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Angiographic Anatomy of the Prostatic Artery in the Korean Population: A Bicentric Retrospective Study

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Objective: The aim of this study was to analyze the origins of prostatic arteries (PAs) in the Korean population and compare them with those reported in the literature.
Materials and Methods: From April 2018 to February 2024, 108 male (mean age ± standard deviation: 71.6 ± 9.7 years) with lower urinary tract symptoms (n = 102) or refractory hematuria (n = 6) underwent prostatic artery embolization (PAE). Computed tomography and angiography images were retrospectively reviewed. The branching pattern of the internal iliac artery (IIA) was classified according to the Yamaki system. The origin of the PA was categorized using the de Assis definition, and the incidence of each type was recorded. A systematic literature review was conducted and the most common types of PA were investigated.
Results: PAE was successfully implemented on 211 of the 216 pelvic sidewalls. PA cannulation failed in five sidewalls due to a steno-occlusive state. The most common IIA type was type A, in which the IIA was divided into the superior gluteal artery and gluteal–pudendal trunk (77%). Of 226 PAs analyzed, including 15 in 211 sidewalls exhibiting dual PAs, the most common PA origin was the internal pudendal artery (type IV, 35%), followed by the superior vesical (type I, 25%) and obturator (type III, 21%) arteries. Anterior division of IIA (type II) was less common (10%). Type V (uncommon origins) occurred in 8% of cases, including five distal internal pudendal arteries, four quadfurcations, three inferior gluteal arteries, three trifurcations, two medial femoral circumflex arteries, and two rectal arteries. Two of the five patients with surgically or endovascularly altered anatomy were successfully treated via PAs originating from the medial femoral circumflex arteries. Globally, type I is the most common PA type.
Conclusion: In the Korean population, the most common IIA pattern and PA origin were types A and IV, respectively.
Keywords: Prostatic artery; Benign prostatic hyperplasia; Prostatic cancer; Prostatic artery embolization; Anatomy; Lower urinary tract symptoms

INTRODUCTION

Since DeMeritt et al. [1] first described prostatic artery embolization (PAE) for hematuria in 2000, PAE has emerged as an important armamentarium in the treatment of lower urinary tract symptoms (LUTS). A recent meta-analysis revealed that PAE provides efficacy comparable to surgical treatment, but with better safety [2]. Furthermore, its application can be broadened to cancer-related treatments for hematuria and chemoembolization [3,4]. However, PAE remains a challenge for many practitioners because it is time consuming, requires a high level of effort, and carries a risk of unexpected complications. A complete understanding of the anatomy of the prostatic artery (PA) is crucial to successfully treat LUTS without adverse events. Meanwhile, a literature review suggested that PA origins can have characteristics associated with particular ethnic groups that may differ between individuals of Western and Eastern

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origins. This study aimed to analyze the origins of PAs in a Korean population with LUTS or refractory hematuria and compare the observations with those in the literature.

MATERIALS AND METHODS

This bicentric, retrospective study was approved by the Institutional Review Board of Incheon Saint Mary's Hospital (IRB No. OC24RIDI0043) and Ewha Woman's University Seoul Hospital (IRB No. 2024-03-051). The requirement for informed consent was waived due to the retrospective nature of the study. Some of the study participants (53 of 108 patients) have been described in a previous study [5]. The previous study [5] addressed the technical outcomes of transradial PAE, whereas the current study focuses on the anatomy of the internal iliac artery (IIA) and PA.

Patients

A total of 108 patients (mean age = 71.6 ± 9.7 years) with LUTS (n = 102) or malignant hematuria (n = 6) underwent PAE from April 2018 to February 2024 (Table 1). Seventy-five patients were treated at Incheon St. Mary's Hospital and 33 were treated at Ewha Womans University Seoul Hospital. Indications for PAE included medically refractory LUTS and multiple comorbidities; unwillingness to undergo surgical treatment; failure to receive minimally invasive treatment, such as UroLift; and prostatic-cancer–induced uncontrollable hematuria.

Table 1. Patients' characteristics

Variable	Value
Total patients	108
Age, yrs	71.6 ± 9.7
Indication for PAE	
LUTS	102 (94)
Refractory hematuria	6 (6)
Prostatic volume, mL	75 ± 58
IPSS	22 ± 8
QoL	4.1 ± 1.4
Qmax, mL/s	7.7 ± 5.0
PSA, ng/mL	4.2 [2.0–9.8]

Data are number of patients (percentage), mean ± standard deviation, or median [interquartile range].
PAE = prostatic artery embolization, LUTS = lower urinary track symptoms, IPSS = international prostate symptom score, QoL = quality of life, Qmax = peak flow rate, PSA = prostate-specific antigen

Computed Tomography Angiography

Preprocedural computed tomography angiography (CTA) was performed to assess the vascular anatomy and determine procedural feasibility. The CT scans performed at Incheon St. Mary's Hospital (64 slices; Aquilion PRIME; Canon Medical Systems, Otowara, Japan) included arterial and 80-seconds delayed phases with 100–120 mL of contrast medium (Iomeron 350; Bracco, Milan, Italy) and reconstructed 1- and 5-mm thicknesses, respectively. The CT scanning parameters were as follows: 262 mAs with 100 kVp; matrix size, 512 x 512; collimation, 6.2 mm; slice thickness, 1.0 mm; pitch, 0.810. Ewha Womans University Seoul Hospital also obtained CTAs before the procedure, including pelvic arterial phase CT and delayed lower-extremity scan with 130 mL of contrast medium (Omnihexol 350; Korea United Pharm, Seoul, Korea) and reconstructed 1.25- and 5-mm thicknesses, respectively. The CT scanning parameters were as follows: 262 mAs with 100 kVp; matrix size, 512 x 512; collimation, 6.2 mm; slice thickness, 1.0 mm; pitch, 0.810.

Prostatic Artery Angiography

Two angiography machines of the same model (Allura Xper FD20; Philips Healthcare, Best, the Netherlands) at Incheon St. Mary's Hospital and one angiography machine (Artis Q Biplane; Siemens Healthineers, Forchheim, Germany) at Ewha Womans Seoul University Hospital were used for PAE. Ipsilateral oblique angiograms of the IIAs were obtained, and contralateral oblique angiograms were obtained, depending on each patient's anatomy, to obtain the best view of the PA origin. Cone-beam CT (CBCT) with transcatheter contrast media injection (0.2–1.0 mL/s, depending on the arterial diameter, for 10–12 seconds with a 4-seconds delay) was obtained for all patients for catheterization of the PA or identification of unexpected communications with non-target organs. In patients with complex vascular anatomy, CBCT with IIA catheterization (2–3 mL/s for 10–12 seconds with a 4-seconds delay) was performed to clearly visualize the PA origin [6]. Various combinations of microcatheters and guide wires were used for PA catheterization. The most commonly used microcatheters included Progreat Lambda (130/150/170 cm, 1.7/1.9 Fr; Terumo, Tokyo, Japan), Direxion (105/130/155 cm, 2.4 Fr; Boston Scientific, Marlborough, MA, USA), Merit Pursue (110/130/150 cm, 1.7 Fr; Merit Medical, South Jordan, UT, USA), and ASAHI Veloute (105 cm, 1.7 Fr; Asahi Intecc, Aichi, Japan). The guidewires were 0.016 inches (ASAHI Meister; Asahi Intecc)

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or 0.014 inches (Transend; Boston Scientific).

Definition and Classification of the IIA and the PA

PAs communicating with non-target arteries were defined as those with a connection between the prostate and a rectal or penile artery. These can lead to clinically significant adverse events, such as hematochezia or penile skin necrosis, requiring coil embolization of the non-target artery or super-selective embolization to avoid embolization of the non-target artery.

IIA branching patterns were classified according to the Yamaki system, which divides IIAs into four groups according to three main branches: the superior and inferior gluteal and internal pudendal arteries (Fig. 1) [7]. PA types were classified according to the de Assis definition, which classifies PAs into five types [8]. Patients who have undergone surgery or endovascular treatment often develop unique collateral supplies; therefore, a surgically or

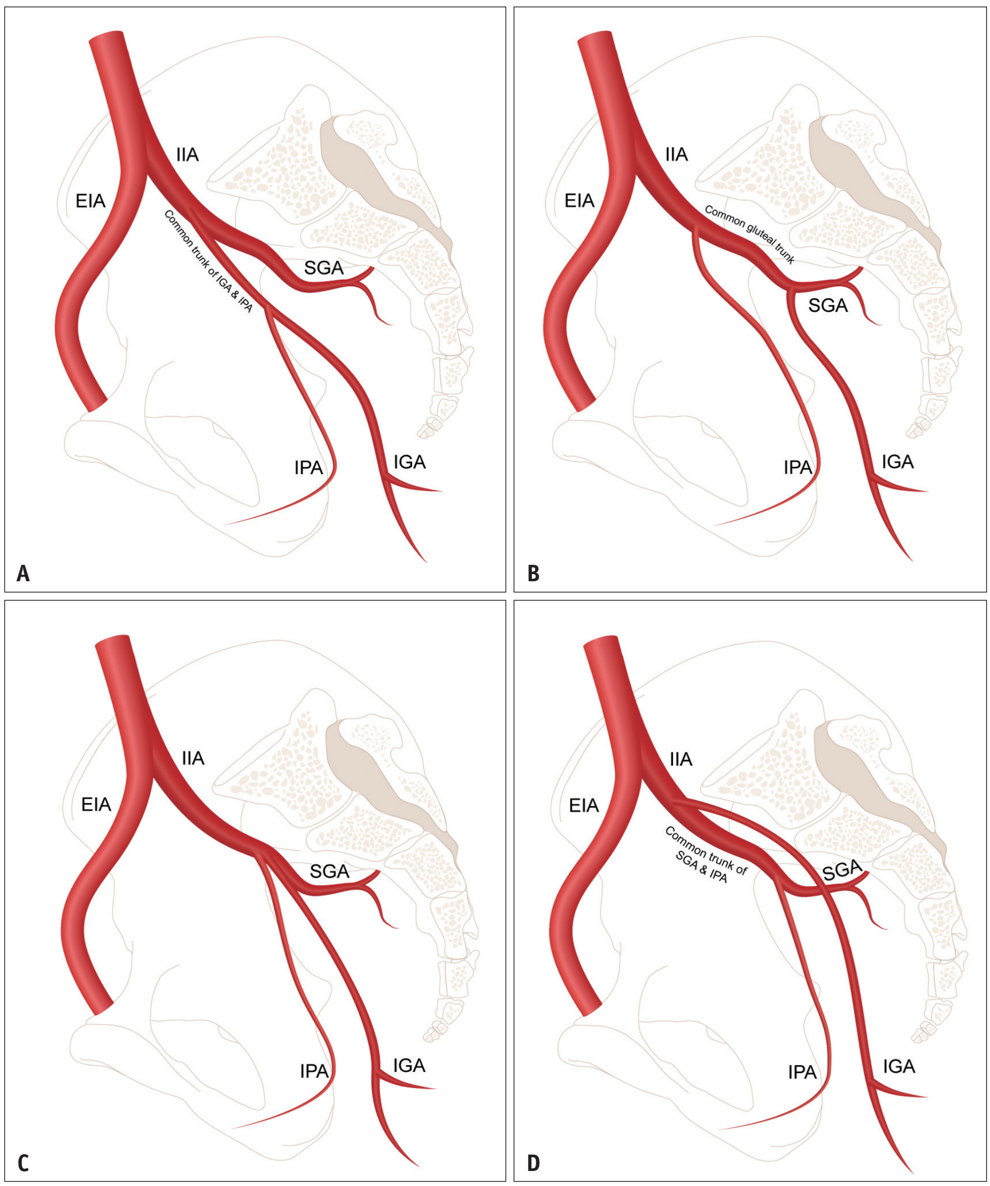

Fig. 1. Illustrations of the IIA branching patterns. The IIA can be classified into four types according to the branching pattern of the SGA and IGA and the IPA. **A:** The IIA divides into the gluteal–pudendal trunk and the SGA. The gluteal–pudendal trunk gives rise to the IPA and the IGA. **B:** The IIA branches into the IPA and the gluteal trunk. The gluteal trunk divides into the SGA and the IGA. **C:** The IIA trifurcates into the SGA, the IGA, and the IPA. **D:** The IIA gives early rise to the IGA and the gluteal–pudendal trunk. The gluteal–pudendal trunk branches into the SGA and the IPA. IIA = internal iliac artery, SGA = superior gluteal artery, IGA = inferior gluteal artery, IPA = internal pudendal artery, EIA = external iliac artery

endovascularly altered anatomy category was added to the de Assis classification.

Imaging and Statistical Analyses

A radiology resident (S.L.) and an interventional radiologist with 9 years of experience (D.J.S.) reviewed all relevant images. Discrepancies between the readers' opinions were resolved by a third party, an interventional radiologist with 6 years of experience (D.K.). The branching pattern of the IIA and origin of the PA were categorized on CTA images. Angiographic and CBCT images were subsequently assessed using standard methods. Preprocedural analyses were compared with the angiographic images. Data were assessed using a spreadsheet program (Excel; Microsoft, Redmond, WA, USA) and a statistical program (MedCalc, v22.021; MedCalc Software Ltd., Ostend, Belgium). The normality of each PA type within European and Asian populations was evaluated using the Shapiro-Wilk test, and the frequency of PA types in European and Asian populations was compared using an independent-samples Student's *t*-test.

Literature Review

A systematic literature review was conducted using the queries detailed in Supplementary Table 1 to identify studies on PA anatomy. The PubMed, Embase, and Cochrane Library databases were queried by one author (D.J.S.), an interventional radiologist with 10 years of experience. Among the literature retrieved, relevant studies classified according to the de Assis classification reports were reviewed, and the most common types of PA and the countries of origin of the affected patients were investigated.

RESULTS

Preprocedural prostatic CTAs dedicated to the PA (thin-section reconstructed images of the pelvis less than 1.5 mm thick) were obtained for 101 patients. The CTA findings were in concordance with the angiographic findings in 159 of the 202 sidewalls (79%).

PAE was successfully implemented for 211 of the 216 pelvic sidewalls. PA cannulation failed in five sidewalls due to severe stenosis of the PA orifices (n = 2) or total IIA occlusion (n = 3). Among these patients, two underwent unilateral IIA embolization accompanied by endovascular aneurysm repair, and one patient had post-surgical altered anatomy (rectal cancer). The other two sidewalls could not be cannulated because of severe orifice stenosis with acute angles.

The most common IIA was the A-type (divided into the superior gluteal artery and gluteal–pudendal trunk, 76%). Fifteen of 216 sidewalls exhibited dual PAs. The origins of 226 PAs (15 dual and 196 single) were investigated, including both single and dual origins (Table 2). The most common type of PA had an internal pudendal artery (IPA) origin (type IV), accounting for 34.5% of cases, followed by a superior vesical artery origin (type I, 24.8%) and an obturator origin (type III, 21.2%). An anterior division of the IIA origin (type II, 10.2%) was less common. Type V (uncommon origin) arteries occurred in 8.4% of cases, including five distal IPAs, four quadfurcations, three inferior gluteal arteries, three trifurcations, two medial femoral circumflex arteries, and two rectal arteries. Five pelvic side walls were associated with postsurgical and endovascular aneurysm repair. Among them, three PAs were totally occluded, and two PAs were reconstituted via a medical femoral circumplex artery and were successfully treated. Representative images and illustrations are shown in Figures 2-7.

Non-target artery communications were found in 12 sidewalls, comprising six rectal and six penile arteries. The connections were embolized with microcoils (Concerto; Medtronic, Minneapolis, MN, USA) in four PAs, six connections were treated in a super-selective manner, and the treatment

Table 2. Frequencies of the types of internal iliac and prostatic arteries in this study

Type	No (%)	Description
Internal iliac artery (n = 216)		
A	165 (76)	
B	43 (20)	
C	3 (1)	
D	0 (0)	
Unclassifiable	5 (2)	
Prostatic artery (n = 226)		
I	56 (25)	Superior vesical artery
II	23 (10)	Anterior segment of internal iliac artery
III	48 (21)	Obturator artery
IV	78 (35)	Internal pudendal artery
V*	19 (8)	Other uncommon origins
Surgically/endovascularly altered anatomy	2 (1)	Medial femoral circumflex artery

*Details of type V: distal internal pudendal artery = 5; quadfurcation = 4; trifurcation = 3; inferior gluteal artery = 3; medial femoral circumflex artery = 2; rectal artery = 2

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was aborted in two PAs as the risks outweighed the benefits.

Seventeen studies were included in the systematic literature review (Supplementary Fig. 1, Supplementary Table 2). Type I was the most common type of PA globally (32%, 95% confidence interval [CI] 26–37). When PAs were grouped by region, type IV was most common in European

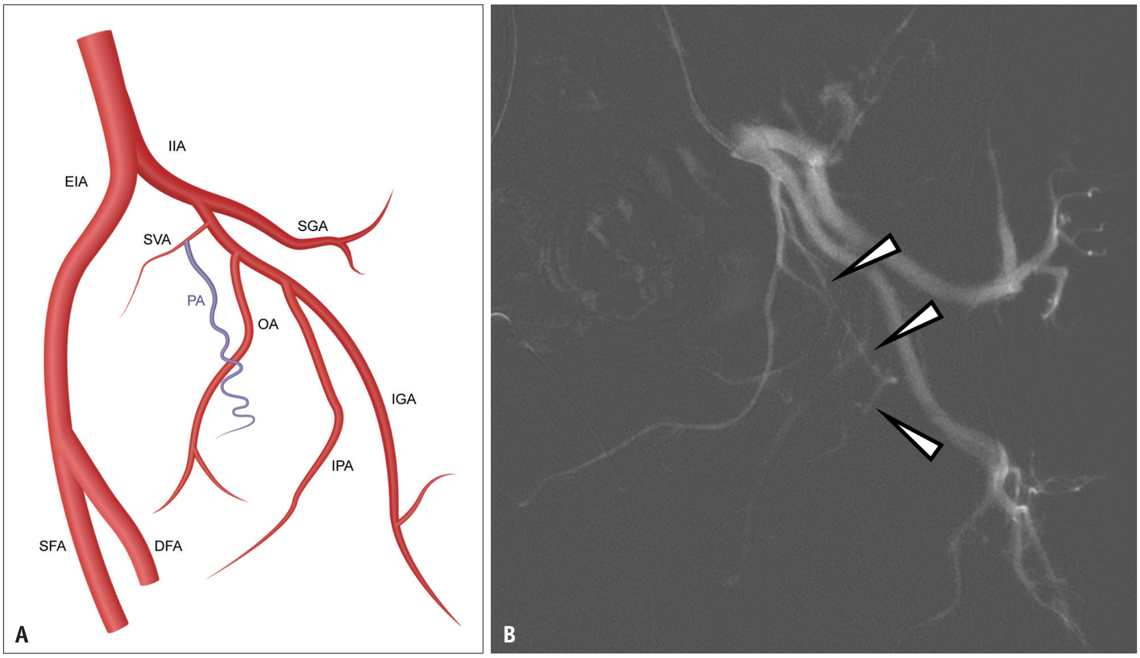

Fig. 2. Illustration and representative case of a type I PA. **A:** Illustration of a type I PA. **B:** Microcatheter angiogram of the left SVA on the left oblique view showing the PA (arrowheads) branching from the SVA and a typical tortuous running of the PA. PA = prostatic artery, SVA = superior vesical artery, IIA = internal iliac artery, EIA = external iliac artery, SGA = superior gluteal artery, OA = obturator artery, IGA = inferior gluteal artery, IPA = internal pudendal artery, SFA = superficial femoral artery, DFA = deep femoral artery

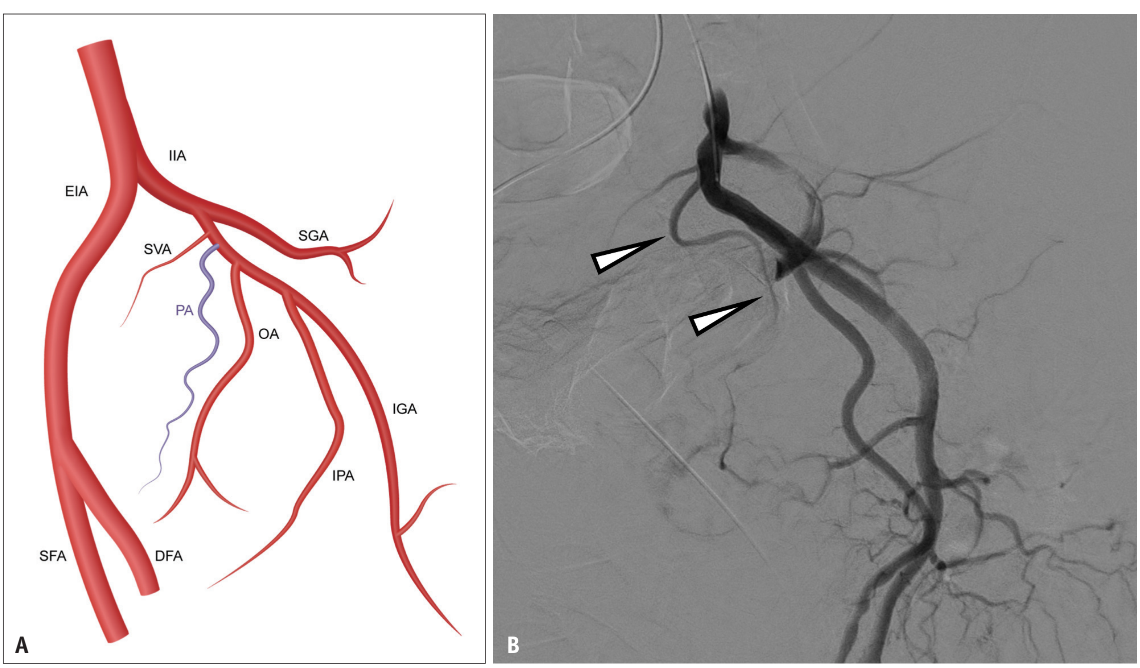

Fig. 3. Illustration and representative case of a type II PA. **A:** Illustration of a type II PA. **B:** Microcatheter angiogram of the right IIA on the left oblique view showing the direct origin of the PA (arrowheads) from the anterior division of the IIA. PA = prostatic artery, IIA = internal iliac artery, EIA = external iliac artery, SGA = superior gluteal artery, SVA = superior vesical artery, OA = obturator artery, IGA = inferior gluteal artery, IPA = internal pudendal artery, SFA = superficial femoral artery, DFA = deep femoral artery

countries (32%, 95% CI 25–40), whereas type I was more common in Asian countries (34%, 95% CI 23–45). However, the trends were inconsistent among the same countries and regions regarding PA type distribution, and there were no statistically significant differences between European and Asian populations.

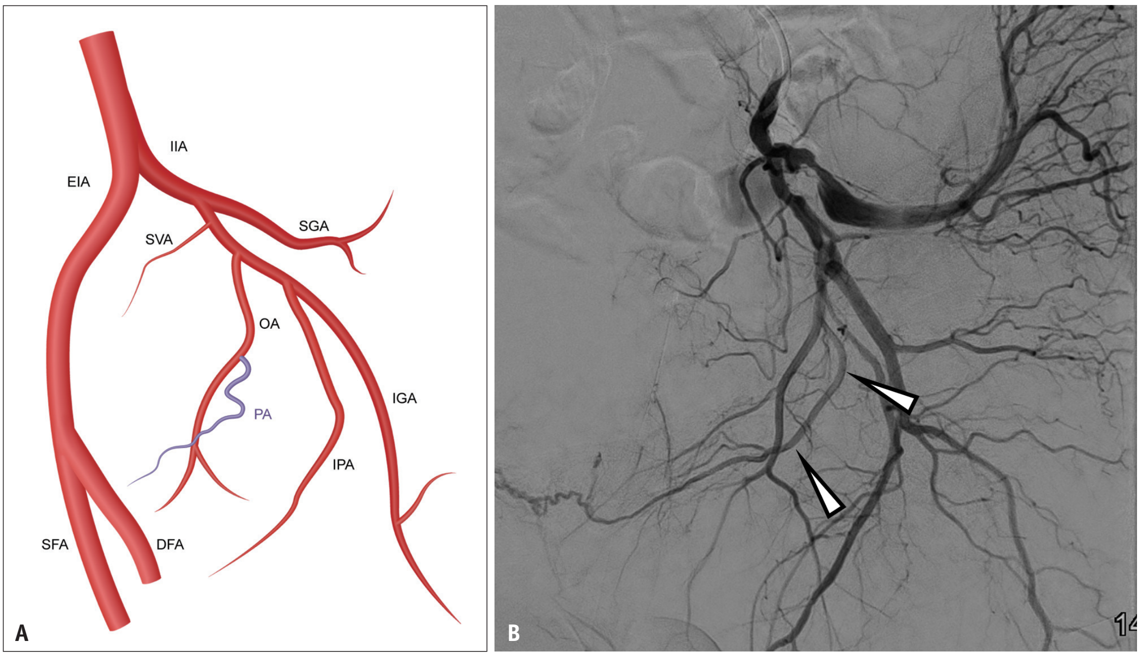

Fig. 4. Illustration and representative case of a type III PA. **A:** Illustration of a type III PA. **B:** Angiogram of the left IIA on the left oblique view showing the PA (arrowheads) originating from the OA. PA = prostatic artery, IIA = internal iliac artery, OA = obturator artery, EIA = external iliac artery, SGA = superior gluteal artery, SVA = superior vesical artery, IGA = inferior gluteal artery, IPA = internal pudendal artery, SFA = superficial femoral artery, DFA = deep femoral artery

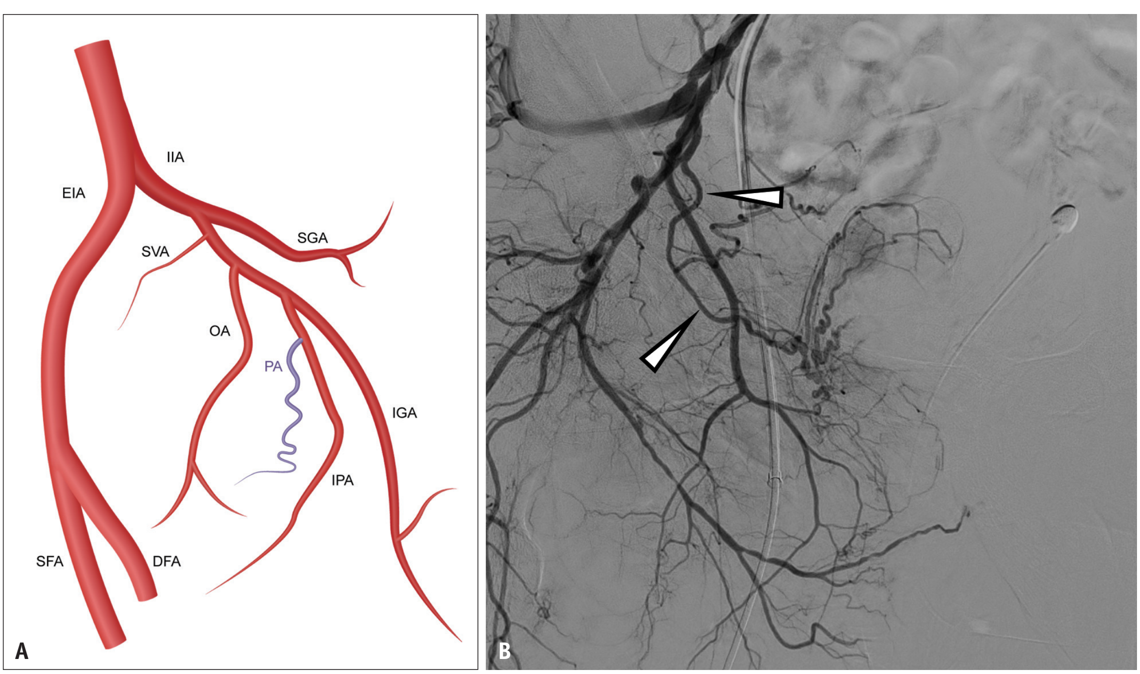

Fig. 5. Illustration and representative case of a type IV PA. **A:** Illustration of a type IV PA. **B:** Angiogram of the right IIA on the right oblique view showing the PA (arrowheads) originating from the IPA. PA = prostatic artery, IIA = internal iliac artery, IPA = internal pudendal artery, EIA = external iliac artery, SGA = superior gluteal artery, SVA = superior vesical artery, OA = obturator artery, IGA = inferior gluteal artery, SFA = superficial femoral artery, DFA = deep femoral artery

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DISCUSSION

In our study population, the most common IIA branching type was type A (76.4%), and the most common PA was type IV (34.5%), followed by type I (24.8%), type III (21.2%), type II (10.2%), and type V (8.4%). Surgical

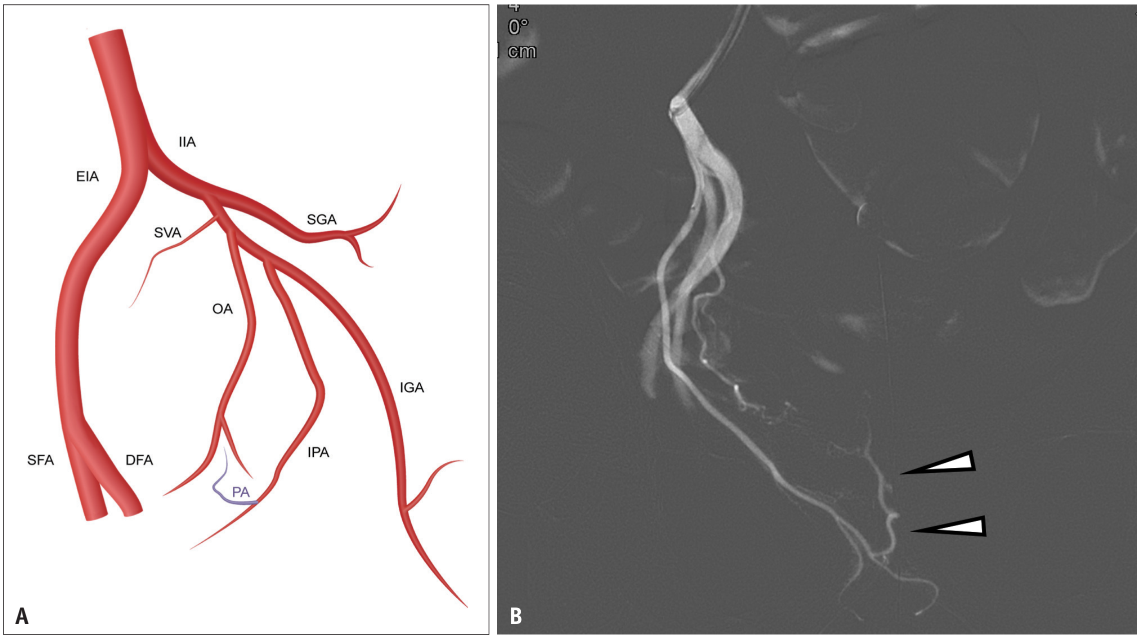

Fig. 6. Illustration and representative case of a type V PA. **A:** Illustration of a type V PA. **B:** Microcatheter angiogram of the right IIA on the right oblique view showing the PA (arrowheads) originating from the distal IPA. PA = prostatic artery, IIA = internal iliac artery, IPA = internal pudendal artery, EIA = external iliac artery, SGA = superior gluteal artery, SVA = superior vesical artery, OA = obturator artery, IGA = inferior gluteal artery, SFA = superficial femoral artery, DFA = deep femoral artery

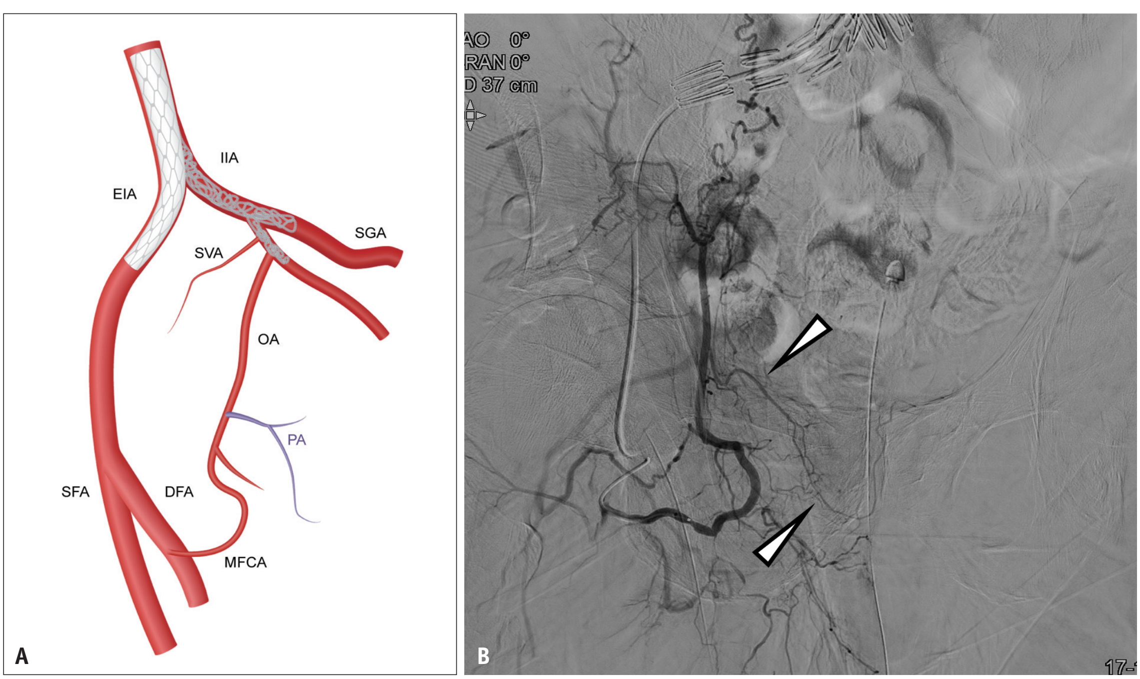

Fig. 7. Illustration and representative case of surgically or endovascularly altered anatomy after endovascular aneurysm repair. **A:** Illustration of a PA after endovascular aneurysm repair. **B:** Microcatheter angiogram of the right MFCA on an anteroposterior view showing the PA (arrowheads) originating from the reconstituted obturator artery. PA = prostatic artery, MFCA = medial femoral circumflex artery, IIA = internal iliac artery, EIA = external iliac artery, SGA = superior gluteal artery, SVA = superior vesical artery, OA = obturator artery, SFA = superficial femoral artery, DFA = deep femoral artery

or endovascularly altered anatomy accounted for 0.9% of cases. In a systematic literature review, type I PAs were most common (32%) in a global pooled analysis [8-24]. However, the prevalence of anatomical types varied greatly, both regionally and within a single country. In European countries, the most common type of PA was type IV followed by type I. In contrast, studies from Asia, including those conducted in China, Korea, and Vietnam, reported that type I was the most common type of PA, followed by type IV (Table 3). However, there were no statistically significant differences between European and Asian populations. Given the differences in the length of the common iliac artery among various ethnicities [25], further studies may be warranted to substantiate any actual ethnicity-associated differences. Another noteworthy finding that diverges from previous studies concerned the aberrant origin of the PA. In previous research, the PA was reported to originate from the corona mortis arising from the inferior epigastric artery [7,26-28]. However, in the present study, the PA frequently arose from the medial circumflex femoral artery via the deep femoral artery, particularly in cases of IIA occlusion. This finding is consistent with that of a Japanese study on anatomical changes after endovascular aneurysm repair, which suggested that the PA could be primarily reconstituted via the medial circumflex femoral artery [29].

When implementing PAE, understanding the PA anatomy is crucial for ensuring safe and effective treatment. First, an understanding of the anatomy can improve technical success rates. Second, it is essential to avoid non-target embolization, which can lead to various complications,

Table 3. Frequencies of PA origins in the literature, including those described in this study

Reference	Continent	Country	No. of PAs	Types of PA						Types in frequency-based order				
				I	II	III	IV	V	M/C type V	1st	2nd	3rd	4th	5th
Şerbănoiu et al. [9]	Europe	Romania	70	21	27	11	37	3	IGA	IV	II	I	III	V
Moschouris et al. [10]	Europe	Greece	355	31	16	13	31	9	Accessory IPA	IV	I	II	III	V
Vogl et al. [11]	Europe	German	108	19	5	11	51	14	Tri-/quadfurcation	IV	I	V	III	II
Boeken et al. [12]	Europe	France	430	37	6	17	27	9	IGA	I	IV	III	V	II
Enderlein et al. [13]	Europe	Germany	160	28	20	24	23	5	IGA	I	III	IV	II	V
Anract et al. [14]	Europe	France	80	55	1	18	25	1	SGA	I	IV	III	II	V
Maclean et al. [15]	Europe	UK	220	18	23	19	36	4	Replaced OA	IV	I	V	III	II
Bilhim et al. [16]	Europe	Portugal	150	20	18	13	34	15	IGA	IV	I	II	V	III
Amouyal et al. [17]	Europe	France	143	35	13	15	31	5		I	IV	III	II	V
Eldem et al. [18]	Middle East	Turkey	119	36	11	19	29	6	Accessory IPA	I	IV	III	II	V
Fu et al. [19]	Asia	China	352	52	5	8	29	7	MRA	I	IV	III	V	II
Xuan et al. [20]	Asia	Vietnam	630	34	14	18	24	10	Accessory OA	I	IV	III	II	V
Zhang et al. [22]	Asia	China	106	22	30	19	26	3	Accessory IPA	II	IV	I	III	V
Wang et al. [24]	Asia	China	296	37	31	5	24	3	MRA	I	II	IV	III	V
Zhang et al. [25]	Asia	China	110	33	40	0	28	0		II	I	IV	III	V
Lee et al.†	Asia	Korea	216	25	10	21	35	8	Distal IPA	IV	I	III	II	V
de Assis et al. [8]	South America	Brazil	286	20	18	13	34	15	Accessory IPA	IV	I	II	V	III
Basiouny et al. [21]	Africa	Egypt	165	49	22	18	9	2	Accessory IPA	I	II	III	IV	V
Regional analysis														
	Europe	Mean		30	13	16	32	8		IV	I	III	II	V
		L 95% CI		20	4	13	25	4						
		U 95% CI		41	19	20	40	12						
	Asia*	Mean		34	22	12	28	5		I	IV	II	III	V
		L 95% CI		23	7	3	23	1						
		U 95% CI		45	36	21	32	9						
	Global	Mean		32	17	14	30	7		I	IV	II	III	V
		L95CI		26	12	11	25	4						
		U95CI		37	22	17	34	9						

*Includes China, Vietnam, and Korea, †Presenting study.
PA = prostatic artery, M/C = most common, IGA = inferior gluteal artery, IPA = internal pudendal artery, SGA = superior gluteal artery, OA = obturator artery, MRA = middle rectal artery, L 95% CI = lower 95% confidence interval, U 95% CI = upper 95% confidence interval

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such as hematuria, hemospermia, rectal ulceration or bleeding, and penile injury [28]. Third, a comprehensive understanding of the anatomy can considerably reduce the procedure time and radiation exposure of the patient. PAE is notorious for its extended procedure time, because of the numerous anatomical variations of the PA, which are often obscured by overlapping adjacent arteries on angiography [30]. In addition, the small size of the artery and its abrupt branching patterns can complicate catheterization. Hence, a preprocedural imaging study is indispensable, and the reported accuracy of CTA is 94.2% [15]. However, CTA findings often do not correlate with the angiography results. This discrepancy may be partly due to motion artifacts or the inherent nature of the CT modality and its known difficulties in identifying very short segmental occlusions. Furthermore, the presence of numerous adjacent small arteries can cause confusion; notably, the small diameter of the PA compounds its proper identification. Recently, we adopted a new CTA protocol involving a narrow field of view covering both femoral heads and the administration of a vasodilator. We expect that this protocol will yield reliable results [31]. However, transarterial angiography has several limitations. Angiography and CBCT are often used to confirm proper cannulation of the PA and can be performed using a small amount of contrast medium. However, the entire pelvic vasculature is often not fully recognized using these approaches.

Obtaining ipsilateral oblique images is crucial for the angiographic detection of the PA. These images provide a standard viewpoint, allowing for the precise identification and tagging of each artery. For example, the typical 'L' shape of an IPA can be recognized. The obturator artery gives rise to anterior and posterior branches, often exhibiting a "mermaid tail" shape [32]. Some investigators have noted that the PA tends to cross the obturator artery, a phenomenon dubbed the "crossing obturator sign," which can be appreciated in a 45° ipsilateral oblique view in 90.6% of patients [33].

However, we noted some ambiguities in the nomenclature of the PA types. For instance, although some investigators distinguished the PA from the inferior vesical artery (IVA), others, including us, classified the IVA as a PA. Practically, there was no significant benefit in distinguishing the IVA from the PA. Another example is the classification of a very early origin of the PA from the superior vesical artery, which a practitioner may categorize as a trifurcation (type V) or type I depending on the situation. We propose defining tri- or quadfurcations as cases in which the PA emerges within 3 mm of the origin, as multiple branches with a very short neck can prolong catheterization compared with typical type I cases. The term "distal IPA" can lead to confusion; thus, we propose that PA branching occurring after the angled portion adjacent to the ischial tuberosity should be classified as a distal IPA. Patients with a small accessory inferior gluteal artery can also be a source of confusion. This circumstance may be overlooked by some investigators and classified as a type IV PA, whereas others may categorize it as a gluteal–pudendal trunk or classify it as a type II PA.

This study has several limitations, including its retrospective nature and relatively small sample size. Additionally, although this bicentric study involved two large centers, it was not conducted nationwide, warranting further large-scale research.

In conclusion, the predominant IIA pattern in the Korean population was type A and the most common PA origin was type IV.

Supplement

The Supplement is available with this article at https://doi.org/10.3348/kjr.2024.0451.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Dong Jae Shim. Data curation: Seunghyun Lee, Doyoung Kim, Soo Buem Cho, Seung Hwan Baek. Formal analysis: Dong Jae Shim. Investigation: Doyoung Kim. Methodology: Dong Jae Shim. Project administration: Jung Whee Lee. Resources: Dong Jae Shim. Software: Dong Jae Shim. Supervision: Dong Jae Shim. Validation: Dong Jae Shim. Visualization: Dong Jae Shim. Writing—original draft: Doyoung Kim. Writing—review & editing: Edward Wolfgang Lee, Dong Jae Shim.

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