Techniques in Vascular and Interventional Radiology

Prostate Arterial Anatomy: A Primer for Interventional Radiologists

Srini Tummala, MD,* Ashli Everstine, BA, MS,† Vedant Acharya, BS,‡ and Shivank Bhatia, MD, FSIR*

Identification of the prostatic arteries (PAs) is one of the most challenging aspects of prostate artery embolization for treatment of benign prostatic hyperplasia-associated lower urinary tract symptoms. Operators require a detailed understanding of the prostate arterial anatomy to ensure technical and clinical success with minimal complications. Due to substantial variability in internal iliac artery branch patterns and specifically the origin of the PA, we focus on 3 clinically relevant classification systems used to categorize the pelvic vasculature. These include classification systems to understand the internal iliac artery branching pattern, PA origin variation, and intraprostatic branching.
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Introduction

Prostate artery embolization (PAE) is a minimally invasive treatment option for benign prostatic hyperplasia-associated lower urinary tract symptoms. Many studies have shown the effectiveness and safety of PAE.[1-6] Operators require a detailed understanding of the prostate arterial anatomy to ensure technical and clinical success with minimal complications.[7]

Because of the high variability in pelvic vascular anatomy, several classification systems have been developed to better identify and characterize pelvic and prostate arteries. In this paper we discuss 3 clinically relevant classification systems used to categorize the pelvic vasculature. These include classification systems to understand the internal iliac artery (IIA) branching pattern, prostate artery (PA) origin variation, and intraprostatic branching.

Normal Branching of the IIA

The common iliac artery gives rise to the external and internal iliac arteries. The IIA typically originates as a common trunk which ultimately divides into anterior and posterior divisions at the superior greater sciatic foramen. The anterior division typically gives rise to the superior vesical artery (SVA), inferior vesical artery (IVA), obturator artery (OA), middle rectal artery, inferior gluteal artery, and internal pudendal artery (IPA). The IPA supplies the perineum and male external genitalia and from an imaging perspective, it is practical to assume that the internal pudendal artery terminates into the perineal scrotal artery and the penile artery. The posterior division typically gives rise to the iliolumbar artery, lateral sacral artery, and the superior gluteal artery.[8,9] Although this anatomy is the most common branching pattern, substantial IIA branching variability exists.

IIA Branching Pattern Classification

To better organize IIA variation, Yamaki et al proposed a clinically relevant classification system (based on 645 cadaver

*University of Miami Miller School of Medicine, Department of Interventional Radiology, Miami, FL.
†Howard University College of Medicine, Washington DC.
‡University of Miami Miller School of Medicine, Miami, FL.
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Address reprint requests to Srini Tummala, MD, Department of Interventional Radiology, University of Miami Health System, University of Miami - Miller School of Medicine, Miami, FL 33136. E-mail: DrSriniTummala@gmail.com

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dissections of pelvic halves) focused on classifying the IIA branching pattern into 4 groups: A, B, C, and D.[10]

In group A, the IIA divides into 2 branches: the superior gluteal artery and a common trunk of the inferior gluteal and internal pudendal arteries called the common anterior gluteal-pudendal trunk (Fig. 1). This is the most frequent branching pattern, occurring in 79.5% of cases.[10-12]

In group B, the IIA divides into 2 branches: the internal pudendal artery and a common gluteal trunk giving rise to the superior gluteal and inferior gluteal arteries (Fig. 2). In this group the anterior division of the IIA is smaller since it consists of the internal pudendal artery and the posterior division is larger because it consists of both the superior and inferior gluteal arteries. This is the second most frequent branching pattern, occurring in 15% of cases.[10-12]

In group C, the IIA divides into 3 major branches: the superior gluteal, inferior gluteal, and internal pudendal arteries (Fig. 3). This pattern occurs in 5.3% of cases.[10-12]

In group D, the IIA divides into an anterior division, which consists of a common trunk with the superior

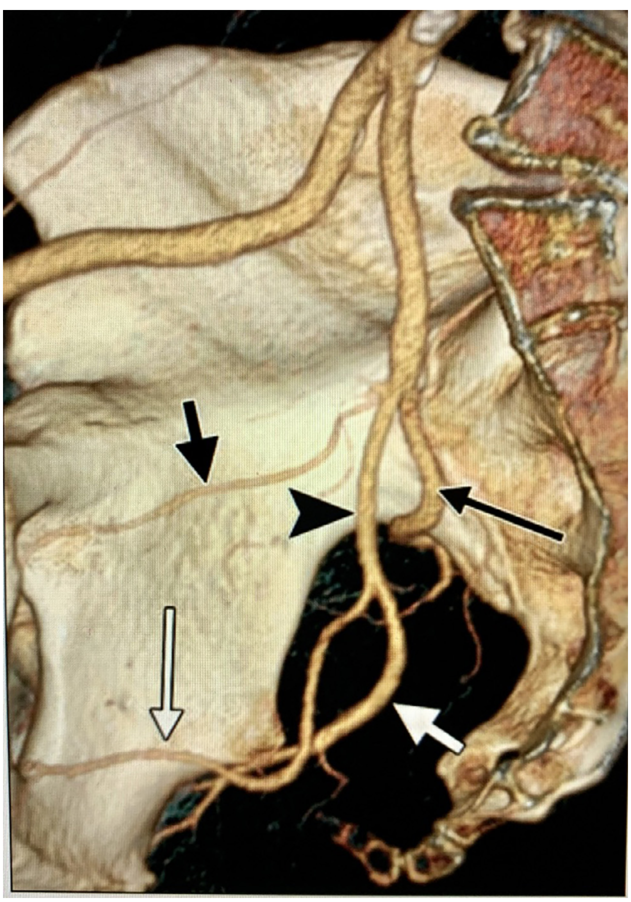

Figure 1 Group A bifurcation of IIA. Lateral projection 3D volume-rendered reformatted CT angiogram shows right IIA dividing into 2 branches: superior gluteal artery (thin black arrow) and common trunk of inferior gluteal and internal pudendal arteries (common anterior gluteal-pudendal trunk) (arrowhead). Common anterior gluteal-pudendal trunk bifurcates into internal pudendal artery (thin white arrow) and inferior gluteal artery (thick white arrow). Thick black arrow indicates obturator artery arising from superior gluteal artery. (Adapted with permission from Tiago Bilhim T, Pereira JA, Fernandes L, et al.[20])

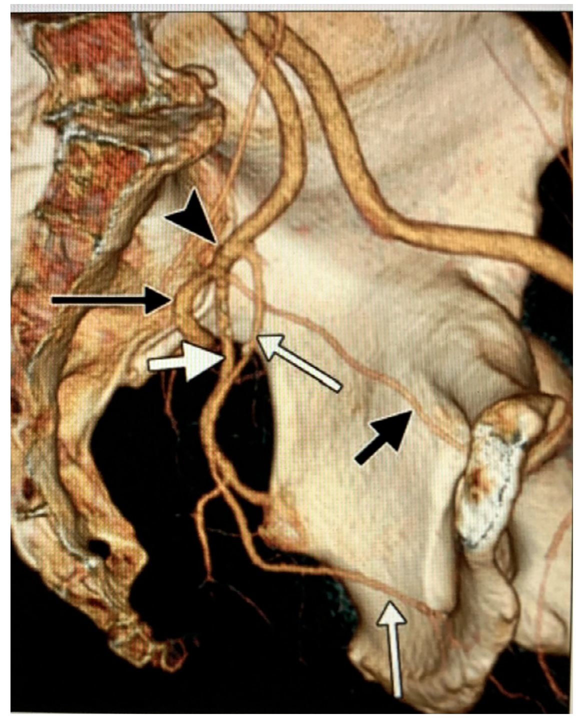

Figure 2 Group B bifurcation of IIA. Lateral projection 3D volume-rendered reformatted CT angiogram shows left IIA dividing into 2 branches: internal pudendal artery (thin white arrows) and common gluteal trunk (arrowhead) of superior gluteal (thin black arrow) and inferior gluteal (thick white arrow) arteries. Thick black arrow indicates obturator artery. (Adapted with permission from Tiago Bilhim T, Pereira JA, Fernandes L, et al.[20])

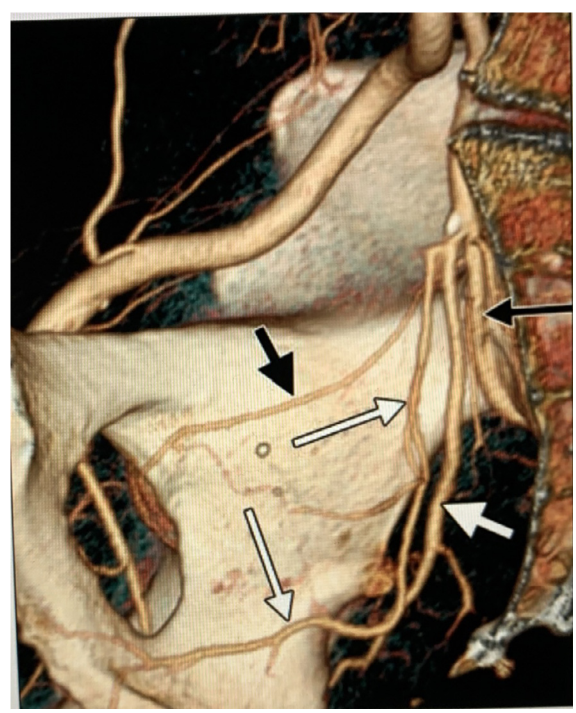

Figure 3 Group C bifurcation of IIA. Lateral projection 3D volume-rendered reformatted CT angiogram shows IIA dividing simultaneously into superior gluteal (thin black arrow), inferior gluteal (thick white arrow), and internal pudendal arteries (thin white arrows). Thick black arrow represents obturator artery arising from superior gluteal artery. (Adapted with permission from Tiago Bilhim T, Pereira JA, Fernandes L, et al.[20])

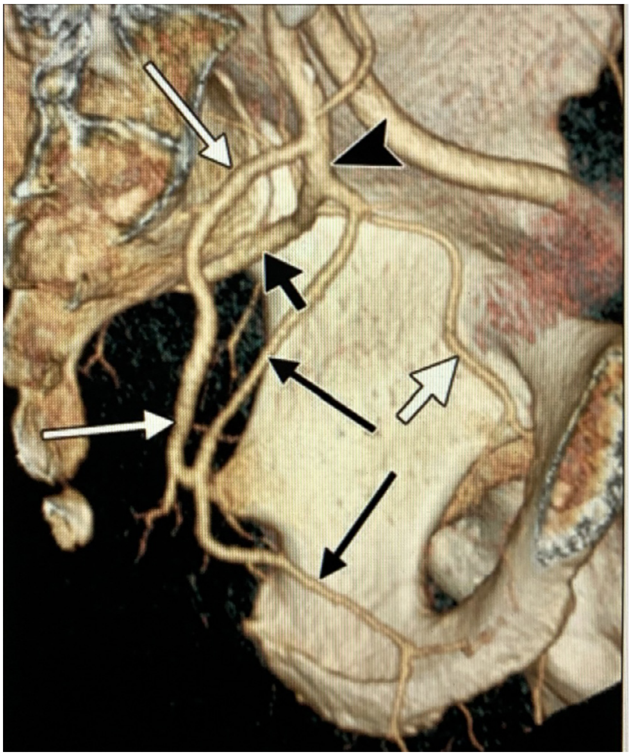

Figure 4 Group D bifurcation of IIA. Lateral projection 3D volume-rendered reformatted CT angiogram shows left IIA dividing into 2 branches: posterior division with inferior gluteal artery (thin white arrows) and anterior division (arrowhead). Anterior division gives rise to superior gluteal artery (thick black arrow) and internal pudendal artery (thin black arrows). Thick white arrow indicates obturator artery arising from superior gluteal artery. (Adapted with permission from Tiago Bilhim T, Pereira JA, Fernandes L, et al.[20])

gluteal and internal pudendal arteries, and into a posterior division which gives rise to the inferior gluteal artery (Fig. 4). This branching pattern is rare, occurring in 0.2% of cases.[10-12]

Table 1 De Assis Classification of the Prostate Artery Origin. (286 Pelvic Sides Evaluated)

Author	I (N)	II (N)	III (N)	IV (N)	V (N)
De Assis (2015)	28.7% (82)	14.7% (42)	18.9% (54)	31.1% (89)	5.6% (16)

PA Origin Classification

In addition to the high variability of the IIA branching, the PAs have a highly variable origin. Using angiographic images from 143 PAE procedures, De Assis et. al analyzed 286 male pelvic sides to classify the PA origins into 5 subtypes (Table 1).[7,13]. A few years later, Carnevale et al discussed the technical details related to each of these subtypes.[8] In type I, the IIA gives off a common trunk consisting of the SVA and IVA. The IVA branches from the common trunk and then continues as the prostatic artery. Based on the length and proximity of the common trunk to the IIA bifurcation, catheterization may be difficult (Fig. 5). In type II, the PA branches directly from the anterior division of the IIA, inferior to the SVA origin, and then continues as the prostatic artery. Compared to the Type 1 pattern, a Type II PA is longer and has fewer branches making catheterization easier (Fig. 6). In type III, the PA branches from the upper or middle third of the OA. It usually has a tortuous angled origin and is a long artery. In contrast, the pelvic branches that originate from the lower third of the OA have a straighter course (Fig. 7). In type IV, the PA branches from the upper or middle third of the IPA (Fig. 8). In type V, the PA has a rare or less common origin. The authors found the PA subtypes in descending order of frequency to be: Type IV (31.1%), Type I (28.7%), Type III (18.9%), and type II (14.7%). The authors concluded that types I-IV accounted for nearly 95% of the PA origins.[7] Four other studies from 2011 to 2018 have analyzed the PA origins and none show a single most common origin.[14-17] Two of the studies show the type IV pattern as the most prevalent[14,16] in agreement with the

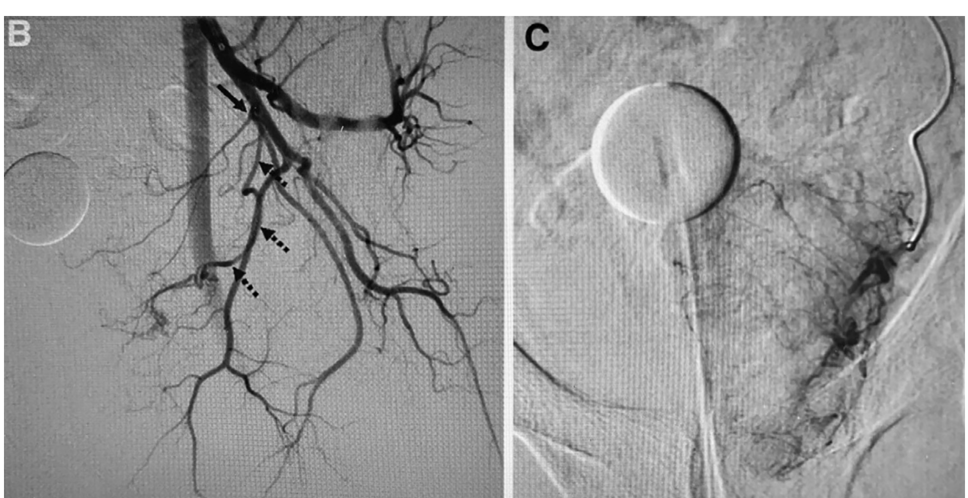

Figure 5 Type I PA branch pattern. Left image shows digital subtraction angiogram of the left IIA and the left PA (dashed black arrows) arising as a common trunk with the superior vesical artery (solid black arrow). Right image shows selective catheterization of the left PA and the classic angiographic blush of the hemiprostate. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

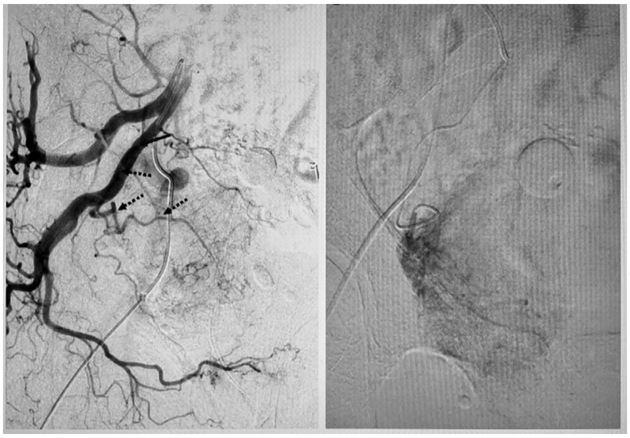

Figure 6 Type II PA branch pattern. Left image shows digital subtraction angiogram of right IIA and the right PA (dashed black arrows) arising directly from the anterior division of the internal iliac artery (solid black arrow). Right image shows selective catheterization of the right PA and the classic angiographic blush of the hemiprostate. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

results shown by De Assis et al. Another study finds the type II pattern to be the most prevalent,[15] while the final study finds the type I pattern to be the most prevalent.[17] Despite the lack of consensus among these studies, between 78% and 100% of cases in these studies were classified as one of the 4 main types as outlined by De Assis et al.

Rare or Less Common Origins of the PA

Rare or less common PA origins are classified as type V in the De Assis classification system (Table 2). In their study, De Assis et al found Type V PA origins 5.6% of the time.[7] The accessory internal pudendal artery was the most common Type V anatomy and the second most common origin was from a trifurcation of the anterior division of the IIA. Additional type V PA origins included the distal internal pudendal artery (Fig. 9), directly from the IIA at a common origin where the anterior division and posterior division arise (Fig. 10), inferior epigastric artery, posterior division of the IIA, proximal third of the inferior gluteal artery, aberrant, or accessory obturator artery (Fig. 11) and the middle rectal artery.[14,17,19]

PA Branching Pattern and Intraprostatic Branch Classification

While PA origins can be variable, there is also variability in terms of intraprostatic blood supply. In 92% of cases, a single PA divides into a superior and inferior prostatic pedicle and in 8% of cases they arise as independent origins.[7,14-16] The superior prostatic pedicle, known as the medial or central gland branch, may be duplicated in 5.6% of hemipelves and primarily supplies the superior and central gland (CG).[7,17,18] The inferior prostatic pedicle, known as the lateral or capsular branch, primarily supplies the peripheral zone (PZ) and apex. These 2 pedicles create an intricate intra-gland anastomotic network.[7,17,18] In 2018, DeMerritt et al proposed a classification system to further characterize dual CG branching and prostate vascularization.[18] This system includes 4 subtypes (Fig. 12):

Type 1A (79.2%) is defined as the classic pattern in which a single main PA divides into CG and PZ branches.

Type 1B (9.7%) is defined as a variant of the classic pattern with separate CG and PZ branches.

Type 2 (6.9%) is defined as at least 2 communicating or overlapping prostate pedicles supplying a single CG compartment (± a separate PZ pedicle).

Type 3 (4.2%) is defined as at least 2 independent, non-communicating prostate pedicles each supplying a

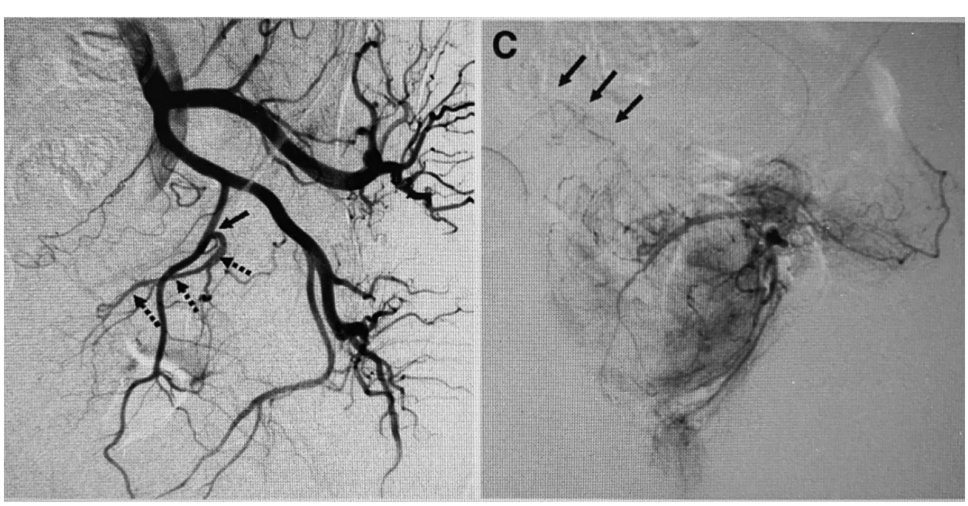

Figure 7 Type III PA branch pattern. Left image shows digital subtraction angiogram of left IIA and PA (dashed black arrows) arising from obturator artery (solid black arrow). Right image shows digital subtraction angiogram after selective catheterization of the left PA with left hemiprostatic angiographic blush along with branches supplying the median prostatic lobe (black arrows). (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

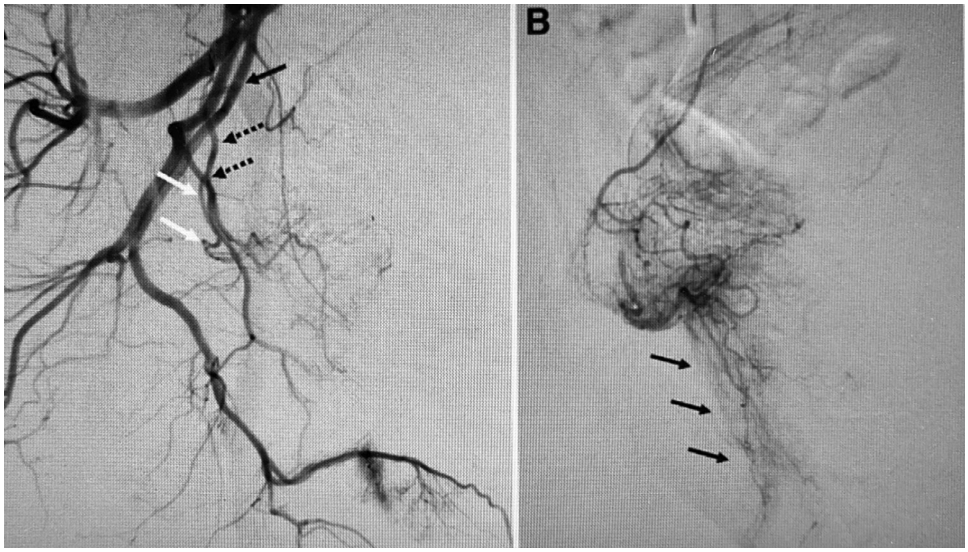

Figure 8 Type IV PA branch pattern. Left image shows digital subtraction angiogram of right IIA and the right PA (dashed black arrows) arising from the internal pudendal artery (solid black arrow). A branch was suspected to supply the rectum (white arrows). Right image shows selective catheterization of the right PA branch confirming both prostate and rectal supply with angiographic rectal blush (black arrows). (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

portion or fraction of the CG, constituting multiple isolated CG compartments (± a separate PZ pedicle).

PA Anastomoses With Adjacent Arteries

PA anastomoses with adjacent arteries are also common as shown by both Bilhim and Zhang.[14,15] Based on cone-beam computed tomography (CT) and digital subtraction angiography (DSA), Zhang showed that the detection of these arterial anastomoses was variable and depended on injection rate, volume, and pressure of the contrast agent used during PA angiography. Specifically, when selective PA DSA was performed with manual contrast injections, fewer arterial anastomoses were visualized compared with using an automatic contrast injector.[15] Although selective DSA obtained with a power injector showed more anastomoses, the filling of these vessels is not always based on physiologic flow.[15] Zhang showed that intra-prostatic anastomoses between PAs and contralateral PA branches were found in 61.8% of hemipelves and Bilhim showed that PA anastomoses to the contralateral and ipsilateral prostatic branches occurred 17.6% and 13.4% of the time, respectively.[14]

Extra-prostatic anastomoses between PAs and adjacent arteries are also common. They are identified in 39.1% of hemipelves. The most frequent anastomoses found were to the internal pudendal artery (25.5%-43.3%), the rectal

Table 2 De Assis Type V Anatomy (Rare or Less Common Origins of the PA). (286 Pelvic Sides Evaluated)

Author	PA Origin	Prevalence (N)
De Assis (2015)	aIPA	2.1% (6)
	Trifurcation of Anterior Division IIA	1.8% (5)
	Quadrifurcation of Anterior Division of IIA	0.35% (1)
	Inferior epigastric artery	0.35% (1)
	Posterior division of IIA	0.35% (1)
	Distal segment of the IPA	0.35% (1)
	Prox 1/3 Inferior Gluteal Art	0.35% (1)

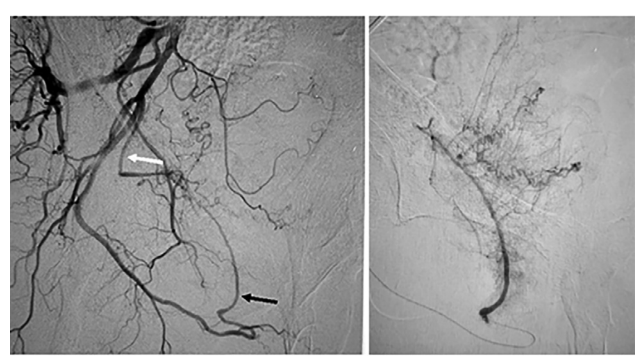

Figure 9 Type V PA branch pattern. Left image depicts right internal iliac artery digital subtraction angiogram showing the right PA (black arrow) arising as a terminal branch from the IPA. Middle rectal artery (white arrow). Right image depicts digital subtraction angiogram of the right PA arising from the IPA with a classic angiographic blush of the right hemiprostate. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

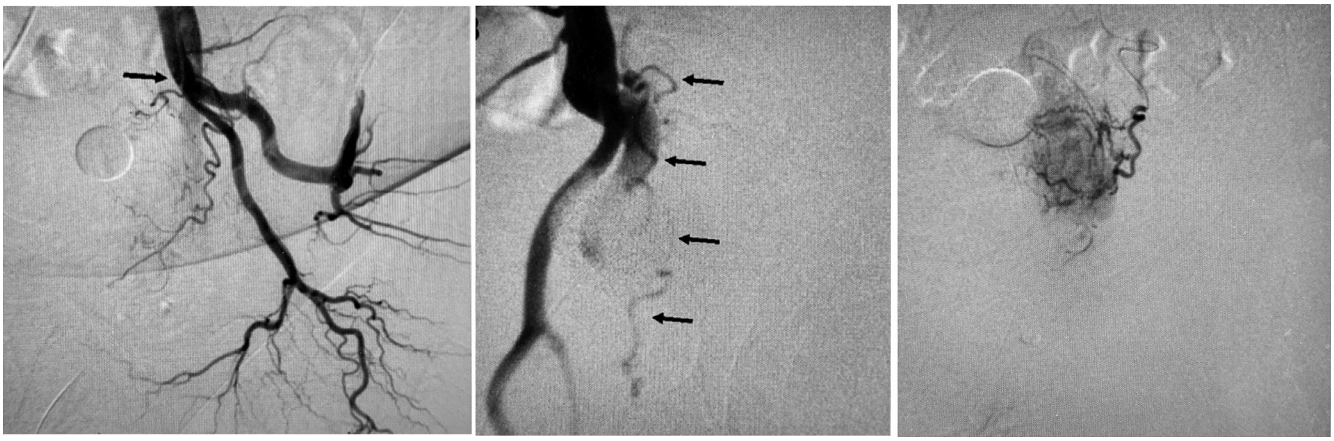

Figure 10 Type V PA branch pattern. Left image shows digital subtraction angiogram of the left IIA and the PA (black arrows) arising directly from the IIA at a common origin where the anterior division (superimposed on the proximal PA) and posterior division of the IIA also arise. Middle image shows orthogonal oblique digital subtraction angiogram of the left IIA profiling the origin of the left PA (black arrows) to allow for easier cannulation. Right image shows digital subtraction angiogram through a microcatheter in the left PA confirming prostatic angiographic blush prior to embolization. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

branches (14.4%-16.4%; Fig. 13), both the internal pudendal artery and rectal branches (6.4%), and the vesicle arteries (3.6%-11.3%) (Fig. 14).[14,15] PAs were found to have no significant anastomoses to the obturator artery or the inferior gluteal artery.[15]

Using CT angiography and selective PA DSA, Bilhim et al also found 2 different types of anastomoses relevant during embolization. One through small pericapsular and postcapsular branches and the other through large precapsular branches that course alongside the anterior and lateral aspect of the prostate from the base to the apex. These branches terminate in the perineum with anastomoses to the internal pudendal artery (also called lateral accessory pudendal arteries). This is important because the IPA in the perineum terminates into the perineal scrotal artery and the penile artery. Therefore a search for this penile collateral

Figure 11 Type V PA branch pattern. Left image shows digital subtraction angiogram of the left IIA, SVA (black arrow), IVA (white arrow), and IPA (dashed black arrow). "Empty Pelvis Sign" with no OA seen. Middle image shows digital subtraction angiogram of the left external iliac artery with a common trunk supplying the inferior epigastric artery (black arrow) and OA (white arrow). The left PA (dashed black arrow) arises from the OA. Right image shows digital subtraction angiogram through a microcatheter in the left PA confirming supply to the left hemiprostate but also cross-filling into the right hemiprostate. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

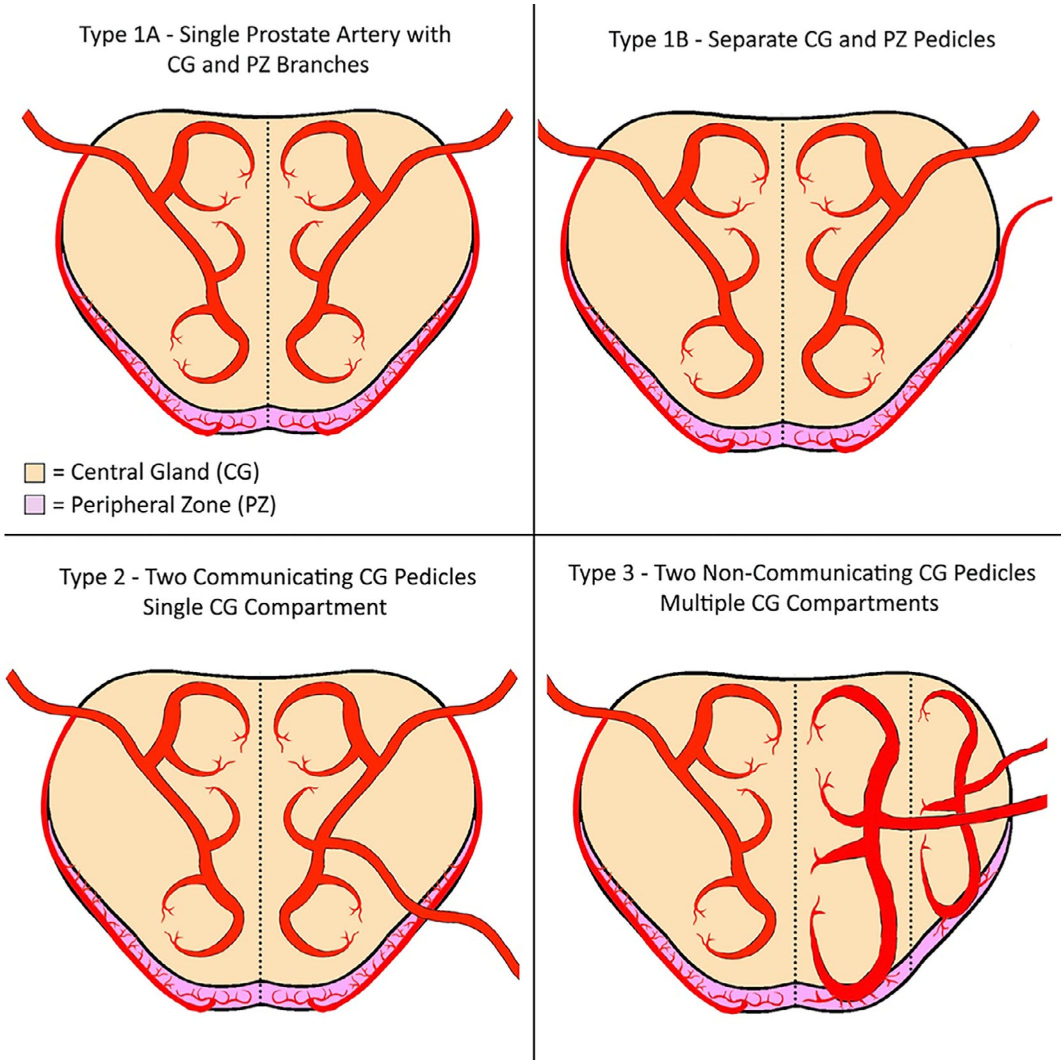

Figure 12 Visual coronal plane representation of DeMeritt classification system for CG Branching and Prostate Vascularization. The left hemiprostate in each example is the portion of the prostate demonstrating the subtype. Note that Types 1 and 2 both reflect a single CG vascular compartment, only differing in the number of CG pedicles. Type 3 reflects multiple CG vascular compartments with corresponding multiple noncommunicating CG vascular pedicles. In Type 3 vascularization, the classic intra-prostatic arborization pattern into medial and lateral branches is not depicted, with split CG and PZ supply conforming to the orientation of their respective vascular compartments. Types 2 and 3 are illustrated without an independent PZ pedicle. (Adapted with permission from DeMeritt JS, Wajswol E, Wattamwar A, et al.[18])

supply is important to avoid nontarget embolization and prevent penile region ulceration/necrosis and sexual dysfunction (Fig. 15).[13,20]

Conclusion

PAE is a promising new minimally invasive treatment option for patients with benign prostatic hyperplasia-associated lower urinary tract symptoms. An expert knowledge of the anatomy is essential to perform the procedure in an efficient manner and achieve optimal clinical outcomes without nontarget embolization to periprostatic tissues. Despite the high vascular variation in the pelvis, 3 clinically relevant classification systems can be used to understand IIA branching pattern, PA origin variation, and intra-prostatic branches. Hopefully, by outlining the most common presentations of the pelvic and prostate arterial vasculature and some rare variants, the reader can use this article as a primer and guide to better understand PA anatomy.

Figure 13 PA branches to rectum. Digital subtraction angiogram shows left PA arising from the IPA with branches to the rectum. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

Figure 14 PA branches to the IVA. Left image shows right digital subtraction angiogram of a common trunk to the right IVA (white arrow) and PA (black arrow). The right IVA was embolized with a 4 mm × 2 cm Tornado (Cook, Inc, Bloomington, IN) coil to protect the bladder from nontarget embolization. Minimal flow into the IVA and preferential flow into the PA was seen postembolization. Right image shows selective digital subtraction angiogram after advancing the microcatheter into the PA with classic right prostatic angiographic blush. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

Figure 15 PA branches to the cavernosal artery and dorsal penile supply. Left image shows right PA digital subtraction angiogram showing communication with the cavernosal artery and dorsal penile supply. Right image shows right PA angiogram with predominant right hemiprostate angiographic blush after 4 mm × 8 cm coil embolization (black arrow) of this branch distal to the intraprostatic feeders. (Adapted with permission from Bhatia R, Sinha VK, Abdul-Rahim O, et al.[21])

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