VIA MEDICA

REVIEW ARTICLE

Folia Morphol.
Vol. 83, No. 3, pp. 517–530
DOI: 10.5603/fm.97800

ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

The anatomy of the internal iliac artery: a meta-analysis

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[Received: 20 September 2023; Accepted: 9 November 2023; Early publication date: 21 November 2023]

Background: *The internal iliac artery (IIA) originates from the common iliac artery at the level of the sacroiliac joint and bifurcates between the L5 and S1 vertebrae. The aim of the present meta-analysis was to demonstrate the most up-to-date and evidence-based data regarding the general anatomy of the IIA, including their variations, length, and diameter.*
Materials and methods: *Major online medical databases such as PubMed, Scopus, Embase, Web of Science, Cochrane Library, and Google Scholar were searched to find all studies considering the anatomy of the IIA. Eligibility assessment and data extraction stages were performed.*
Results: *In the general population the pooled prevalence of Type I (The superior gluteal artery arises independently with the inferior gluteal and internal pudendal arteries arising from a common trunk which dividing inside [Type IA] or outside [Type IB] pelvic cavity) was found to be 56.57% (95% CI: 53.00–60.10%). The pooled mean length of the IIA was 39.95 mm (SE = 1.79) in the overall population. The pooled mean diameter of the IIA was found to be 6.86 mm (SE = 0.27).*
Conclusions: *The IIA is responsible for supplying most of the structures located in the pelvis. Hence, it is crucial to be aware of the possible variants of the said vessel. The results presented in our study may be highly significant in various surgical procedures performed in that region.* (Folia Morphol 2024; 83, 3: 517–530)

Keywords: internal iliac artery, common iliac artery, abdominal aorta, pelvis, surgery, anatomy

INTRODUCTION

The internal iliac artery (IIA) originates from the common iliac artery at the level of the sacroiliac joint and bifurcates between the L5 and S1 vertebrae. The internal iliac vein and the lumbosacral trunk separate the said vessel from the sacroiliac joint. Subsequently, the IIA descends around the greater sciatic foramen and then divides into the anterior and posterior divisions. While descending, it accompanies the external iliac vein medially and the peritoneum laterally [37]. The anterior division later branches into superior and inferior vesical, middle rectal, vaginal, obtura-

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tor, inferior gluteal, and internal pudendal arteries. The uterine and the vaginal arteries occur in women, and in men the inferior vesical artery replaces the vaginal artery, while the uterine artery is absent. The posterior division gives rise to the iliolumbar, lateral sacral, and superior gluteal arteries [37]. The IIA and its branches deliver blood to the pelvic viscera and muscles of the pelvis, the peritoneum, and the gluteal and medial thigh regions. Hence, the IIA is a major supplier of the pelvis.

The cardiovascular system begins to form in the foetus in the mid-third week [41]. The umbilical artery arises as a ventral branch of the dorsal aorta [52], and during prenatal development, the IIA derives from the umbilical artery, which is responsible for the blood and nutrient supply of the placenta. After childbirth, the umbilical cord is cut, and the distal parts of the umbilical artery occludes. Postnatally, the remaining part of the umbilical artery is the IIA [37, 48]. Additionally, the distal part of the umbilical artery obliterates into the medial umbilical ligament [49]. The process of forming the IIA and its branches varies significantly. As a result, the vascular pattern of the IIA differs in the population [33].

Over the years, researchers created numerous classification systems to distinguish variants of the IIA and its branches. In 1928, Adachi [1] formulated a classification system that became the most popular. This classification assumes that the umbilical artery is a continuation of the main stem of the IIA, while the superior gluteal, inferior gluteal, and internal pudendal arteries are the principal branches of the IIA. Thus, the variants of the ending of the IIA divide into 5 types and 8 groups.

The IIA is the major supplier of the pelvis, so the knowledge of its morphology is crucial from a clinical perspective. Understanding the anatomical implications of the IIA is necessary in the case of pelvic fracture treatment [25], various gynaecological procedures [60], and transplantation surgery [29]. Therefore, the main objective of the present meta-analysis was to summarise the extensive knowledge about the general anatomy of the IIA. In our article, we describe the branching variants of the IIA using the Adachi classification and the morphometric properties of the said vessel. It is hoped that our results may be a helpful tool for physicians, especially surgeons, performing procedures related to the IIA.

MATERIAL AND METHODS

Search strategy

Major online medical databases such as PubMed, Scopus, Embase, Web of Science, Cochrane Library, and Google Scholar were searched to find all studies considering the anatomy of the IIA. The systematic search was performed in 3 stages. In the first step, the following search terms were used in all databases: ((iliac artery) OR (common iliac artery) OR (external iliac artery) OR (internal iliac artery)) AND anatomy). Neither the date, language, type of article, nor text availability conditions were applied. (2) Furthermore, the mentioned databases were searched once again using another set of search phrases: (a) (internal iliac [Title/Abstract]) AND (anatomy [Title/Abstract]); (b) (internal iliac [Title/Abstract]) AND (variation [Title/Abstract]); (c) (internal iliac [Title/Abstract]) AND (morphology [Title/Abstract]); (d) (internal iliac [Title/ /Abstract]) AND (topography [Title/Abstract]); and (e) (internal iliac [Title/Abstract]) AND ((branch [Title/ /Abstract]) OR (branches [Title/Abstract])); (f) (internal iliac [Title/Abstract]) AND (type [Title/Abstract]). (3) Finally, a manual search was also performed throughout all references from the initially submitted studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed during the study. The search started in June 2023 and was completed in December 2023. It was ensured that each source was checked up to December 2023. To ensure the highest quality of findings the Critical Appraisal Tool for Anatomical Meta-Analyses (CATAM) and the Anatomical Quality Assessment (AQUA) tools were used to evaluate submitted articles [8, 16].

Eligibility assessment

Initially, a total of 4870 articles were evaluated by 2 independent reviewers (JWi and MM). Subsequently, 3181 papers were removed because they were duplicates or irrelevant. To minimise potential bias and maintain an accurate statistical methodology, articles such as case reports, case series, conference reports, reviews, letters to the editor, and studies that provided incomplete or irrelevant data were excluded. The inclusion criteria involved original studies with extractable numerical data on the anatomy, morphology, topography, and variations of the IIA. Finally, 40 studies met the inclusion criteria and were considered

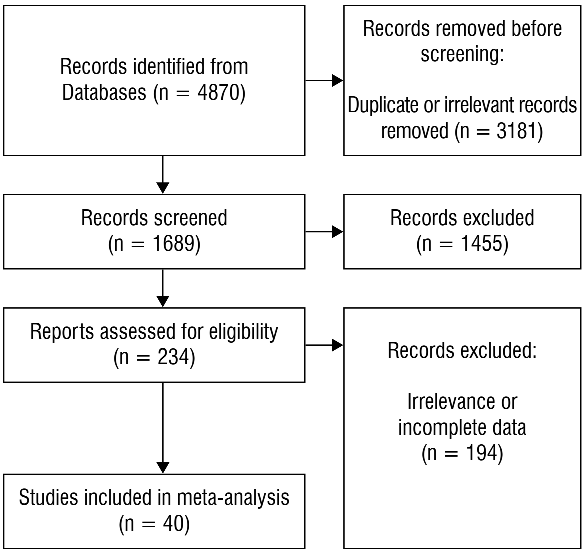

Figure 1. Flow chart presenting the process of collecting the data included in this meta-analysis.

in the present meta-analysis [1–7, 9, 12–15, 19, 21, 22, 24, 26, 27, 30–35, 38–40, 42–47, 50, 54–59]. The flow chart that describes the study inclusion process is shown in Fig. 1.

Characteristics of included studies

Thirty-three out of 40 studies were cadaveric dissections. The remaining 7 were radiological studies. Nineteen articles included fewer than 100 specimens, 9 articles included 101–200 specimens, 4 articles included 201–300 specimens, 3 articles included 301–400 specimens, and the remaining 5 articles included more than 400 specimens.

Most of the articles (25/40) included assessment of the IIA according to Adachi's main classification system. The length of the IIA was studied in 9 articles. The diameter of the IIA was assessed in 6 of the included studies, whereas analysis of the location of bifurcation of the CIA into IIA and EIA was studied in 3 articles. Furthermore, the distance from the greater sciatic notch to the IIA was studied in 2 articles. The prevalence of the origin of the obturator artery from the posterior division of the IIA was assessed in 6 articles. Detailed characteristics of the submitted studies can be found in Table 1.

Data extraction

Data from studies that met the inclusion criteria were extracted by 2 independent researchers (DP and JWi). Qualitative data, such as data collection methodology, year of publication, and country of

Table 1. Characteristics of studies included in this meta-analysis.

Abeysuriya, V. 2023	
Continent, country	Asia, Sri Lanka
Methods	Cadaveric dissection
Participants	45 specimens
Outcomes	Adachi's main classification system
Adachi 1928	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	121 specimens
Outcomes	Length, Adachi's main classification system
Al-Talalwah 2014	
Continent, country	Asia, Saudi Arabia
Methods	Cadaveric dissection
Participants	171 cadavers (79 females + 92 males); 342 specimens
Outcomes	Adachi's main classification system
Notes	A modified classification system is proposed because 65 specimens of the type of internal iliac artery could not be classified
Arai 1936	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	500 specimens
Outcomes	Adachi's main classification system
Ashley 1941	
Continent, country	North America, USA
Methods	Cadaveric dissection
Participants	247 specimens
Outcomes	Adachi's main classification system
Bilhim, T. 2010	
Continent, country	Europe, Portugal
Methods	Radiological study — angio MR, angio CT, digital angiography
Participants	42 specimens (21 male patients) Age: 73.2 (range 58–83) years
Outcomes	Yamaki classification system
Bleich 2007	
Continent, country	North America, USA
Methods	Cadaveric dissection
Participants	54 cadavers (54 females + 0 male); 108 specimens
Outcomes	Length
Boonruangsri 2015	
Continent, country	Asia, Thailand
Methods	Cadaveric dissection
Participants	41 specimens
Outcomes	Length

→

Table 1. Characteristics of studies included in this meta-analysis

Braithwaite 1952	
Continent, country	Europe, United Kingdom
Methods	Cadaveric dissection
Participants	169 specimens
Outcomes	Adachi's main classification system
Fatu 2006	
Continent, country	Europe, Romania
Methods	Cadaveric dissection
Participants	50 cadavers (20 females + 30 males), 100 specimens
Outcomes	Length, diameter, Adachi's main classification system
Notes	One of cases could not be included in
	Adachi's classification, 109 specimens in Adachi classification
Fisher 1959	
Continent, country	Europe, Germany
Methods	Radiological study
Participants	50 specimens
Outcomes	Adachi's main classification system
Francis 2018	
Continent, country	Asia, India
Methods	Cadaveric dissection
Participants	80 cadavers, 160 specimens
Outcomes	Length
Gabryszuk, K. 2023	
Continent, country	Europe, Poland
Methods	Computed tomography angiography analysis
Participants	145 arteries
Outcomes	IIA Diameter
Havaldar 2014	
Continent, country	Asia, India
Methods	Cadaveric dissection
Participants	50 specimens
Outcomes	Origin of IIA from different levels, distance from greater sciatic notch
Hoshai 1938	
Continent, country	Asia, Japan
Methods	Adachi's main classification system
Participants	379 specimens
Outcomes	Adachi's main classification system
Iwasaki 1987	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	251 specimens
Outcomes	Adachi's main classification system

Table 1. Characteristics of studies included in this meta-analysis

Jastschinski 1891	
Continent, country	Europe, Germany
Methods	Cadaveric dissection
Participants	396 specimens
Outcomes	Adachi's main classification system
Jusoh 2010	
Continent, country	Asia, Malaysia
Methods	Cadaveric dissection
Participants	17 cadavers, 34 specimens
Outcomes	Prevalence of obturator artery deriving from posterior division of IIA
Katara, P. 2023	
Continent, country	Asia, India
Methods	Cadaveric dissection
Participants	30 cadavers, 60 specimens
Outcomes	Mean length of the IIA
Khan 2021	
Continent, country	Africa, South Africa
Methods	Cadaveric dissection
Participants	20 cadavers, 40 specimens
Outcomes	Prevalence of obturator artery deriving from posterior division of IIA
Li, L. 2019	
Continent, country	Asia, China
Methods	Radiological study — computed tomography angiography, digital subtraction angiography
Participants	86 specimens (43 patients with pelvic tumours) Age: 52.7 (range 24–91) years
Outcomes	Yamaki classification system
Lipshutz 1916	
Continent, country	North America, USA
Methods	Cadaveric dissection
Participants	181 specimens
Outcomes	Adachi's main classification system
Lorbeer, R. 2018	
Continent, country	Europe, Germany
Methods	Gadolinium-enhanced magnetic resonance angiography
Participants	756 male participants (median age = 52 years, range = 21–82 years)
Outcomes	Diameter of the IIA
Mamatha 2012	
Continent, country	Asia, India
Methods	Cadaveric dissection
Participants	50 specimens
Outcomes	Distance from greater sciatic notch, Origin of the IIA from different levels, Prevalence of obturator artery deriving from posterior division of IIA

Table 1. Characteristics of studies included in this meta-analysis

Miyaji 1935	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	179 specimens
Outcomes	Adachi's main classification system
Morita, S. 1974	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	267 specimens
Outcomes	Adachi's main classification system
Naveen, N. 2011	
Continent, country	Asia, India
Methods	Cadaveric dissection
Participants	60 specimens
Outcomes	Adachi's main classification system
Nguyen, B. 2022	
Continent, country	Asia, Vietnam
Methods	Cadaveric dissection
Participants	18 cadavers, 36 specimens
Outcomes	Origin of the IIA from different levels, Mean diameter and length of the IIA
Ongidi, I. 2021	
Continent, country	Africa, Kenya
Methods	Cadaveric dissection
Participants	57 specimens (48 males + 9 females)
Outcomes	Adachi's main classification system, origin of the iia from different levels, location of the IIA in relation to the sacroiliac joint, mean diameter and length of the IIA
Pereira, J.A. 2013	
Continent, country	Europe, Portugal
Methods	Radiological study — computerised tomography angiography and digital subtraction angiography
Participants	42 specimens (21 male patients with arteriogenic erectile dysfunction), age: 67.2 (range 57–78) years
Outcomes	Yamaki classification system
Pradhan, A. 2022	
Continent, country	Asia, Nepal
Methods	Cadaveric dissection
Participants	15 cadavers, 30 specimens
Outcomes	Prevalence of obturator artery deriving from posterior division of IIA, mean diameter and length of the IIA, Adachi's main classification system
Quain, J. 1908	
Continent, Country	Europe, United Kingdom
Methods	Cadaveric dissection
Participants	297
Outcomes	Length

Table 1. Characteristics of studies included in this meta-analysis

Ramakrishnan, P. K. 2012	
Continent, country	Asia, India
Methods	Cadaveric dissection
Participants	50 specimens
Outcomes	Adachi's main classification system
Roberts, W. 1967	
Continent, country	North America, USA
Methods	Cadaveric dissection
Participants	167 specimens
Outcomes	Adachi's main classification system, prevalence of obturator artery deriving from posterior division of IIA
Sakthivelavan, S. 2014	
Continent, country	Asia, India
Methods	Cadaveric dissection
Participants	116 specimens (34R + 34L males, 24R + 24L females)
Outcomes	Adachi's main classification system, prevalence of obturator artery deriving from posterior division of IIA
Suzuki, H. 1951	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	490 specimens
Outcomes	Adachi's main classification system
Takenaka, Y. 2023	
Continent, country	Asia, Japan
Methods	Radiological study — three-phase multidetector row computed tomography
Participants	60 specimens (30 patients with colorectal cancers) Age: 67 (range: 47–78) years
Outcomes	Adachi's main classification system
Tsukamoto, N. 1929	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	287 specimens
Outcomes	Adachi's main classification system
Yamaki, J. 1998	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	645 specimens
Outcomes	Adachi's main classification system
Notes	A modified classification system is proposed — 5 types and 19 groups
Yasukawa, S. 1954	
Continent, country	Asia, Japan
Methods	Cadaveric dissection
Participants	544 specimens
Outcomes	Adachi's main classification system

origin, were assembled. Quantitative data about the IIA, such as prevalence of each anatomical variation, with respect to patients' sex and origin, morphological data regarding length, diameter, and other extractable numerical data were gathered. Any discrepancies between the studies identified by the 2 reviewers were resolved by contacting the authors of the original studies wherever possible or by consensus with a third reviewer.

Statistical analysis

To perform the meta-analyses, STATISTICA version 13.1 software (StatSoft Inc., Tulsa, OK, USA), MetaXL version 5.3 software (EpiGear International Pty Ltd., Wilston, Queensland, Australia), and Comprehensive Meta-analysis version 4.0 software (Biostat, Inc., Englewood, NJ, USA) were used. A random effects model was used in all analyses. The chi-square test and the I-squared statistic were used to assess the heterogeneity among the studies [17, 18]. A p-value and confidence intervals were used to determine statistical significance between studies. A p-value lower than 0.05 was considered statistically significant. In the event of overlapping confidence intervals, differences were considered statistically insignificant. I-squared statistics were interpreted as follows: values of 0–40% were considered as "might not be important", values of 30–60% were considered as "might indicate moderate heterogeneity", values of 50–90% were considered as "may indicate substantial heterogeneity", and values of 75–100% were considered as "may indicate substantial heterogeneity".

RESULTS

The anatomical types of the IIA and their prevalence were evaluated according to the classification presented by Adachi et al. in 1928 (Fig. 2) [1]:

1. Type I: The superior gluteal artery arises independently with the inferior gluteal and internal pudendal arteries arising from a common trunk, which divides inside (Type IA) or outside (Type IB) the pelvic cavity [1, 56].
2. Type II: The superior and inferior gluteal arteries arise from a common trunk, which divides inside (Type IIA) or outside (Type IIB) the pelvic cavity, with the internal pudendal artery arising independently [1, 56].
3. Type III: The superior and inferior gluteal and internal pudendal arteries all arise from the internal iliac artery independently [1, 56].
4. Type IV: The superior and inferior gluteal and internal pudendal arteries arise from a common trunk [1, 56].
5. Type V: The internal pudendal and superior gluteal arteries arise from a common trunk with the inferior gluteal having a separate origin [1, 56].

In the general population the pooled prevalence of Type I was found to be 56.57% (95% CI: 53.00–60.10%). The pooled prevalence of Type II was established at 16.46% (95% CI: 14.03–19.05%). The pooled prevalence of Type III was found to be 20.28% (95% CI: 17.31–23.43%). The pooled prevalence of Type IV was found to be 4.84% (95% CI: 3.64–6.20%). The pooled prevalence of Type V was found to be 0.27% (95% CI: 0.05–0.62%). All the results mentioned above and more detailed ones can be found in Table 2.

Furthermore, subgroup analyses were performed according to the patients' sex and origin. The pooled prevalence of Type I in females was found to be 57.75% (95% CI: 42.17–72.61%), whereas in males it was established at 63.41% (95% CI: 57.39–69.23%). The pooled prevalence of Type II in females was found to be 17.69% (95% CI: 12.38–23.69%), whereas in males it was established at 12.84% (95% CI: 10.48–15.40%). Type V was found to occur statistically significantly ($p = 0.0002$) more often in females than in males. All the results mentioned above and more detailed ones regarding the pooled prevalence with respect to the patients' sex can be found in Table 3. The pooled prevalence of Type I in the Asian population was found to be 58.44% (95% CI: 46.36–70.04%), whereas in the European population it was found to be 57.14% (95% CI: 51.29–62.98%). All the results mentioned above and more detailed ones regarding the pooled prevalence with respect to the patients' origin can be found in Table 4.

The pooled mean length of the IIA was set to be 39.95 mm (SE = 1.79) in the overall population. In females, it was found to be 34.88 mm (SE = 5.08), whereas in males it was 45.43 mm (SE = 8.62). The pooled mean diameter of the IIA was found to be 6.86 mm (SE = 0.27). All the results mentioned above and more detailed ones regarding the IIA morphology can be found in Table 5.

Furthermore, an analysis of the anatomical types of the IIA according to the classification by Yamaki et al. (1998) [58] was performed: Group A: The internal iliac artery divides into 2 branches, the superior gluteal artery and the common trunk of the inferior gluteal and internal pudendal arteries. Group B: The

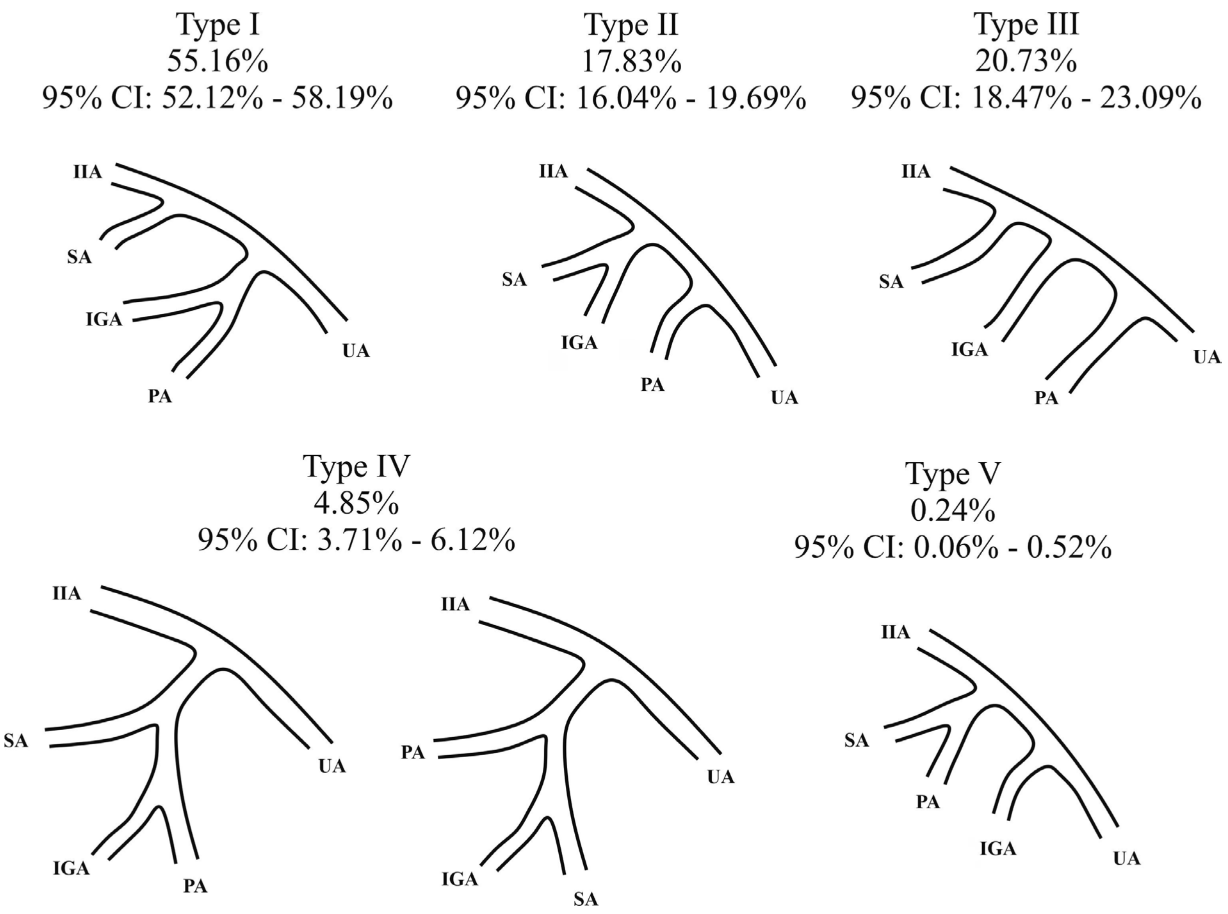

Figure 2. Scheme, presenting the types of the internal iliac artery (IIA) according to Adachi's classification: **Type I:** The superior gluteal artery arises independently with the inferior gluteal and internal pudendal arteries arising from a common trunk, dividing inside (Type IA) or outside (Type IB) the pelvic cavity [1, 56]. **Type II:** The superior and inferior gluteal arteries arise from a common trunk, which divides inside (Type IIA) or outside (Type IIB) the pelvic cavity, with the internal pudendal artery arising independently [1, 56]. **Type III:** The superior and inferior gluteal and internal pudendal arteries all arise from the internal iliac artery independently [1, 56]. **Type IV:** The superior and inferior gluteal and internal pudendal arteries arise from a common trunk [1, 56]. **Type V:** The internal pudendal and superior gluteal arteries arise from a common trunk with the inferior gluteal having a separate origin [1, 56]. IIA — internal iliac artery; SA — superior gluteal artery; IGA — inferior gluteal artery; PA — internal pudendal artery; UA — umbilical artery.

Table 2. Statistical results of this meta-analysis regarding the pooled prevalence of each type of internal iliac artery (IIA) according to Adachi's classification.

Category	Number of articles	Number of studied arteries	Pooled prevalence	LCI	HCI	Q	I^2
Main types							
Type I	22	5695	56.57%	53.00%	60.10%	141.87	85.20
Type II			16.46%	14.03%	19.05%	125.68	83.29
Type III			20.28%	17.31%	23.43%	160.63	86.93
Type IV			4.84%	3.64%	6.20%	96.48	78.23
Type V			0.27%	0.05%	0.62%	73.28	71.34

Type I: The superior gluteal artery arises independently with the inferior gluteal and internal pudendal arteries arising from a common trunk which dividing inside (Type IA) or outside (Type IB) pelvic cavity [1, 56]. **Type II:** The superior and inferior gluteal arteries arise from a common trunk, which divides inside (Type IIA) or outside (Type IIB) the pelvic cavity, with the internal pudendal artery arising independently [1, 56]. **Type III:** The superior and inferior gluteal and internal pudendal arteries all arise from the internal iliac artery independently [1, 56]. **Type IV**: The superior and inferior gluteal and internal pudendal arteries arise from a common trunk [1, 56]. **Type V:** The internal pudendal and superior gluteal arteries arise from a common trunk with the inferior gluteal having a separate origin [1, 56]. The presented results are based on 22 of the included studies [1–3, 7, 9, 12, 13, 17, 19, 21, 22, 31, 35, 38, 39, 42, 45, 47, 50, 54–59]. LCI – lower confidence interval. HCI – higher confidence interval. Q – Cochran's Q.

Table 3. Statistical results of this meta-analysis regarding the pooled prevalence of each type of internal iliac artery (IIA) according to Adachi's classification, with respect to patients' sex.

Category	Sex	Number of articles	Number of studied arteries	Pooled prevalence	LCI	HCI	Q	I^2	P-value
Type I	Females	5	386	57.75%	42.17%	72.61%	27.13	85.25	0.58
	Males		709	63.41%	57.39%	69.23%	7.92	49.50	
Type II	Females		386	17.69%	12.38%	23.69%	6.55	38.90	0.13
	Males		709	12.84%	10.48%	15.40%	2.25	0.00	
Type III	Females		386	17.50%	13.22%	22.24%	4.77	16.18	0.49
	Males		709	20.51%	14.33%	27.47%	13.65	70.70	
Type IV	Females		386	2.60%	0.06%	7.55%	13.67	70.73	0.95
	Males		709	2.94%	1.48%	4.84%	5.44	26.45	
Type V	Females		386	4.21%	0.00%	15.46%	57.41	93.03	0.0002
	Males		709	0.14%	0.00%	0.49%	0.89	0.00	

Adachi's classification: **Type I:** The superior gluteal artery arises independently with the inferior gluteal and internal pudendal arteries arising from a common trunk which dividing inside (Type IA) or outside (Type IB) pelvic cavity [1, 56]. **Type II:** The superior and inferior gluteal arteries arise from a common trunk, which divides inside (Type IIA) or outside (Type IIB) the pelvic cavity, with the internal pudendal artery arising independently [1, 56]. **Type III:** The superior and inferior gluteal and internal pudendal arteries all arise from the internal iliac artery independently [1, 56]. **Type IV:** The superior and inferior gluteal and internal pudendal arteries arise from a common trunk [1, 56]. **Type V:** The internal pudendal and superior gluteal arteries arise from a common trunk with the inferior gluteal having a separate origin [1, 56]. The presented results are based on 5 of the included studies [7, 12, 42, 50, 58]. LCI — lower confidence interval; HCI — higher confidence interval; Q — Cochran's Q.

Table 4. Statistical results of this meta-analysis regarding the pooled prevalence of each type of internal iliac artery (IIA) according to Adachi's classification, with respect to the geographical region.

Category	Number of articles	Number of studied arteries	Pooled prevalence	LCI	HCI	Q	I^2
Asia							
Type I	6	1561	58.44%	46.36%	70.04%	97.30	94.86
Type II			14.06%	9.23%	19.70%	36.39	86.26
Type III			22.62%	16.19%	29.77%	42.89	88.34
Type IV			3.62%	1.10%	7.35%	42.57	88.25
Type V			0.16%	0.01%	0.43%	3.94	0.00
Europe							
Type I	2	278	57.14%	51.29%	62.89%	0.37	0.00
Type II			16.79%	12.62%	21.40%	1.23	0.00
Type III			15.94%	6.19%	28.76%	9.59	58.28
Type IV			2.61%	0.97%	4.95%	4.06	1.41
Type V			9.71%	0.00%	35.74%	41.39	90.34

Adachi's classification: **Type I:** The superior gluteal artery arises independently with the inferior gluteal and internal pudendal arteries arising from a common trunk which dividing inside (Type IA) or outside (Type IB) pelvic cavity [1, 56]. **Type II:** The superior and inferior gluteal arteries arise from a common trunk, which divides inside (Type IIA) or outside (Type IIB) the pelvic cavity, with the internal pudendal artery arising independently [1, 56]. **Type III:** The superior and inferior gluteal and internal pudendal arteries all arise from the internal iliac artery independently [1, 56]. **Type IV:** The superior and inferior gluteal and internal pudendal arteries arise from a common trunk [1, 56]. **Type V:** The internal pudendal and superior gluteal arteries arise from a common trunk with the inferior gluteal having a separate origin [1, 56]. The presented results are based on 8 of the included studies (Asia: [22, 39, 50, 55, 56, 58], Europe: [7, 12]). LCI — lower confidence interval; HCI — higher confidence interval; Q — Cochran's Q.

internal iliac artery divides into 2 branches, the internal pudendal artery and the common trunk of the superior gluteal and inferior gluteal arteries. Group C: The internal iliac artery simultaneously divides into 3 major branches. Group D: The internal iliac artery divides into the common trunk for the superior gluteal and internal pudendal arteries and the inferior gluteal artery [58]. The pooled prevalence of Type A was found to be 71.16% (95% CI: 62.72–78.92%). Detailed results regarding this classification can be found in Table 6.

DISCUSSION

In 1928 Adachi et al. [1] formulated a classification system concerning the branching pattern of the IIA. They stated that the superior gluteal, the inferior gluteal, and the internal pudendal arteries are the principal branches of the IIA [Fig. 3]. According to Ad-

Table 5. Statistical results of this meta-analysis regarding the morphometric parameters and location of the internal iliac artery (IIA).

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value
Length							
Overall [mm]	39.95	1.79	3.21	36.14	43.16	22.12	0.00
Studies from Asia only [mm]	43.82	2.38	5.65	39.16	48.48	18.44	0.00
Females [mm]	34.88	5.08	25.83	24.92	44.84	6.86	0.00
Males [mm]	45.43	8.62	74.30	28.54	62.33	5.27	0.00
Right IIA [mm]	41.33	4.71	22.15	32.10	50.55	8.78	0.00
Left IIA [mm]	39.79	3.63	13.19	32.67	46.91	10.96	0.00
Diameter							
Overall [mm]	7.43	0.19	0.03	7.06	7.80	39.72	0.00
Distance from the mid-sagittal line							
Overall [mm]	32.25	0.25	0.06	31.76	32.74	128.99	0.00

The presented results are based on 12 of the included studies [1, 5, 6, 12, 14, 32, 39, 42, 46, 50].

Table 6. Statistical results of this meta-analysis regarding the pooled prevalence of each type of internal iliac artery (IIA) according to Yamaki classification.

Category	Number of articles	Number of studied arteries	Pooled prevalence	LCI	HCI	Q	I^2
Main types							
Type A	4	901	71.16%	62.72%	78.92%	16.08	75.12
Type B			15.29%	9.79%	21.73%	13.66	70.72
Type C			12.60%	5.55%	21.80%	29.84	86.60
Type D			0.21%	0.00%	0.65%	0.26	0.00

Group A: The internal iliac artery divides into 2 branches, the superior gluteal artery and the common trunk of the inferior gluteal and internal pudendal arteries. **Group B:** The internal iliac artery divides into 2 branches, the internal pudendal artery and the common trunk of the superior gluteal and inferior gluteal arteries. **Group C:** The internal iliac artery simultaneously divides into 3 major branches. **Group D:** The internal iliac artery divides into the common trunk for the superior gluteal and internal pudendal arteries and the inferior gluteal artery [58]. The presented results are based on 4 of the included studies [4, 30, 43, 58]. LCI — lower confidence interval; HCI — higher confidence interval; Q — Cochran's Q.

achi's classification system, we distinguished 6 main types of the branching pattern of the IIA (Tab. 2). The classification system consisted of the following types: Type I — the superior gluteal artery originates from the main stem, while the inferior gluteal and internal pudendal arteries occur as a common trunk. If these arteries are located within the pelvis, this branching pattern is classified as Ia. However, in cases where the embranchment is present outside the pelvis, it is presented as Type Ib. Type II — the superior and inferior gluteal arteries arise together from the IIA, and the internal pudendal originates from the stem of the IIA as a second branch. Similarly to Type I, when the embranchment exists within the pelvis, it is classified as Type IIa, and when it occurs outside the pelvis, it is classified as Type IIb. Type III – the superior gluteal, inferior gluteal, and internal pudendal arteries arise independently from the IIA. When these vessels form a common trunk and the superior gluteal artery (IVa) or the internal pudendal artery (IVb) branches out first, this variant is classified as Type IV. Type V — the superior gluteal and the internal pudendal arteries arise as a common trunk, and the inferior gluteal as a separate branch [1].

The results presented in our meta-analysis demonstrate that Type I is the most common branching pattern (56.57%) in the general population. Type III is the second most observed branching type (20.28%), while Type II is the third (16.46%). Types IV and V were found to be relatively rare (less than 5%). These results do not differ much from the observations of other researchers. Yamaki et al. [58] examined 645 pelvic halves to determine which branching pattern of the IIA is the most common. They noted that 58% of patients had the Type I branching pattern. Similarly, Sakthivelavan et al. [50] dissected 116 Indian specimens to analyse the variability of the IIA branching. They demonstrated similar conclusions: Type I was observed in 63.2% of cases. Both teams of researchers proved that the second most commonly observed is Type III: 22.8% and 21%, respectively.

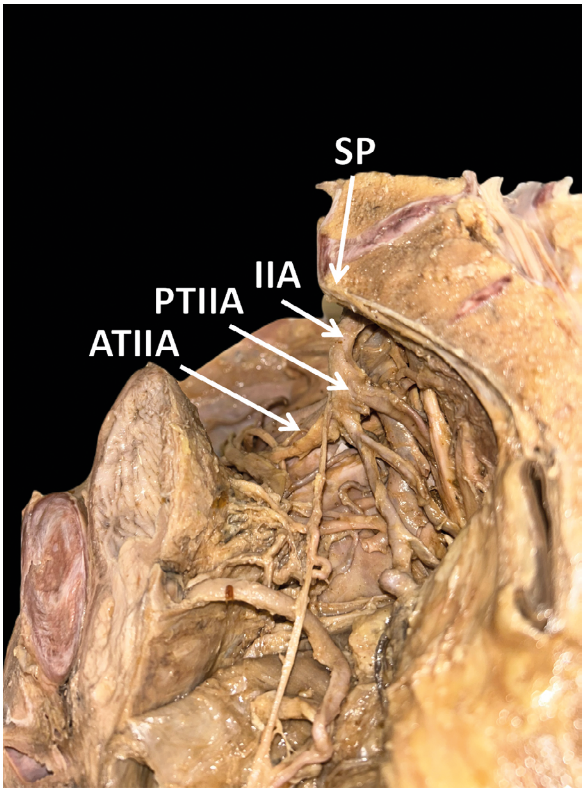

Figure 3. Photo of a cadaveric dissection of internal iliac artery (IIA) and its close anatomical area. SP — sacral promontory; PTIIA — posterior trunk of internal iliac artery; ATIIA — anterior trunk of internal iliac artery.

However, original research done by Adachi et al. [1] revealed that the second most common branching pattern corresponds with Type II. Roberts et al. [47] examined 167 Caucasian specimens to compare Adachi's results (Japanese population) with the ones analysed in their own study. Their conclusions were similar to those of Adachi: Type II was found in 26.8%, while Type III occurred in 14.4% of patients. Furthermore, Type V is rare in the general population — Yamaki et al. [58] observed it in only one out of 645 specimens (0.2%). Our studies revealed that the pool prevalence of type V amounts to 0.27%. Many researchers did not find this type of branching in their studies [42, 47, 50]. However, when Type V was found, it occurred only in single cases. Yevstifeieva et al. [60] reviewed the literature to determine the prevalence of the branching patterns of the IIA. They found that the fifth type of branching is present in 0.5% of cases. Similarly, Yamaki et al. [58] found it only in 0.2% of cases.

The pooled prevalence of each type of the IIA concerning the patient's sex were also analysed. Type I was the most common in both sexes. However, it was found in 63.41% of men, while in the case of women, it was present only in 57.75% of cases. The second most common branching was Type III, present in 20.51% of men. In women, the prevalence of Type II was higher (17.69%) than that of Type III (17.50%). Type V was absent in men, but in women, it occurred in 4.21% of cases. Braithwaite et al. [7] proved that Type II is present in 10.1% of men and 24.5% of women. This conclusion corresponds with our findings.

Most research concerning the Adachi classification of the IIA originated from Asia. The most common branching pattern was found to be Type I in both Asian and European populations (58.44% and 57.14%, respectively). However, Type III is the second most frequent type in the Asian population (24.58%), but in the case of the European population, it is replaced by Type II (16.79%). Furthermore, the Type V is rare in Asians (0.16%), while 9.71% of European patients presented this type of branching. Adachi examined Japanese patients [1] and revealed that Type I was present in 51.2% of cases. Furthermore, Fatu et al. [12] examined Romanian individuals and found that in 60% of patients, the branching pattern is Type I. Moreover, the Polish population was analysed by Kosinski et al. [28]. In that study, Type I occurred in 79% of patients. These results demonstrate a different distribution of branching patterns in the discussed groups. However, regardless of the geographical region, Type I is the most common branching pattern.

Although the Adachi classification has become the primary system for distinguishing branching types of the IIA, it is burdened with limitations. This classification correlates with embryological processes. Thus, some researchers state that it is not clinically useful. Hence, various improvements have been implemented. Yamaki et al. [58] excluded the umbilical artery from their classification because it is not clinically significant after birth. Ashley and Anson [3] proposed a new approach: the obturator artery constitutes the base for further divisions. However, this classification was compatible with the Adachi classification in 95% of cases. Al Talalwah et al. [56] accentuated the need to include the coexistence of the sciatic artery in the overall classification. He noted that type IIA, according to Adachi's classification, may be misinterpreted by radiologists, resulting in surgical complications.

The IIA is one of the terminal branches of the common iliac artery. It originates anteromedially from the sacroiliac joint. According to Ongidi et al. [42], the origin lies medially from the sacroiliac joint. However, Mohammadbaigi et al. [36] noted that the origin is located anteriorly to it. Generally, the common iliac artery gives rise to the IIA at the level of the L5/S1 intervertebral disc [10]. This has been confirmed in several articles in the past [33, 42]. However, according to Naveen et al. [39], the origin of the IIA is located at the level of the S1 vertebra (58.3% of cases). Moreover, our study revealed that the distance of the IIA from the midsagittal plane amounts to 32.25 mm. Other researchers came up with similar results. Ongidi et al. [42] noted that the mean distance was 31.47 mm. Furthermore, Fatu et al. [12] measured the distance between the IIA and the midsagittal plane on the right and left side (right: 29–36 mm, left: 40–50 mm). In our article, we summarised the information about the IIA origin to create a helpful tool in preoperative planning. Pelvic surgery may be burdened with potential threats, such as acute haemorrhage. Thus, radiologists and surgeons should be aware of different variants of the anatomy of the IIA. A well-planned surgical procedure may prevent injury to major pelvic vessels, including the common iliac artery.

The results in the present meta-analysis demonstrate that the mean length of the IIA was 39.95 mm. The right IIA was found to be longer (41.33 mm) than the left (39.79 mm). Furthermore, men were found to have significantly longer IIA (45.43 mm) than women (34.88 mm). The measurements by other researchers revealed that the mean length of the IIA is 37.00 mm [42, 50]. The difference in the length of the IIA between our and previous studies is minor and may result from the larger sample in our study compared to others. According to Francis et al. [34], the overall length of the right IIA equals 39.43 mm, and the left: is 36.10 mm. Furthermore, our research revealed that the overall diameter of the IIA is 6.86 mm. Fatu et al. [12] presented similar results: the diameter of the IIA was stated to be 6.83 mm.

The origin and length of the IIA can determine the possible outcome of endovascular procedures. These aspects of the said vessel should be included in the preoperative planning of pelvic surgery, which could be accompanied by potential complications, such as severe bleeding. Performing a selective anterior division ligation or embolisation of the IIA branches requires a thoughtful operation and should be well-planned [5, 51]. The IIA and its branches are a major supplier of the pelvis. Thus, it plays a significant role in various areas of medicine. Kachlik et al. [25] analysed possible fractures of the pelvis with vascular damage. In the study, they distinguished different types of pelvic injuries — 3 of them referred to the IIA. The most probable cause of the injury was dislocation. Dzupa [11], Zhang [61], and Hussami [20] presented similar conclusions. Because the IIA plays a significant role in the blood supply of the pelvis, it is crucial to be aware of the possible damage that may result from the injury of the pelvis. Additionally, the ligation of the said artery is used in case of pelvic fracture [23]. Hence, the surgeons must be aware of the possible variations in the anatomy of the IIA to avoid intra- and postoperative complications. The anatomy of the IIA is also highly significant for gynaecologists and obstetricians. Yevstifeieva et al. [60] proved that the IIA has great clinical value in gynaecological surgery. Surgeons ligate the IIA in cases of bleeding resulting from a hysterectomy, known as the Wertheim operation [25, 53]. The ligation procedure serves in the prevention and treatment of postpartum haemorrhage [25]. According to the data published by the World Health Organisation, postpartum haemorrhage causes 35% of maternal deaths. Hence, having adequate knowledge of the morphological properties of the internal iliac arteries is crucial to provide safer and more effective surgical treatments. A recent study showed that the IIA plays a significant role in the transplantation of the uterus because it is required to form anastomoses and supply the organ with blood [29].

The presented meta-analysis includes extensive knowledge about the internal iliac arteries and their principal branches. However, this study is not without limitations. Since meta-analyses refer to research by other authors, they are burdened with potential bias. Our study is no exception. Furthermore, most of the studies we refer to are from Asia. Hence, our result may reflect mostly the Asian rather than the global population. Nevertheless, we hope this research will be an effective and helpful tool for surgeons and clinicians. We believe that knowledge of the anatomy and variants of the IIA will contribute to safer and more accurate treatment.

CONCLUSIONS

Our study describes the prevalence of the IIA branching patterns according to the Adachi classification. Type I was the most common in the general population. There is no difference regarding the patient's sex and ethnicity. Furthermore, the length of the IIA was found to be 39.95 mm, and the arterial diameter was 6.86 mm. The IIA is responsible for supplying most of the structures located in the pelvis. Hence, it is crucial to be aware of the possible variants of the vessel. The results presented in our study may be highly significant in various surgical procedures performed in that region.

ARTICLE INFORMATION AND DECLARATIONS

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Dawid Plutecki — literature search, data extraction.
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Michał Bonczar — writing, statistical analysis, figures, tables.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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