase inhibitors (dutasteride and finasteride), and a low-dose oral phosphodiesterase (PDE)–5 inhibitor (tadalafil) (2). The decision of which medication to start depends on symptoms, size of the gland, PSA measurement, and patient preference. α-adrenergic blockers work by relaxing smooth muscle tone in the bladder neck and prostatic stroma. 5-α reductase inhibitors shrink the prostate by inhibiting conversion of testosterone to dihydrotestosterone, which results in decreased cellular proliferation (8). 5-α-reductase inhibitors take up to 6 months for improvement and can decrease prostate size by 20%–30% (14). The mechanism of PDE-5 inhibitors affecting prostatic obstruction is unknown, but randomized controlled trials demonstrate improved IPSS with low-dose tadalafil (15). These medications may be associated with several adverse effects such as hypotension, headache, dizziness, erectile disorders, and ejaculatory dysfunction.

Surgical Treatments

Surgical therapy is recommended for patients who undergo unsuccessful medical therapy; desire to stop therapy; or have a substantially elevated PVR volume, recurrent urinary tract infections, recurrent hematuria, bladder stones, or postrenal acute kidney injury (2). Procedure options range from minimally invasive therapies to simple prostatectomy and are recommended on the basis of prostate size, the presence of urinary retention, comorbidities, and patient preference.

TURP is considered the surgical standard of care for medium-sized prostates, while prostates larger than 100 mL may require simple prostatectomy (16). With the use of a rigid resectoscope, the prostate is resected by means of electrocautery until a visual defect is noted. Patients typically are observed overnight with continuous bladder

irrigation through a three-way large-bore urethral catheter for control of bleeding. Patients are counseled to expect postoperative irritation with voiding and intermittent mild hematuria for up to 8 weeks.

According to a review (17) of 3885 patients, the most common intraoperative complications were bleeding that required transfusion in 2.5% of patients and transurethral resection syndrome in 2% of patients. The dilutional hyponatremia of transurethral resection syndrome is due to irrigation with isotonic fluid during monopolar TURP. In the postoperative period, 6.5% of patients were unable to void, 3.9% required transfusion, and 2.3% had a genitourinary infection. Seventy-eight percent of patients were discharged from the hospital by day 5. Postoperative complications were higher in those with glands larger than 45 mL. Ejaculatory dysfunction is reported in up to 66.1% of cases (18). Decreased ejaculatory volume contributes to reduced quality of life. Urethral strictures, urinary incontinence, and erectile dysfunction are uncommon but devastating long-term complications.

Other methods of transurethral resection include photoselective vaporization of the prostate and holmium laser enucleation of the prostate. They vary with regard to the type of energy used but have generally similar postoperative courses and treatment outcomes, although with lesser need for blood transfusion. The American Urological Association (AUA) recommends them equally as options for surgical treatment of benign prostatic hyperplasia and suggests making a treatment choice on the basis of patient presentation, anatomy, the surgeon's experience, and a discussion of potential risks and benefits (2).

Minimally Invasive Surgical Therapies

Minimally invasive surgical therapies are performed to reduce symptoms while avoiding the sexual adverse effects of TURP and reducing hospitalization, bleeding risks, and postoperative pain. A wide variety of minimally invasive therapies has been described, and the AUA guidelines currently recommend prostate urethral lift, transurethral wave vapor thermoablative therapy, transurethral microwave therapy, and transurethral incision of the prostate for appropriately selected patients. Transurethral needle ablation of the prostate is another popular minimally invasive therapy; however, it is not recommended in the guidelines because of insufficient evidence (16). Interventional radiologists should develop a general familiarization with the variety of available surgical procedures to counsel patients appropriately before treatment.

Prostatic urethral lift (UroLift; NeoTract, Pleasanton, Calif) can be performed in the operating room or as a clinical procedure with local anesthesia. A rigid cystoscope is used to place nonabsorbable sutures through the prostatic urethra, traversing the lateral prostate lobes and exiting at the periphery. The sutures are then deployed and retract the obstructing tissue to open the prostatic urethra. The procedure is generally best suited for patients with a prostate volume of less than 80 mL and is relatively contraindicated in patients with acute urinary retention or with PVR volume greater than 250 mL (19). It was previously contraindicated in patients with obstructing medial lobes but has been approved for this indication recently (20). The overall complication rate is less than 10%, with no major adverse events reported. Studies (19,21) have shown improvement in IPSS and urine flow 1–5 years after the procedure. There is less improvement in symptoms but no reported ejaculatory dysfunction with prostatic urethral lift compared with those of TURP.

Transurethral radiofrequency water vapor thermoablation (Rezum; NxThera, Maple Grove, Minn) consists of the injection of sterile water vapor into the prostatic urethra with a cystoscope, which results in convective thermal destruction of prostatic tissue, and ultimately, reduced outlet obstruction. Prostate cell death and necrosis take up to 3 months. The therapy is an office procedure performed with local anesthesia by means of a prostatic block. It is indicated for prostates smaller than 80 mL. Durable improvement was demonstrated up to 3 years after the procedure, with preservation of sexual function (22,23).

In transurethral incision of the prostate, the prostate is incised with an electrocautery device or laser, beginning at the bladder neck and extending to the verumontanum. Unlike in TURP, the prostate adenoma is not removed during the procedure. Transurethral incision of the prostate is performed typically for prostates smaller than 30 mL, and it results in less improvement in peak urinary flow but fewer complications and improved sexual function compared with TURP (22). There is an increased risk for reintervention after transurethral incision of the prostate compared with TURP (18).

Several other minimally invasive therapies have been described, such as thermoablative therapies including transurethral microwave therapy (the use of microwave energy to induce necrosis) and transurethral needle ablation of the prostate (the use of radiofrequency signal between two antennas), but they are performed less commonly. Aquablation is a technique of hydrodissection with high-velocity saline solution guided by transrectal US. Investigations are also ongoing regarding intraprostatic injectable molecules and a temporary implantable nitinol urethral stent (21).

While offering less morbidity, minimally invasive surgical therapies have demonstrated promising outcomes in short-term studies.

Indications for Embolization

Clinical trials are currently ongoing to determine the ideal patients to undergo PAE and to determine where PAE fits into the spectrum of available urologic treatment options. Currently PAE is performed for patients with moderate to severe lower urinary tract symptoms from benign prostatic obstruction who have not responded to medications or for patients who find the medications intolerable because of adverse effects (Fig E2). Patients are evaluated by a urologist, and surgical treatments are discussed. Patients may choose to avoid surgery because of a fear of adverse effects such as erectile dysfunction, ejaculatory disorders, incontinence, and bleeding.

The ideal prostate size for treatment has not yet been determined, to our knowledge. Treatment is often recommended for prostate glands with volumes of 40 mL or larger. Strict inclusion criteria vary in the published studies, but as a general guideline, patients should have moderate to severe lower urinary tract symptoms (IPSS ≥ 13–18 and quality-of-life score ≥3) and evidence of decreased urinary flow (Q_{max} rate <12–15 mL/sec) or acute urinary retention.

Patients are excluded from treatment if they have malignancy, renal insufficiency, large bladder diverticuli, bladder stones, a neurogenic bladder, a neurologic disorder that may affect bladder function, detrusor failure, urethral stricture, an active urinary tract infection, or prostatitis. Advanced atherosclerosis is a relative contraindication that may be assessed at preprocedural imaging.

Pelvic Arterial Anatomy

A detailed understanding of pelvic arterial anatomy is essential for effective and safe PAE. The peripheral zone of the prostate comprises approximately 70% of the glandular volume. Typically, prostate cancers arise from this region. The transitional zone is found in the central gland and hypertrophies with age in patients with benign prostatic enlargement (24). Benign prostatic hyperplasia adenomas arise in the transitional zone and are the primary targets for embolization. The transitional zone is highly vascular, and effective treatment requires vigorous embolization of the prostate blood supply. To accomplish this in a safe manner and reduce the risks of nontarget embolization, interventional radiologists must have a comprehensive understanding of pelvic arterial anatomy, including IIA branching patterns and variants.

Preprocedural Imaging

CT or MR angiography may be performed to determine the IIA and PA anatomy before embolization. This may allow reduction in radiation exposure and procedure time during intervention and help in choosing the best arterial access site, but it is not required in all cases, especially when cone-beam CT imaging is available.

An example of a preprocedural pelvic CT angiographic protocol includes power settings of 80–120 kV and 200–300 mA; matrix, 1024 × 1024 pixels; field of view, 400 mm; voxels, 0.625 × 0.625; and pitch, 1. Iodinated contrast material is administered at 4–6 mL/sec with bolus triggering in the abdominal aorta above the renal arteries, with a target threshold of 300 HU. Mean acquisition time is 3 seconds for a range of 29.5 cm. Vasodilation performed with 800 μg of sublingual nitroglycerin administered 3–5 minutes before imaging increases PA diameter and peak opacification (25). Patients should be screened for hypotension and the use of phosphodiesterase inhibitors within the preceding 48 hours. Voltage and contrast material dose may be adjusted on the basis of patient weight. Images are viewed in 1.25-mm sections with multiplanar reformatted and maximum intensity projection images to aid in the understanding of pelvic arterial anatomy.

In a study (26) of 110 patients, preprocedural CT angiography allowed successful identification of the PAs in 97.3% of pelvic sides. CT angiography is particularly useful when the PA arises from a branch of the external iliac artery, such as an accessory obturator artery. Preprocedural knowledge of the pelvic anatomy prevents increased radiation exposure and prolonged procedural time associated with interrogating individual branches of the IIA when the PA origin is not identified at intraprocedural angiography.

MR angiography shows parenchymal vascularity, glandular volume, and malignancy, while avoiding the radiation exposure of CT. A study (27) of 17 patients recommended an MRI protocol with multiplanar two-dimensional rapid acquisition with relaxation enhancement, three-dimensional sampling perfection with application-optimized contrasts with different flip-angle evolution T2-weighted imaging, and diffusion-weighted imaging with apparent diffusion coefficient map. MR angiography was performed with 1.5 mL/sec of 0.1 mL/kg of gadobutrol (Gadovist; Bayer, Mississauga, Ontario, Canada) and a three-dimensional volumetric interpolated spoiled gradient-echo sequence. The field of view was from the aortic bifurcation to the common femoral arteries, with 2-mm section thickness. Other settings included matrix, 256 × 179; repetition time, 4.3 msec; echo time, 2.45 msec; and

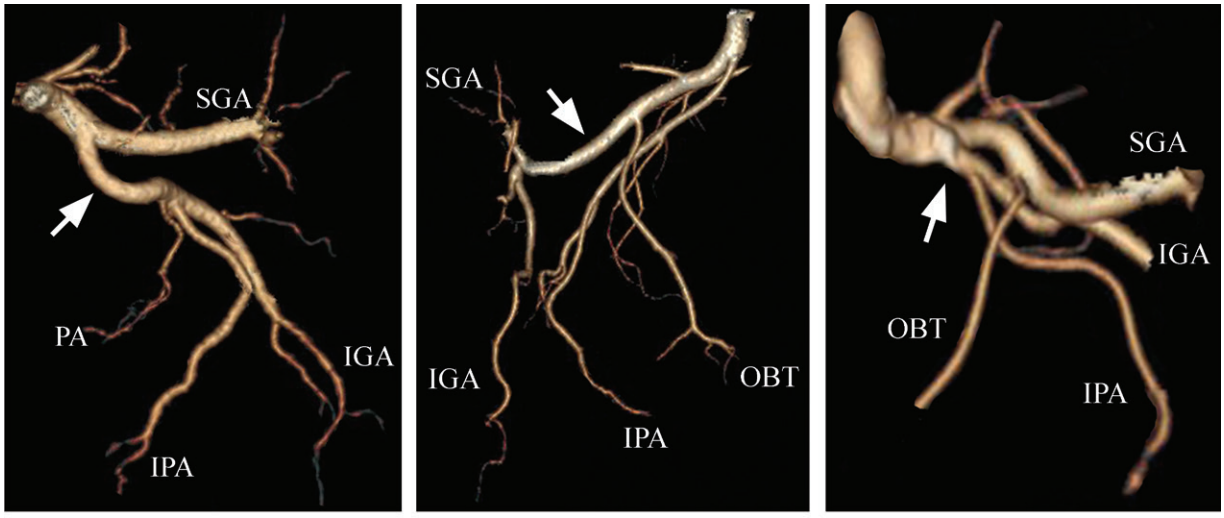


Figure 1. Yamaki classification of IIA branching patterns. *IGA* = inferior gluteal artery, *SGA* = superior gluteal artery. **(a, b)** Three-dimensionally reconstructed CT angiograms show the group A branching pattern **(a)**, with division to the superior gluteal artery and gluteal-pudendal trunk (arrow in **a**), and the group B branching pattern **(b)**, with division to the common gluteal trunk (arrow in **b**) and the IPA. The obturator artery *(OBT)* origin is highly variable; it arises from the common gluteal trunk in this example. **(c)** Three-dimensionally reconstructed CT angiogram shows the group C branching pattern, with trifurcation (arrow) to the superior gluteal artery, IPA, and inferior gluteal artery. *OBT* = obturator artery.

acquisition time, 20 seconds. With the use of this technique, 79.4% of the PA origins were identified correctly on axial and coronal curved planar and multiplanar reformatted images.

To reduce the radiation dose and save patient time and cost, a cone-beam CT technique can be used to provide an overview of pelvic arterial anatomy at the time of the procedure and avoid the need for preprocedural imaging (28). With a flush catheter placed in the distal abdominal aorta, cone-beam images can be acquired and reformatted to reveal pelvic arterial anatomy similar to that of CT angiography. For example, 50% dilute contrast material can be power injected at 4 mL/sec for 11 seconds, and cone-beam CT can be performed with a 6-second spin and a 5-second delay to obtain detailed angiographic images that can be reformatted to provide guidance during the PAE procedure.

IIA Anatomy

The IIA divides into anterior and posterior divisions supplying parietal and visceral branches. The major visceral branches are the internal pudendal artery (IPA), superior vesical artery, inferior vesical artery, PA, and middle rectal artery. The parietal branches include the superior gluteal artery, inferior gluteal artery, obturator artery, iliolumbar artery, and superior and inferior lateral sacral arteries (29).

The IIA branching pattern is highly variable. Different classification systems are proposed to address the IIA branching patterns (30). The Yamaki classification is simple to understand and includes four groups based on the three main branches: the superior gluteal artery, the inferior gluteal artery, and the IPA. In group A, the IIA divides into the superior gluteal artery and a common gluteal-pudendal trunk of the inferior gluteal artery and the IPA (Fig 1). This branching pattern appears in 60%–80% of cases (29). In group B, the IIA divides into the IPA and a common gluteal trunk of the superior gluteal artery and inferior gluteal artery. In group C, the IIA trifurcates into the superior gluteal artery, the inferior gluteal artery, and the IPA. In group D, the IIA divides into a common trunk of the superior gluteal artery and the IPA, comprising the anterior division, and the inferior gluteal artery, comprising the posterior division (Table 2) (30).

Posterior Division.—The superior gluteal artery is the largest branch of the IIA. It exits the superior aspect of the greater sciatic foramen and terminates in branches to the iliac wing and superficial and deep gluteal muscle branches (31). The iliolumbar artery is the first IIA branch. It courses superior and anterior to the sacroiliac joint and divides into an iliac branch to the iliacus muscle, gluteal and abdominal muscles, and the ilium and a lumbar branch to the psoas major and quadratus lumborum muscles (29,31). The lateral sacral arteries enter the sacral foramen to supply the sacral canal, sacral foramina, and skin and musculature of the dorsum of the sacrum (31).

Anterior Division.—The inferior gluteal artery exits the inferior aspect of the greater sciatic

Table 2: Yamaki Classification of IIA Branching Patterns

Classification	Branching Pattern	Incidence (%)
Group A	IIA to the superior gluteal artery and the gluteal-pudendal trunk	60–80
Group B	IIA to the IPA and the common gluteal trunk	15–30
Group C	IIA trifurcation to the superior gluteal artery, inferior gluteal artery, and the IPA	5–7
Group D	IIA to the superior gluteal artery and/or the IPA trunk and the inferior gluteal artery	<1

Sources.—References 29 and 30.

foramen adjacent to the IPA and terminates into numerous muscular branches and thigh branches. The IPA exits the pelvis in the inferior aspect of the greater sciatic foramen and re-enters the pelvis in the lesser sciatic foramen. It has a characteristic 90° curvature as it courses anteriorly along the pelvic floor. It terminates in perineal branches, supplying the inferior rectal artery, perineal scrotal artery, and penile artery. The penile artery branches off to the bulbar and urethral arteries before terminating in the cavernosal and dorsal arteries of the penis.

The obturator artery origin is variable. The obturator artery travels along the lateral wall of the pelvis and typically exits through the obturator foramen and terminates into anterior and posterior muscular branches with a 90° configuration to supply the hip musculature (31). An accessory or aberrant obturator artery may arise from the inferior epigastric artery (corona mortis) or external iliac artery in up to 30% of cases (29,32).

Several of the smaller visceral branches have variable origins from the anterior division and may arise from a common trunk. This includes the superior vesical artery, which supplies the superior aspect of the bladder and the ureter; the vesiculodeferential artery, which supplies the bladder base, ureters, ductus deferens, and seminal vesicles; the middle rectal artery, which supplies the middle and inferior rectum; and the inferior vesical artery, which supplies the inferior aspect of the bladder and often gives rise to the PA (29).

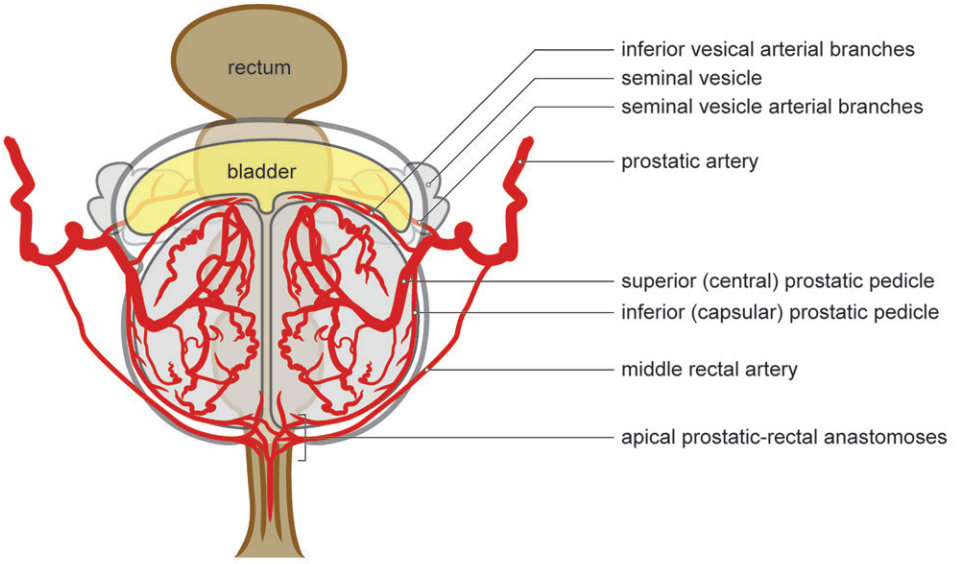
Prostatic Arteries

The vascular supply of the prostate gland consists of vessels that supply the central gland and branches that supply the periphery. These branches may arise from a common trunk or from different parent arteries (33). When they arise from a common trunk, the PA often originates from the inferior vesical artery and, after it supplies the inferior bladder and seminal vesicles, it bifurcates into the central and capsular divisions. These divisions are also referred to as the anterolateral and posterolateral pedicles on the basis of their appearance as they enter the prostate on axial images (Fig 2).

The anterolateral pedicle travels superiorly and medially and is the predominant supply to the central gland (34). On the basis of anatomic studies, this is also called the superior pedicle and is the primary target during PAE. The posterolateral pedicle travels inferiorly and supplies the peripheral gland and prostate apex. When they arise separately, the posterolateral branches are variable but often originate from the inferior rectal artery branch of the IPA. These branches provide limited perfusion to the central gland and anastomose with rectal and perineal branches. If prominent central branches arise from the posterolateral division, they may be embolized selectively, but in general, they are not the primary targets for treatment.

The PA is often tortuous, especially in larger prostates. When the prostate enlarges and increases in height, the PAs remain the same length and are forced to twist and spiral. The intraglandular branches of the PA typically have a "corkscrew" appearance in patients with benign prostatic hyperplasia, which is helpful angiographic confirmation of correct catheter positioning (35). PA anatomy is often asymmetric between the pelvic sides.

The origin of the PA is variable, and differing results are published in anatomic studies and fluoroscopic studies. Bilhim et al (35) reported the most common origins as the IPA in 34.1%, the superior vesical artery in 20.1%, the gluteal-pudendal trunk in 17.8%, and the obturator artery in 12.6% of pelvic sides. There was one PA in 57% and two PAs in 43% of pelvic sides. Zhang et al (36) studied the anatomy of 114 PAs and reported the origin in the anterior trunk in 39.5%, the superior vesical artery in 32.6%, and the IPA in 27.9% of the PAs. There was a single PA per side in 96.4% of 110 hemipelves. PA size ranged from 0.5 mm to 1.5 mm. Extraprostatic anastomoses were found in 39.1% of hemipelves, most commonly to the



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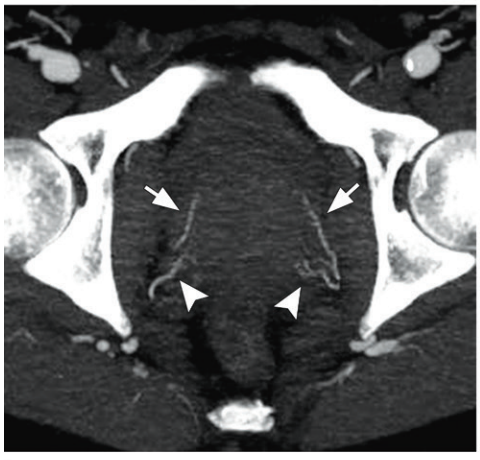

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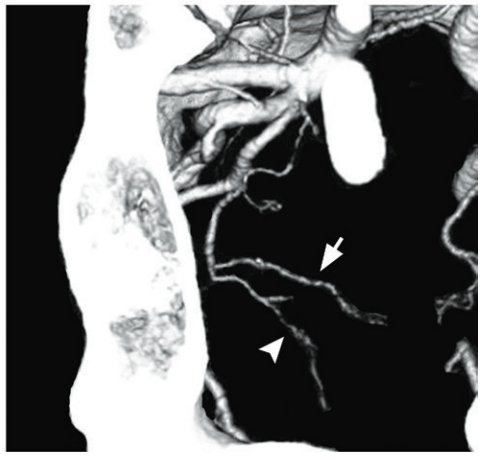

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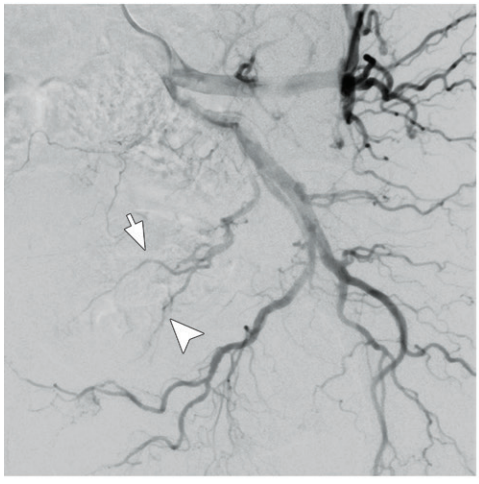

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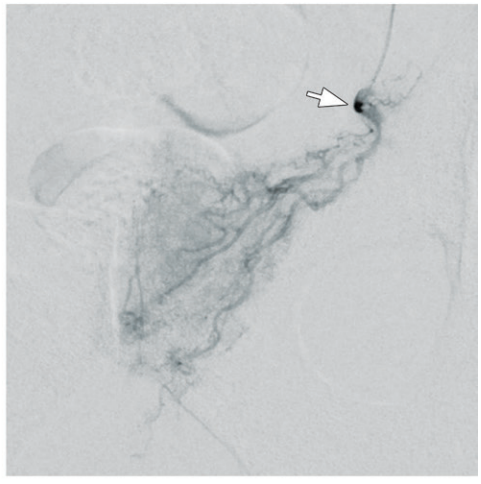


e.

Figure 2. PA central and capsular divisions. **(a)** Diagram shows PA anatomy. **(b–d)** Axial CT angiogram **(b)**, three-dimensionally reconstructed CT angiogram **(c)**, and IIA arteriogram **(d)** show the anterolateral or central (arrows) and posterolateral or capsular (arrowheads) PA divisions. **(e)** Arteriogram after microcatheter selection of the PA shows both divisions arising from a common trunk and prostate blush (arrow).

Table 3: Angiographic Classification of PA Origin

Classification	PA Origin	Incidence (%)
Type I	Common trunk with superior vesical artery	28.7
Type II	Anterior division IIA (gluteal-pudendal trunk)	14.7
Type III	Obturator artery	18.9
Type IV	IPA	31.1

Source.—Reference 37.

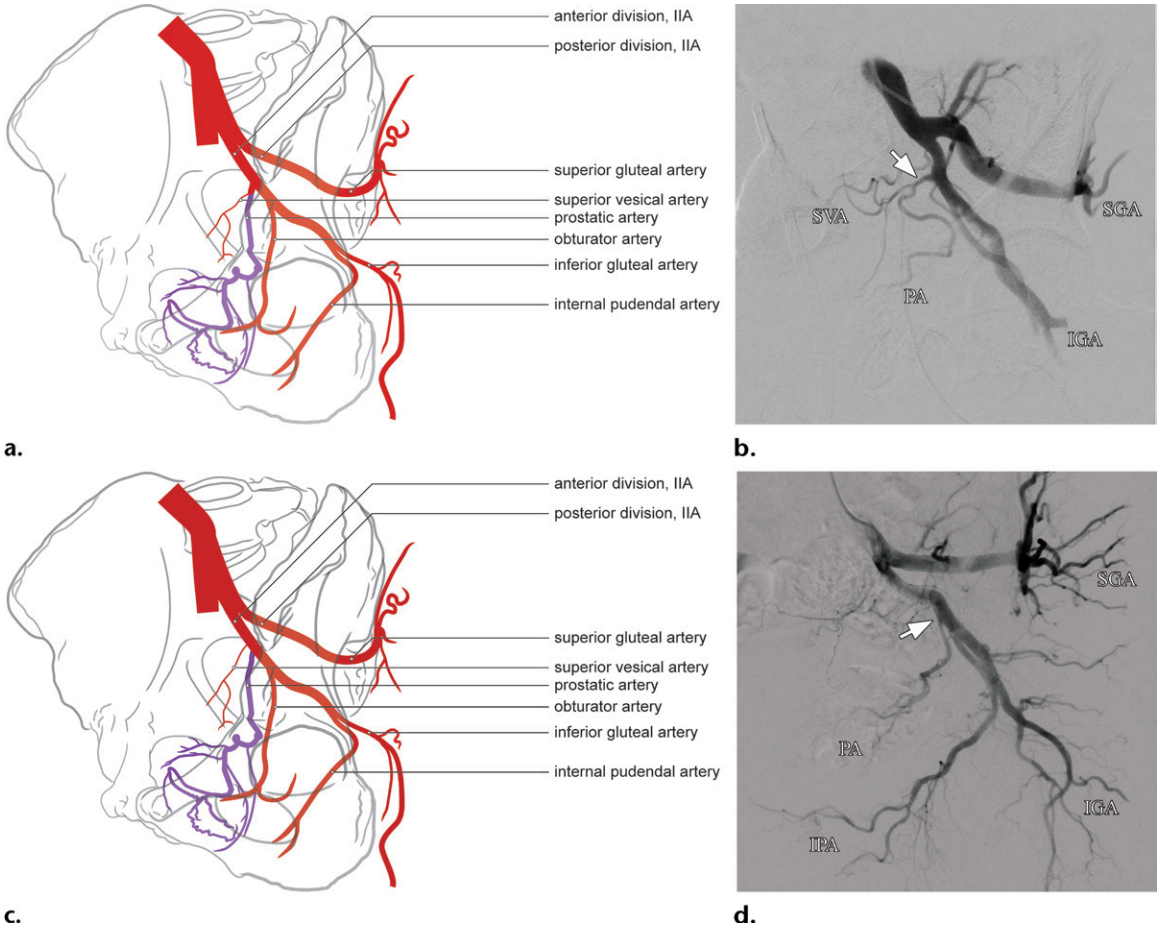


Figure 3. Classification of PA origins. *IGA* = inferior gluteal artery, *SGA* = superior gluteal artery. **(a, b)** Diagram **(a)** and arteriogram **(b)** show a type I PA originating from the superior vesical artery (*SVA*) (arrow in **b**). **(c, d)** Diagram **(c)** and arteriogram **(d)** show a type II PA originating from the gluteal-pudendal trunk (arrow in **d**).

IPA. In comparison, a cadaveric study (34) showed multiple PAs per side in 22.2% of cases.

De Assis et al (37) evaluated 286 pelvic sides and classified 267 (93.3%) of them into four main types (Table 3). The most common origin was the IPA in 31.1% and the second most common was a common trunk with the superior vesical artery in 28.7% of the classified pelvic sides (33) (Figs 3, 4). Two independent PAs per side were seen in 8% of all pelvic sides evaluated. A rectal branch was identified as arising from a common trunk with the PA in 43.8% of cases with an IPA origin. Uncommon origins included the accessory IPA, the IIA anterior division trifurcation or quadrifurcation, the inferior epigastric artery, the posterior division IIA, or the distal IPA.

The distal prostatic arterial distribution also may be classified as pattern A when the PA supplies the prostate without extraprostatic supply, pattern B when the PA has a direct supply to the penis, and pattern C when there is supply to the rectum. Pattern A was found in 62% , pattern B in 12%, and pattern C in 26% of 143 hemipelves (38). Pattern A distal branching was most commonly seen with a type I PA origin, while patterns B and C were most frequent with type IV PA origins.

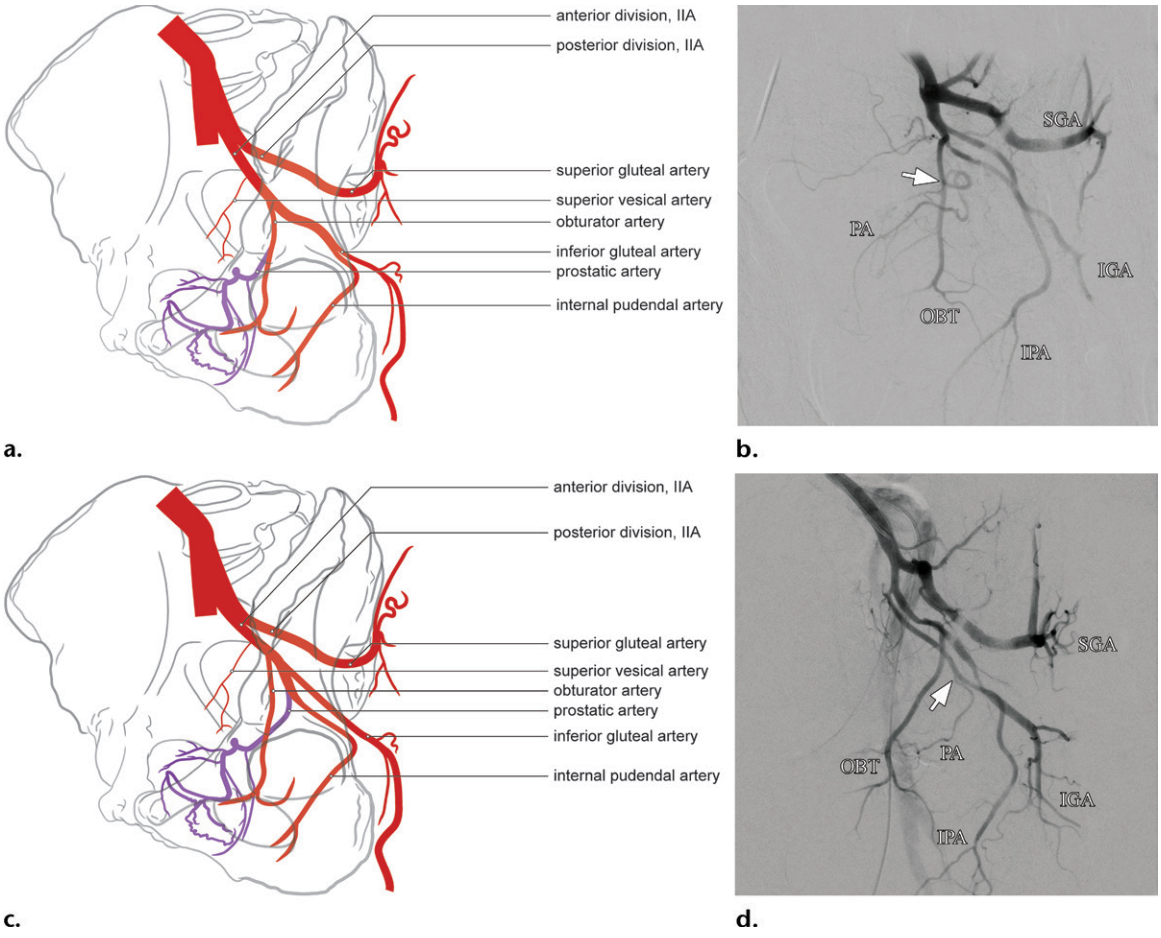


Figure 4. Classification of PA origins. *IGA* = inferior gluteal artery, *OBT* = obturator artery, *SGA* = superior gluteal artery. **(a, b)** Diagram **(a)** and arteriogram **(b)** show a type III PA originating from the obturator artery (arrow in **b**). **(c, d)** Diagram **(c)** and arteriogram **(d)** show a type IV PA originating from the IPA (arrow in **d**).

Anatomic Variants

The middle rectal artery is present in 30%–40% of patients and provides accessory arterial supply to the rectum. It often arises from the PA, forming a prostatorectal trunk in up to 70% of cases (39). At angiography, rectal branches typically course in a craniocaudal orientation, and a rectal blush may be demonstrated. This appearance is in contrast to the corkscrew appearance of the prostatic branches and allows for distinction between them at angiography (Fig 5). Retrograde filling of the superior rectal artery, a branch of the inferior mesenteric artery, may be shown. Care must be taken to avoid embolizing rectal branches, which may result in ischemic rectitis, hemorrhage, and ulceration. Proximal coil embolization of the rectal supply can prevent complications from nontarget particle embolization (40).

Accessory IPAs course along the anterolateral aspect of the prostate near the prostate base or anterolateral prostatic apex (Fig 6). The prevalence of accessory IPAs may be 20%–30% or higher depending on how they are defined, although few of these vessels are the primary supply to the corpora cavernosa (29). Accessory IPAs nearly always form anastomoses with the IPA, and nontarget embolization to the accessory IPA may result in penile ischemia. Short PA branches may arise from the accessory IPA. In these cases, occlusion of the distal accessory IPA may be required to avoid nontarget particle embolization. This may be achieved with coil embolization or a gelatin sponge.

Accessory obturator arteries are often identified arising from the inferior epigastric artery or the external iliac artery (29,32). The prevalence of PAs arising from an accessory obturator artery is estimated to be less than 2% (32). This variant can result in an unnecessarily prolonged or unsuccessful procedure if it is not considered when the PA is absent during initial IIA angiography (Fig 7).

Arterial Anastomoses

The PAs have anastomoses with other pelvic arteries in up to 57% of pelvic sides (35). The most common anastomoses involve the IPA (43.3%), the contralateral PA (17.6%), and the vesical

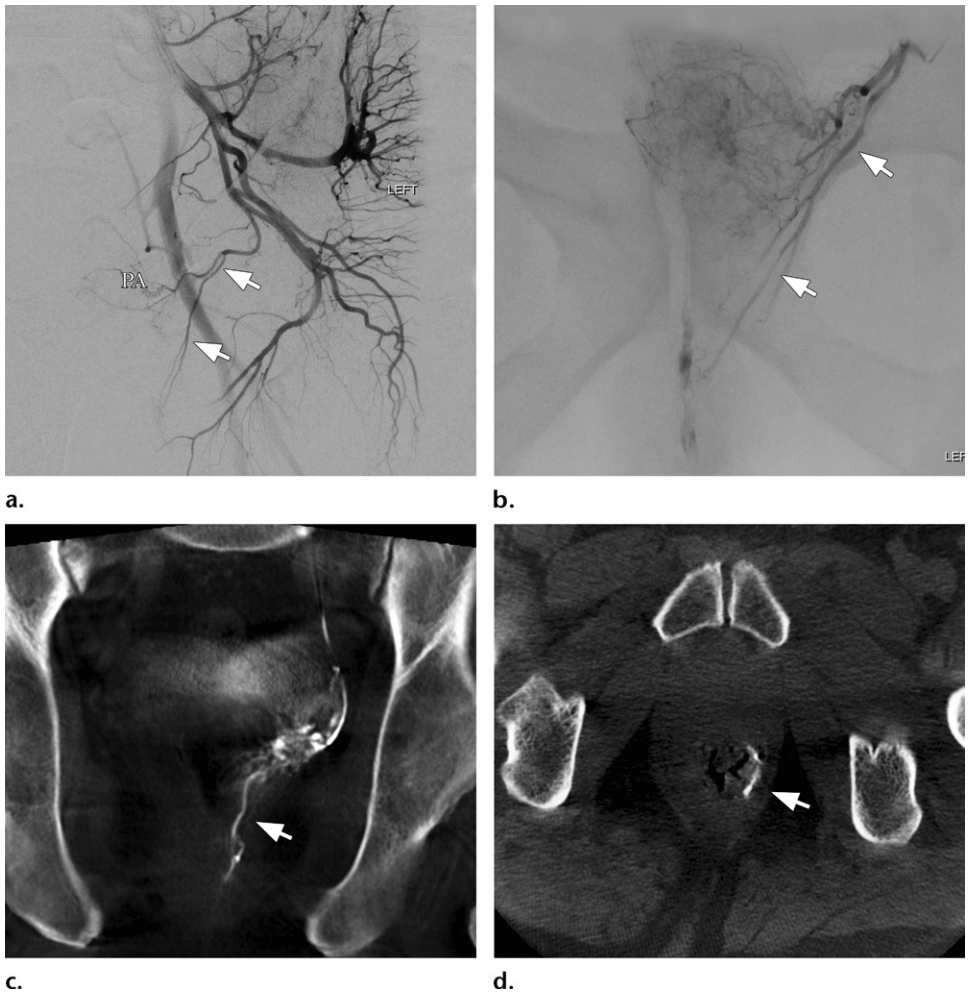


Figure 5. Middle rectal artery arising from the PA. **(a)** Arteriogram shows the middle rectal artery (arrows). Note the characteristic craniocaudal course. **(b)** Selective PA arteriogram shows the middle rectal artery (arrows) and rectal blush. **(c)** Coronal cone-beam CT image shows the craniocaudal course of the middle rectal artery (arrow). **(d)** Axial cone-beam CT image shows perfusion to the rectal wall (arrow). In this case, the microcatheter was advanced distal to the middle rectal artery origin, and embolization was performed safely.

arteries (11.3%). The risk of nontarget embolization is reduced with a supraselective microcatheter position or with proximal coil embolization of anastomoses to prevent particulate flow (Fig 8).

The presence of contralateral anastomoses allows for clinical efficacy in a subset of patients when embolization is only possible on one side. However, positive results are only reported in 50% of patients who undergo unilateral embolization (Fig 9) (41). The contralateral intraprostatic anastomoses also may explain why the first side treated may require a larger volume of embolic solution, because deposition of particles on both sides may be occurring (33). Failure to embolize the posterolateral branch also could be a source of long-term failure, because the central prostate gland may revascularize. However, posterolateral branch embolization should be performed with caution, as there is often communication with distal rectal and IPA territories.

The seminal vesicle arterial supply may arise from the PA or from anastomotic communication with the PAs. Reflux to the seminal vesicle territory should be avoided, if possible. However, embolization is reported to result in self-limited hematospermia and may not result in major complications (33,42). Careful review of intraprocedurally acquired cone-beam CT images is helpful to identify arterial anastomoses and avoid nontarget embolization.

PAE Technique

DeMeritt et al (43) first reported decreased prostate size and improved symptoms after embolization for gross hematuria in a case report published in 2000. In 2010, Carnevale et al (44) described successful PAE to treat two patients with acute urinary retention. Since these initial reports, the PAE technique has been refined in several case series.

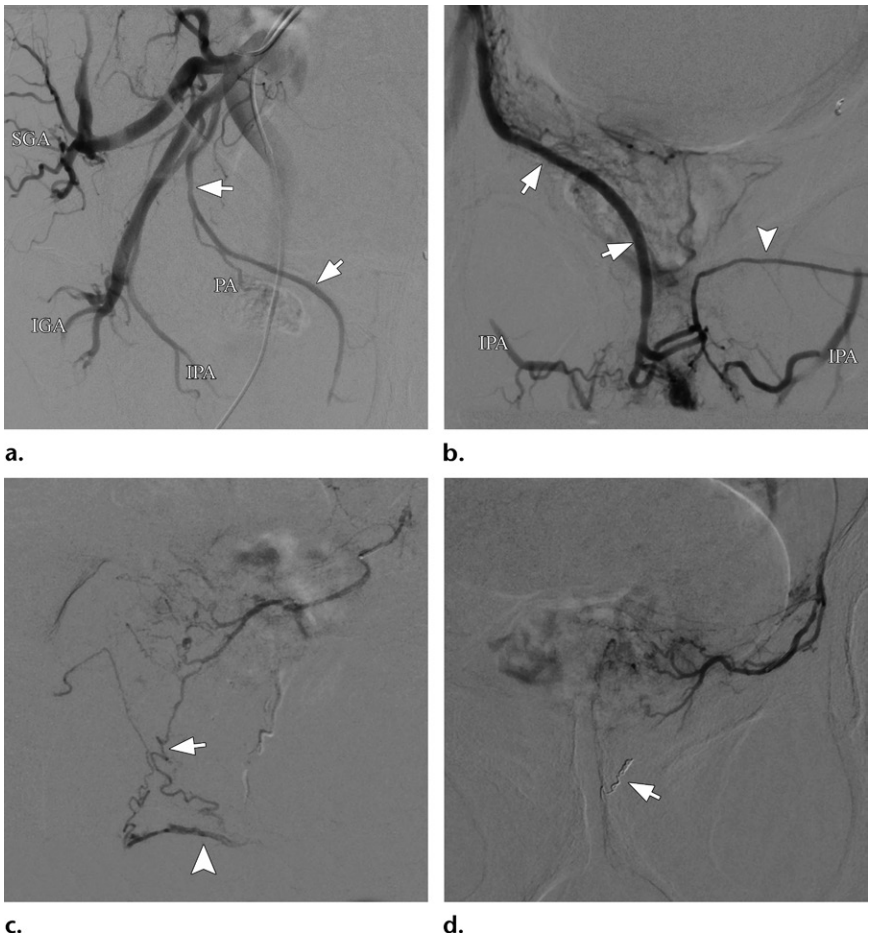


Figure 6. Accessory IPA. **(a)** IIA arteriogram shows the PA arising from an accessory IPA (arrows). *IGA* = inferior gluteal artery, *SGA* = superior gluteal artery. **(b)** Arteriogram of the accessory IPA (arrows) after PA embolization shows the supply to the penile artery (arrowhead) and communication with the distal IPAs. **(c)** Selective PA arteriogram shows an apical collateral network (arrow) communicating with the distal IPA territory (arrowhead). **(d)** The accessory IPA was selected and was embolized with a metallic coil (arrow). The PA arteriogram no longer showed filling of the IPA. Embolization was performed without the risk of nontarget embolization.

PAE is performed under direct fluoroscopic guidance, typically in a modern procedure suite with cone-beam CT capability. Consent should include a discussion of the rare but potentially severe complication of nontarget embolization to the penis, rectum, and bladder. Minor complications include a post-PAE syndrome, dysuria, hematuria, and hematospermia. Patients commonly stop taking 5-α-reductase inhibitors before the procedure but continue α-adrenergic antagonists and may wean off the medication after the 1-month follow-up clinic visit. The procedure is performed with the patient under moderate conscious sedation. Patients are treated with antibiotics and anti-inflammatory medications during the procedure and recovery (45). For example, ciprofloxacin and ibuprofen may be administered at the time of the procedure and continued after treatment. During the procedure, intravenous ketorolac provides effective pain control. Steroids can be used to reduce inflammation. Pyridium, oxybutynin, or solifenacin may be prescribed for postprocedural bladder pain.

The procedure is performed from the common femoral artery or radial artery approach. Trans-radial access may provide greater patient satisfaction and fewer complications compared with transfemoral access. Isaacson et al (46) described the transradial technique in 19 patients with 100% technical success. Patients can ambulate immediately after the procedure, which may facilitate postprocedural urination. The transradial approach is not recommended for patients taller than 74 inches to ensure adequate microcatheter length. Bhatia et al (47) demonstrated decreased procedure time, contrast material volume, and fluoroscopy time with a transradial approach compared with transfemoral access. Access site complications and overall adverse events did not differ between the groups.

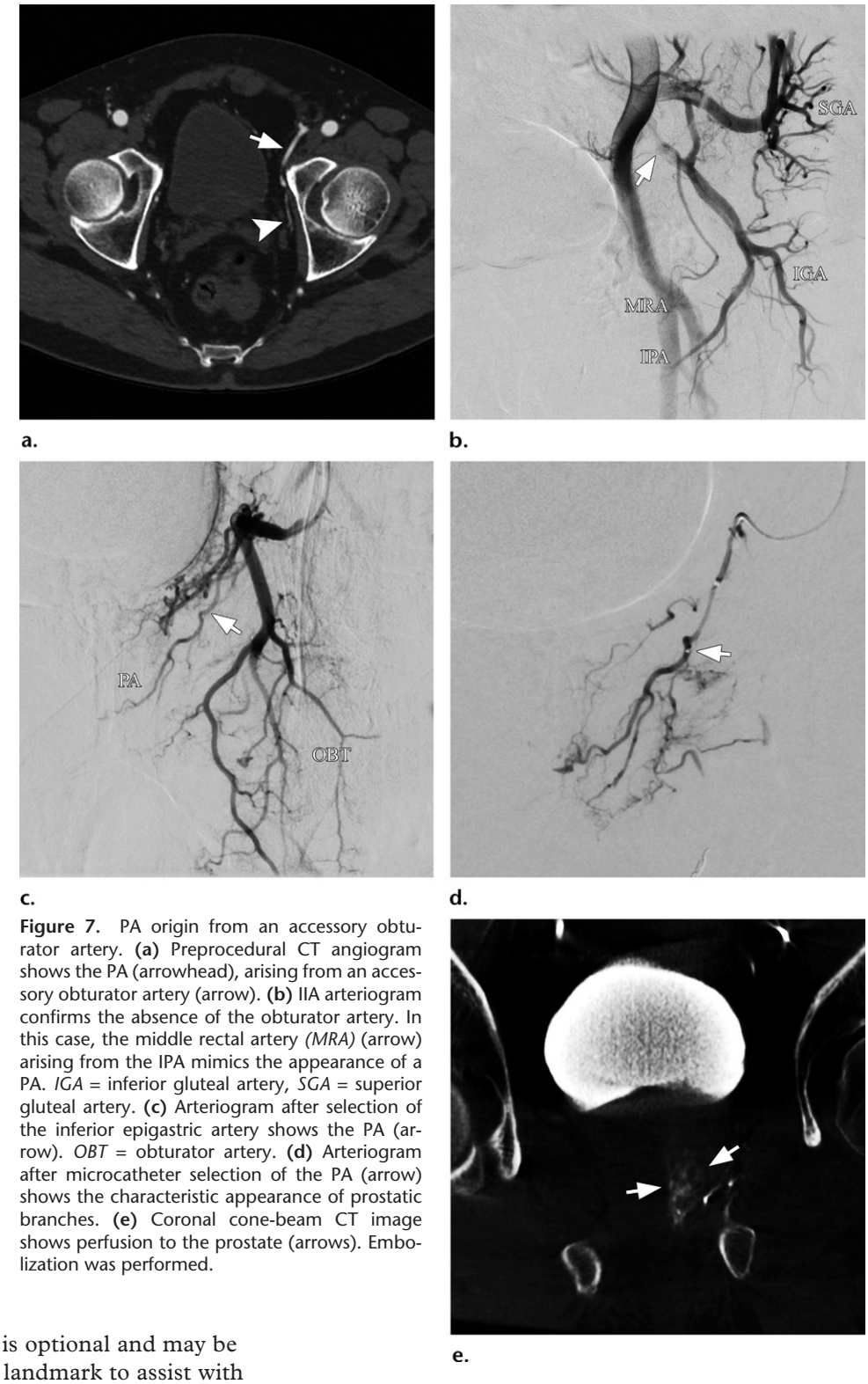
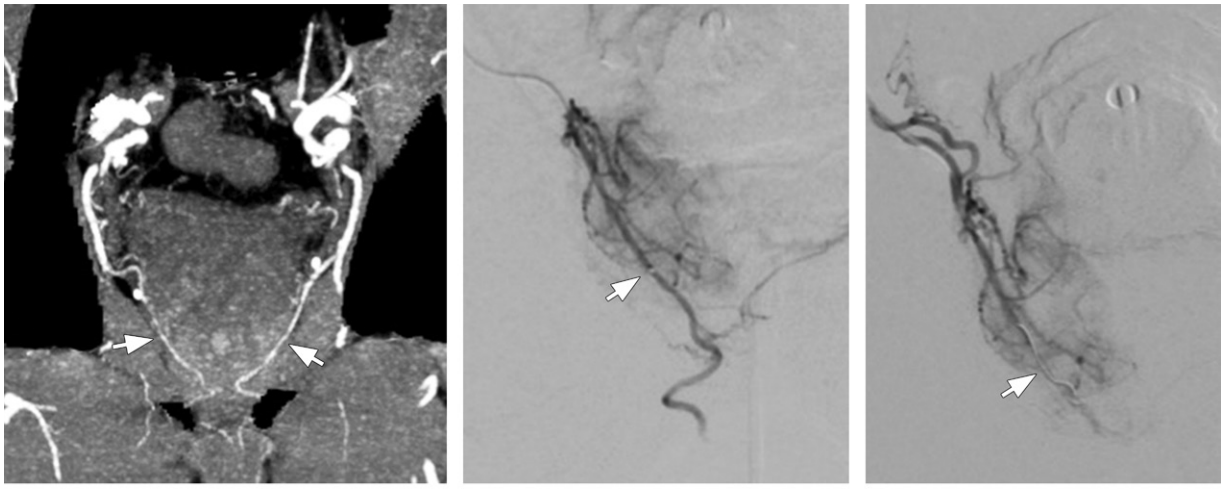


Figure 7. PA origin from an accessory obturator artery. **(a)** Preprocedural CT angiogram shows the PA (arrowhead), arising from an accessory obturator artery (arrow). **(b)** IIA arteriogram confirms the absence of the obturator artery. In this case, the middle rectal artery *(MRA)* (arrow) arising from the IPA mimics the appearance of a PA. *IGA* = inferior gluteal artery, *SGA* = superior gluteal artery. **(c)** Arteriogram after selection of the inferior epigastric artery shows the PA (arrow). *OBT* = obturator artery. **(d)** Arteriogram after microcatheter selection of the PA (arrow) shows the characteristic appearance of prostatic branches. **(e)** Coronal cone-beam CT image shows perfusion to the prostate (arrows). Embolization was performed.

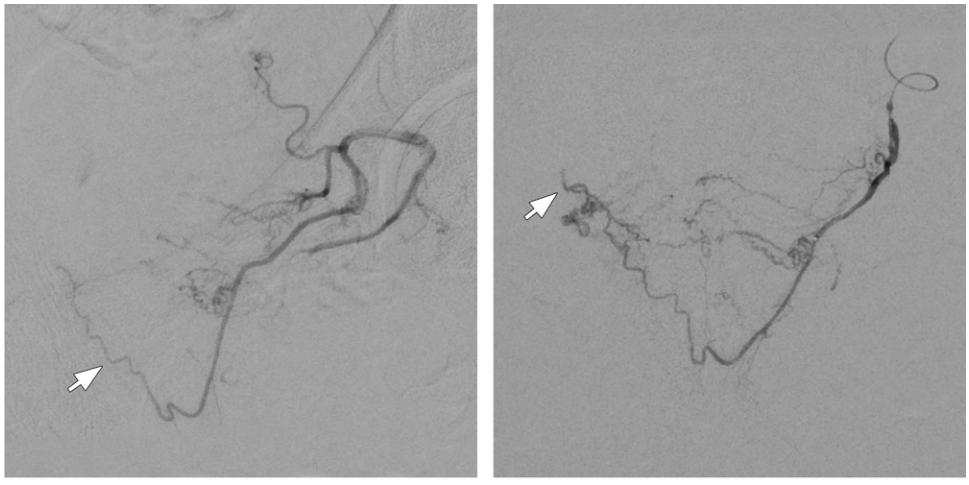
A Foley catheter is optional and may be placed to serve as a landmark to assist with identifying the PAs. Pelvic cone-beam CT may be performed to identify the PAs. From the femoral approach, the contralateral IIA is catheterized with a cobra-shaped catheter or reverse-curve catheter. The catheter is positioned in the proximal IIA, and digital subtraction arteriography is performed with 35°–55° ipsilateral and 10° craniocaudal angulation. This orientation often best separates the anterior and posterior divisions of the IIA. A microcatheter is then used to select the PA. Operators should be familiar with a variety of microwires and microcatheters. Microcatheters (2.4 F and smaller) are required to cannulate the PAs and pelvic anastomoses.

PA angiography is performed in oblique and frontal projection to evaluate for prostate opacification and collateral vasculature. Hand-



a. b. c.

Figure 8. Coil embolization to protect from nontarget embolization. **(a)** Coronal cone-beam CT image shows accessory IPAs (arrows) that must be addressed to avoid nontarget embolization. **(b)** Arteriogram shows the microcatheter (arrow) used to select the nontarget vessel arising from the right PA. **(c)** Arteriogram after placement of a metallic coil (arrow) shows occlusion of the accessory IPA. Embolization was performed safely.

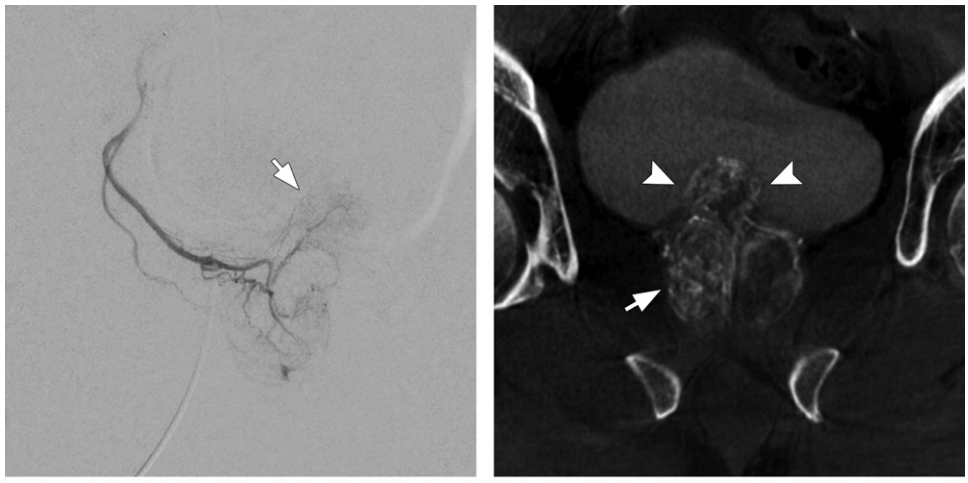


a. b.

Figure 9. PA arteriogram with cross-pelvic vasculature. **(a)** Left PA arteriogram shows a vessel crossing the midline (arrow) to the right prostate territory. **(b)** PA arteriogram shows the microcatheter advanced into the PA to avoid nontarget embolization to the inferior vesical artery, demonstrating filling across the pelvis to the right PA (arrow). The collateral vessel may be embolized if nontarget perfusion is identified.

injection or power-injection arteriography may be performed. The microcatheter is then advanced distally to the inferior vesical, middle rectal, and seminal vesicle branches. Cone-beam CT may be performed after administration of nitroglycerine to confirm perfusion of the prostate without supply to nontarget organs. Cone-beam CT is performed with gentle hand or power contrast material injection that mimics the expected flow during embolization. This is to avoid reflux into nontarget vessels and opening of collateral branches that confuse interpretation of the images.

Once the desired catheter position is reached, the prostate is embolized under direct fluoroscopic visualization. Dilute embolic particles (mixed 50:50 saline solution and contrast material) are administered slowly with a 1-mL or 3-mL syringe until near stasis is achieved. Arteriography is repeated, and if necessary, additional vessels supplying the prostate are selected and embolized for complete treatment. The ipsilateral IIA is selected, and the procedure is repeated. Patients are discharged home when they are able to void and have recovered from sedation. Clinical follow-up may include obtaining symptom scores, prostate gland volume, PSA level, and urine flow studies. Follow-up regimens vary, with the first visit typically at 1–3 months and additional visits at 6 and 12 months after treatment.



a. b.

Figure 10. Cone-beam CT after selection of the right PA. **(a)** Right PA arteriogram shows prostate blush extending medially toward the bladder base (arrow). **(b)** Coronal cone-beam CT of the right PA confirms perfusion to the prostate (arrow), including the median lobe (arrowheads).

Cone-Beam CT

Cone-beam CT can be used to perform pelvic arteriography to identify the origins of the PAs and after PA catheterization to assess prostate perfusion and evaluate for nontarget vasculature. In a study (48) of automatic vessel tracking software, authors evaluated cone-beam images obtained with a catheter positioned in the proximal IIAs and an injection of 24 mL of contrast material at 2 mL/sec, with 4- and 18-second delays. The software was able to detect the PAs with 92% sensitivity. Vessel tracking software can help detect variant and collateral PAs to guide microcatheter positioning and potentially avoid multiple digital subtraction angiography acquisitions before embolization.

After the PA is selected, cone-beam CT may be performed with 1–3 mL of iodinated contrast material injected by hand over approximately 3 seconds, with a 4–6-second imaging delay or with a power injector used at a rate of 0.3 mL/sec (Fig 10). In one study (49), cone-beam CT allowed identification of potential sites of nontarget embolization in 36% of cases. Multiplanar images are reviewed intraoperatively to evaluate prostate perfusion and potential nontarget embolization. The pattern of perfusion may help to determine if there are additional PAs that should be selected.

Understanding potential imaging artifacts is important in the assessment of cone-beam CT images. Pseudorectal enhancement can occur from attenuation differences related to the posterior acetabular walls, and catheters can result in streak artifacts along the area of interest. Contrast material enhancement in the penile corpus at delayed imaging is a normal finding and does not represent collateral filling of the cavernosal vessels (50). Cone-beam CT should be performed with gentle contrast material injection to avoid contrast material reflux into proximal vessels. Contrast material administration should simulate the rate of injection during embolization. Vigorous injection may opacify intraparenchymal and pelvic collateral vessels that do not represent the flow dynamics during embolization.

In a study (51) of 148 patients, cone-beam CT showed 94.7% of the PA origins and provided essential information that affected embolization in 60.8% of patients. In 87.8% of cases, the PA origins were asymmetric between pelvic sides, and one PA was identified in 92.6% of pelvic sides. PA diameter was correlated with prostate gland volume. Anastomoses were present in 22.6% of pelvic sides, most commonly to contralateral prostate branches (10.5%) and to the distal IPA or corpus cavernosal arteries (8.8%).

Embolic Particles

A variety of different particles and sizes are reported during PAE, with good technical success. The most commonly studied particles are nonspherical polyvinyl alcohol particles, tris-acryl gelatin microspheres (Embospheres; Merit Medical, South Jordan, Utah), and hydrogel microspheres with a proprietary coating (Embozene; Boston Scientific, Marlborough, Mass) (52–54).

The ideal particle size is yet to be determined, to our knowledge. Eighty patients were randomized to treatment with 100-μm or 200-μm polyvinyl alcohol particles (54). Patients in the 100-μm group had a greater decrease in PSA values, while patients in the 200-μm group had greater improvement in IPSS and quality-of-life

score. A study (55) was performed to examine PAE outcomes in 30 patients treated with 100–300-μm or 300–500-μm tris-acryl gelatin microspheres (Embospheres, Merit Medical). Differences in improvement of IPSS, quality-of-life score, prostate gland volume, PSA level, and Q_{max} rate were not significant. However, more minor self-limited adverse events were noted in the 100–300-μm group, including cases of decreased ejaculate volume, transient hematuria, transient hematospermia, and hematochezia. A study (56) comparing spherical and nonspherical polyvinyl alcohol particles showed no difference in success rates at 12 months, although a lower posttreatment IPSS was associated with a higher proportion of prostate ischemia measured at MRI a month after treatment. Prostate ischemic volume was also correlated with PSA 24 hours after PAE.

In a study (57) of 24 patients with a prostate gland volume greater than 80 mL, patients were treated with 50-μm polyvinyl alcohol particles followed by 100-μm particles. The mean reduction in prostate volume was 39.1% at 6 months, with improvement in IPSS, quality of life, PVR volume, and Q_{max} rate. Eighty-three percent of patients had sustained clinical success at 12 months. There were no major complications, but 32% of patients required temporary bladder catheter placement for acute urinary retention 1–3 days after PAE.

To our knowledge, there is no consensus on the ideal particle size. A case-by-case decision may be required, or a combined approach with particle upsizing may be most effective. The most commonly studied particle sizes are 300–500 μm, with larger particles resulting in proximal occlusion. Smaller particles are likely to penetrate further into the prostate and induce greater ischemia. More distal penetration may reduce the risk of revascularization through intraprostatic anastomoses but result in more complications from small-vessel anastomoses (54,55).

Advanced Techniques

Treatment is optimized with selection of all vessels supplying the prostate and slow infusion of dilute particles to achieve a complete embolization and avoid early proximal occlusion. The Proximal Embolization First, Then Embolize Distal (PERFECTED) technique was developed to increase the embolic load administered to the prostate (58). In this technique, the microcatheter is positioned in the mid PA so that there is adequate blood flow around the microcatheter. Embolization is then performed from this proximal position. After near stasis is reached, the microcatheter is advanced distally into the intraprostatic branches, and additional embolization is repeated. Thirty to fifty percent more embolic material can be delivered with this technique. A study (59) demonstrated a significantly lower rate of symptom recurrence at 12 months with the PERFECTED technique. However, combining this technique with the use of smaller particles (<300 μm) may result in more complications because of overembolization.

Coil Embolization

Coil embolization of potential nontarget vessels reduces the risk of ischemic complications. Bhatia et al (40) compared 122 patients, 26.2% of whom underwent PAE with coil embolization. Coils were placed when the microcatheter could not be advanced to a safe position distal to anastomotic branches. The most commonly treated vessels were a rectal artery and anastomoses with the penile arteries. There were no significant differences in complications between the groups, although fluoroscopy and procedure times were higher in the coil group. One patient in the coil group developed white discoloration on the glans penis that resolved after 3 weeks.

In a study of 11 patients, Amouyal et al (60) found penile or rectal shunts in 10% of catheterized PAs. Coils were placed distal to prostate branches and close to the extraprostatic anastomosis. Coils were used for rectal branches and gelatin torpedoes were used for IPA branches. There were no major complications at 3- and 6-month follow-up.

Balloon Occlusion

A balloon-occlusion microcatheter (Sniper; Embolx, Los Altos, Calif) was designed to reduce the risk of reflux during embolization. Inflating the balloon prevents reflux into proximal branch vessels. Balloon occlusion also reduces the pressure distal to the catheter tip and results in reversed flow through prostatic anastomoses. Theoretically, this reduced pressure results in small collateral vessels flowing toward the prostate and reduces the risk of nontarget embolization without the need for coil placement (Fig 11). During treatment, the embolization endpoint can be difficult to determine as the catheter alters the flow dynamics. Embolization can be performed until stasis is achieved in intraprostatic arteries after balloon deflation or loss of flow reversal is achieved in extraprostatic anastomoses (61).

Postprocedural MRI

Postprocedural MRI is not standard for clinical follow-up but is being investigated to better understand the effects of embolization (Fig 12). Frenk et al (62) described MRI findings before and at 1, 3, and 12–18 months after PAE in 17 patients.

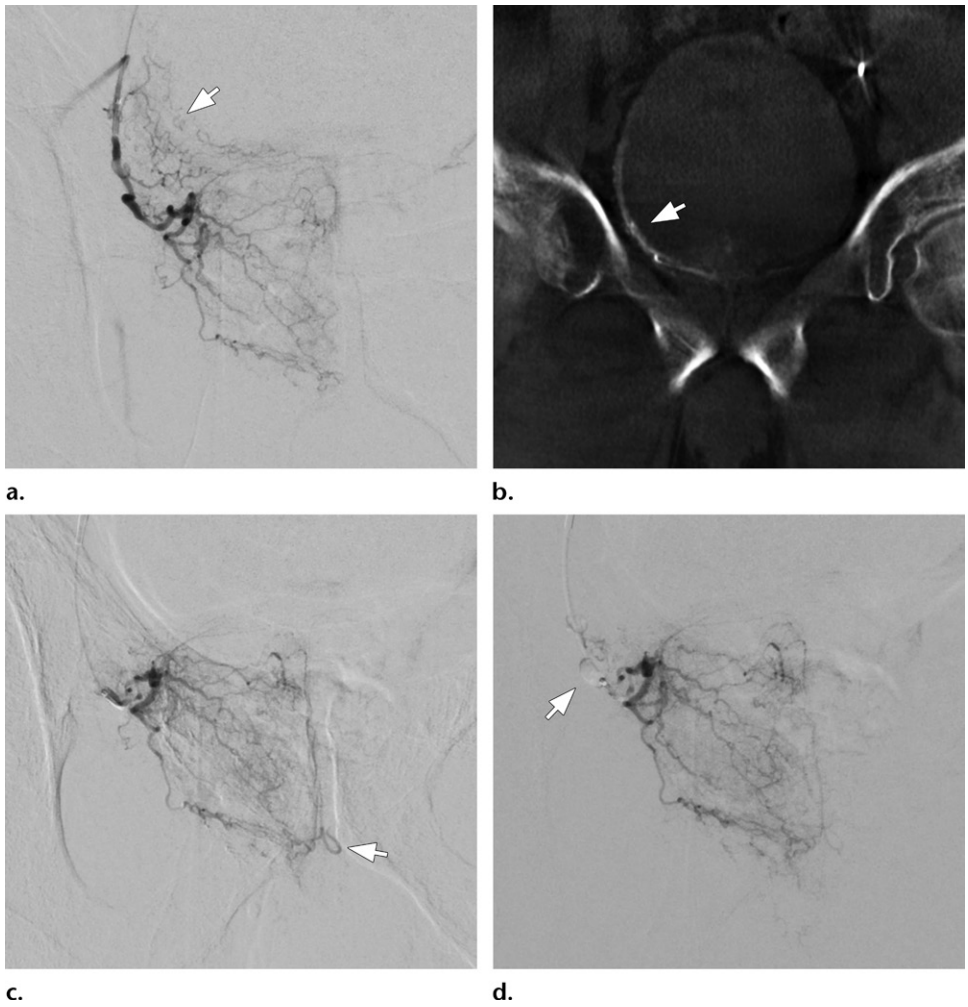


Figure 11. PAE with a balloon occlusion microcatheter. **(a)** Right PA arteriogram shows perfusion to the right prostate lobe and inferior vesical artery branches (arrow). **(b)** Coronal cone-beam CT image shows inferior vesical artery supply to the bladder (arrow) risking nontarget embolization. **(c)** Arteriogram obtained after the microcatheter was advanced distal to the inferior vesical artery shows perfusion to the prostate and an extraprostatic nontarget vessel (arrow). **(d)** The microcatheter occlusion balloon was inflated (arrow) and arteriography was repeated. The extraprostatic vessel was no longer visualized, which suggested reversed flow toward the prostate. The catheter also protects from reflux into the inferior vesical artery.

The MRI protocol consisted of axial and sagittal thin-section high-spatial-resolution T2-weighted fast spin-echo and axial dynamic contrast material–enhanced T1-weighted sequences. At T1-weighted MRI, infarcts were initially hyperintense and became isointense with time. At T2-weighted MRI, infarcts were hypointense, with or without hyperintense foci, and tended to become isointense with time. Infarcts were observed in 70.6% of patients and occurred exclusively in the central gland. Prostate volume (mean ± standard deviation) significantly decreased among patients who developed infarcts, with cumulative reduction at 12–18 months of 32% ± 19.2%. The presence of infarcts was not significantly associated with a change in IPSS in this study, possibly because of the small sample size.

Zhang et al (63) studied findings in 28 patients at MRI 10 days after treatment, and 1, 3, 6, and 12 months after the procedure. Infarcts were observed in all patients and occurred exclusively in the transitional zone. Infarcts began to reduce in size at 12 months. High-*b*-value diffusion-weighted MRI (b = 3000 sec/mm^2) allowed better observation of the infarct. The prostate volume was reduced 37% at 12 months. The greatest volume change was present at 1 month, and no change was noted 10 days after embolization.

In a study (64) of MRI 6 months after PAE in 43 patients, 100% had decreased central gland volume, and 100% of those with intravesical prostatic protrusion at baseline had decreased size of the median lobe at follow-up. T2 signal intensity was decreased in 79% and enhancement was reduced in 51% of patients compared with those at baseline. Infarcts were noted in the central gland in 33% of cases and were associated with a more pronounced reduction in volume.

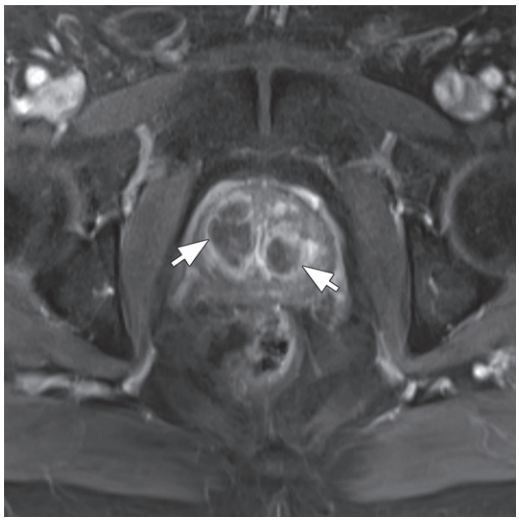


Figure 12. Pelvic image in a 73-year-old man who underwent MRI 3 months after PAE. Axial T1-weighted contrast-enhanced MR image of the pelvis shows regions of low signal intensity in the lateral lobes of the prostate (arrows) that are compatible with devascularization.

Procedure Outcomes

The literature supporting PAE consists of several prospective case series, small randomized controlled trials, and meta-analyses. In a prospective randomized controlled trial (65), 57 patients underwent TURP and 58 patients underwent PAE. The mean procedure time was slightly shorter with TURP, but more patients required postoperative urethral catheterization and admission to the hospital. Although the results were not consistent with those in prior reports, there were more complications in the PAE group, primarily related to self-resolving postembolization syndrome and acute urinary retention. IPSS, quality-of-life score, Q_{max} rate, and PVR volume were improved in both groups, with comparable degrees of improvement at 12 and 24 months. TURP showed greater initial improvement at 1 and 3 months and resulted in greater improvement in PSA values and prostate volume at all time points.

A recently published randomized controlled trial (66) compared PAE with 250–400-μm microspheres to monopolar TURP in 103 patients. IPSS improvement did not differ significantly between the groups at 12 weeks (mean improvement of 9.23 after PAE and 10.77 after TURP), and the noninferiority of PAE was not shown. TURP was more effective in improving Q_{max} rate, PVR volume, and prostate volume. Significantly fewer adverse events, less blood loss, and shorter hospitalization occurred after PAE. Fifty-six percent of patients in the PAE group and 84% of those in the TURP group had ejaculatory dysfunction. Long-term follow-up will be reported for 5 years.

In another study (67), 30 patients were randomized to treatment with TURP or PAE. These patients also were compared with a cohort of 15 patients who underwent PAE with the PERFECTED technique. Clinical success (IPSS ≤8 and/or quality-of-life score ≤3) was 100% in the TURP and PERFECTED PAE groups and 87.6% in the standard PAE group. The posttreatment IPSS was not significantly different between the TURP and PERFECTED groups. Mean prostate volume, quality of life, and Q_{max} rates were significantly better among the patients who underwent TURP. Two patients in the PAE group with hypocontractile bladders had recurrent symptoms at 6 months and 12 months and underwent successful TURP. The TURP group had more adverse events, with 26.7% of patients who underwent TURP experiencing transient urinary incontinence and 100% experiencing retrograde ejaculation. Mean hospitalization time was 2.1 days after TURP and 6 hours after PAE. A retrospective study (68) in which 86 patients who underwent TURP were compared with 70 patients who underwent PAE showed significantly lower direct in-hospital costs and shorter hospital stays with PAE.

A double-center 1:1 matched-pair comparison of PAE and open prostatectomy was reported (69), with 80 patients in each group. Prostate volume was greater than 100 mL in both groups. The prostatectomy group had lower IPSS, PVR volumes, and PSA levels, and greater Q_{max} rates at 1 year. The PAE group had higher postoperative hemoglobin levels, lower hospitalization rates, and lower bladder catheterization rates. However, there was a higher rate of persistent symptoms at 1 year. The overall complication rates were 31.25% for open prostatectomy and 8.75% for PAE.

The UK Register of Prostate Embolization (UK-ROPE) study (70), a multicenter observational study, evaluated the efficacy and safety of PAE with 12-month follow-up compared with a propensity-matched cohort of patients who underwent TURP. Two-hundred sixteen patients underwent PAE, and 89 patients underwent TURP. PAE produced a median 10-point improvement in IPSS compared with a 15-point improvement in the patients who underwent TURP. Results did not support the noninferiority of PAE to TURP regarding IPSS and quality-of-life improvement in 65 propensity score–matched patients. Patients who underwent PAE did demonstrate a significant improvement in prostate volume and Q_{max} rates at 12 months. Two patients underwent nontarget embolization with self-limiting penile ulcers that resolved within 6 months. Seventy-one percent

of patients in the PAE group underwent the procedure on an outpatient basis and returned to normal daily activities sooner than those who underwent TURP. After the results of this study were published, the National Institute for Health and Care Excellence (NICE), a group that provides guidance and advice on improving health care in the United Kingdom, concluded that current evidence is adequate to recommend PAE if patient selection is performed in a collaborative manner and practitioners are adequately trained.

Several prospective case series demonstrate the efficacy of PAE, with minimal reported adverse effects. In a large single-center retrospective cohort study, Pisco et al (71) described the results of 630 patients, 67 of whom had acute urinary retention. Technical success, defined as embolization of at least one PA, was 98.1%. Mean procedure time was 77 minutes and mean fluoroscopy time was 19.5 minutes. Most patients (91.7%) were discharged 3–6 hours after the procedure. There were 104 clinical failures, 82.5% within 1 year of treatment, and most of these occurred within the 1st month. Fifty-eight patients underwent a second PAE. Three hundred twenty-eight patients with complete data at 36 months had mean improvement in IPSS of 12.1 points, mean quality-of-life improvement of 1.69 points, mean prostate volume reduction of 14 mL, mean Q_{max} rate improvement of 3.21 mL/sec, and mean reduction in PVR volume of 37.4 mL.

Cumulative rates of clinical success were 85.1% at 12 months, 81.9% at 30 months, and 76.3% at 78 months. The most common minor complications were dysuria in 24.1% and urinary frequency in 23% of patients. This patient cohort has since been updated to reflect 1000 treated patients, with 89% short-term success, 82.2% midterm success, and 79.1% long-term success (72).

Multiple small studies (73–79) were performed to evaluate PAE for acute urinary retention and/or prostates larger than 80 mL, which are not typically eligible for TURP. The procedure is safe and effective in larger prostates, with reported clinical success in 72.4%–98% of patients in these studies. In a study (74) of 30 patients with acute urinary retention, at a mean of 18.2 days after treatment, 26 (86.7%) patients were no longer reliant on catheters. In another study (80), results in patients with a prostate volume of less than 50 mL were compared with those in patients with a prostate volume of 50–80 mL and those with a prostate volume greater than 80 mL. All groups demonstrated improvement in clinical symptom scores at 6-month follow-up. There were no significant differences among the groups, which suggests that intermediate-term success is not dependent on prostate size. Changes in prostate volume do not necessarily correlate with clinical outcomes (14). Several mechanisms likely contribute to improvement after embolization, including ischemic necrosis, apoptosis, effects on androgens, and changes in prostate innervation that lead to reduced smooth muscle tone.

Systemic reviews and meta-analyses provide an overview of published results to guide treatment decisions (4–7). Uflacker et al (4) presented a meta-analysis that included six studies and demonstrated a decrease in prostate volume of 31.31 mL, a decrease in PVR volume of 85.54 mL, an increase in Q_{max} rate of 5.39 mL/sec, an improvement in IPSS of 20.39 points, and an improvement in quality-of-life score of 2.49 points at 12 months. The most commonly reported complications were transient urinary retention in 7.85% and rectalgia or dysuria in 9.1%. There were 0.3% serious adverse events, including one case of severe urinary tract infection and one case of bladder ischemia. Feng et al (5) analyzed 20 studies with 1318 patients and showed a mean difference in IPSS of 13.25 points, in quality-of-life scores of 2.34 points, in PSA levels of 1.33 μg/mL, in prostate volumes of 28 mL, in Q_{max} rates of 5.51 mL/sec, and in PVR volumes of 67.8 mL. Pyo et al (6) analyzed seven studies including 484 patients and showed a mean improvement in IPSS of 14.06 at 3 months and of 16.41 at 24 months. Q_{max} rates, PVR volumes, prostate volumes, PSA levels, and quality-of-life scores also showed significant improvements up to 12 months. Cizman et al (7) analyzed seven studies with improvement in IPSS, quality-of-life scores, Q_{max} rates, PVR volumes, and PSA levels. Two hundred minor complications and one major complication were reported. IPSS and quality-of-life scores decreased by 59% and 56% at 12 months, respectively, and Q_{max} rates increased by 91%.

Transient ischemic rectitis, radiation dermatitis, and seminal vesicle ischemia are described in case reports. Minor complications include dysuria (9%), urinary tract infection (7.6%), microscopic hematuria (5.6%), hematospermia (0.5%), acute urinary retention (2.5%), and rectal bleeding (2.5%) (41). Severe complications are related to nontarget ischemia. A case of bladder ischemia that required surgical incision was reported (71). Nontarget embolization to the rectum may result in ischemic proctitis, with pain, bloody diarrhea, or ulcers. Transient rectal bleeding is reported in 2.4%–27% of cases (45). Embolization of the penile arteries may lead to ischemia with pain, erythema, ulcers, or sexual dysfunction (45,81).

A study (82) of radiation exposure in 25 patients who underwent PAE reported an average fluoroscopy time of 30.9 minutes and a mean dose-area product of 450.7 Gy · cm^2. The mean peak skin dose was 2420.3 mGy and the average effective dose to the operator was 17 μSv. Cone-beam CT was used in only 28% of cases and can contribute to higher doses. A case of radiodermatitis was reported after a PAE procedure requiring 72 minutes of fluoroscopy (83). The procedure should be performed with attention to radiation dose reduction by limiting fluoroscopy time and the number of cone-beam acquisitions, when possible and by using low-dose mode, pulsed fluoroscopy, collimation, and image hold functions.

A recently published multisociety consensus article concluded that current evidence is adequate to support the use of PAE for benign prostatic hyperplasia in appropriately selected patients (84). In addition, several randomized controlled trials are currently enrolling patients to compare PAE to other therapies, including TURP, medical treatment, prostatectomy, and a sham procedure. A prospective nonrandomized trial is being performed to compare PAE to Urolift. Ultimately, a multicenter randomized controlled study will be required to compare the outcomes of TURP and PAE and to further establish the role of PAE in benign prostatic hyperplasia treatment algorithms.

Practice Development

Building a successful PAE practice requires a multidisciplinary team approach and a dedication to developing procedure expertise and rigorous patient follow-up. Collaboration with urologists is important in the initial development of a PAE program. The goal is not to replace current surgical therapies but to offer an additional option in the spectrum of treatments for benign prostatic hyperplasia that may be appropriate for select groups of men, including men with large prostates, those with surgical comorbidities, those who cannot stop taking anticoagulation therapy for surgery, those with a strong desire to preserve sexual function, and those looking to treat concurrent lower urinary tract symptoms and hematuria with a single procedure. To encourage continued collaboration, it is beneficial for patients to undergo a pre-PAE examination and post-PAE follow-up with a urologist. This allows the urology practice to retain the revenue associated with these services and also allows the urologist performing the follow-up care to experience firsthand the results of PAE. This collaboration will bring growth to both the interventional radiology and urology practices.

Practice building, including outreach to internal medicine, family medicine, and geriatric medicine practices, can be successful, particularly for men who have an initial aversion to seeing a urologist. Diagnostic imaging studies can be screened, and patients can be contacted directly regarding their urologic symptoms. Direct patient marketing often leads to self-referrals. This includes marketing on the Internet and social media, print ads, press releases, and billboards. There are several patient forums on the Internet on which prospective patients can communicate with men who have already undergone PAE. Encouraging patients to post on these forums can result in additional self-referrals.

Interventional radiologists must become experts in the PAE procedure as well as preprocedural evaluation and postprocedural follow-up. The procedure is technically challenging and requires dedication to continuing medical education and refining techniques as new data emerge. To become a valued member of the treatment team, the interventional radiologist must understand the clinical evaluation and the variety of surgical treatment options. Patients must be followed closely after intervention to monitor the effects of treatment and understand the adverse effects. Developing a comprehensive treatment program increases visibility of the practice and improves trust in both referring physicians and patients.

Conclusion

PAE provides an effective treatment option to relieve symptoms caused by prostate enlargement and bladder outlet obstruction. Although TURP is the standard of care treatment, patients also consider minimally invasive surgical therapies such as UroLift and Rezum, and interventional radiologists must understand these procedures to counsel patients effectively. Randomized controlled trials will further establish the role of PAE and help in the selection of patients who will benefit most from the procedure. Development of a collaborative PAE program can effectively strengthen the practice of both urologists and interventional radiologists and improve the care of patients with benign prostatic hyperplasia.

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