

Original communication**INTERNAL ILIAC ARTERY CLASSIFICATION AND ITS CLINICAL SIGNIFICANCE****Waseem Al Talalwah¹, Roger Soames²**¹ *Department of Basic Medical Sciences, College of Medicine, King Saud bin Abdulaziz, University for Health Sciences, Riyadh, Saudi Arabia*² *Centre for Anatomy and Human Identification, College of Art, Science and Engineering, University of Dundee, Dundee, United Kingdom***RESUMEN**

En estudios anteriores de la arteria íliaca interna se la ha clasificado en cinco tipos; sin embargo en base a una revisión de estos estudios parece que no hay una clasificación asociada en coexistencia con una arteria ciática. En este estudio, basado en la disección de 171 cadáveres (92 hombres y 79 mujeres), en 65 especímenes del tipo de la arteria íliaca interna no podía ser clasificada debido a la presencia de una arteria ciática o ausencia de la arteria glútea inferior. Por lo tanto, se propone un sistema de clasificación modificado, ya que es esencial para los radiólogos, cirujanos ortopédicos, obstetras, ginecólogos y urólogos, para ser capaces de reconocer la organización de las principales ramas de las ramas íliacas internas y evitar el trauma iatrogénico y las complicaciones postquirúrgicas, así como mejorar el manejo del paciente.

Palabra clave: *arteria íliaca interna, arteria pélvica, arteria ciática, angiografía pélvica.*

ABSTRACT

In previous studies the internal iliac artery has been classified into five types; however based on a review of these studies it does not appear a classification associated with the coexistence of the sciatic artery. In this study, based on 171 dissected cadavers (92 male, 79 female), in 65 specimens the type of internal iliac artery could not be classified due to the presence of a sciatic artery or absence of the inferior gluteal artery. A modified classification system is therefore proposed as it is essential for radiologists, orthopedics, surgeons, obstetricians, gynecologists and urologists to be able to recognize the organization of the major branches of

the internal iliac branches to avoid iatrogenic trauma and postsurgical complications, as well as to improve patient management.

Keyword: *Internal iliac artery, pelvic artery, sciatic artery, pelvic angiography.*

INTRODUCTION

An early description of the internal iliac artery divisions classified branches in the pelvic wall, pelvic viscera and extrapelvic branches based on their terminal course (Herbert, 1825). Later, Power (1862) presented the simpler classification of internal and external branches according to their terminal course. A different approach was adopted by Jastschinski (1891) based on the size of the artery and classified into three branches. First, the large calibre arteries included the superior gluteal, inferior gluteal and internal pudendal arteries. Second, the medium calibre artery included the obturator artery. Third, the small calibre arteries included the iliolumbar and lateral sacral arteries.

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Subsequently several classifications based on pelvic visceral branches (Testut, 1948; Williams, 1995) and regional branches in the gluteal region, posterior and medial compartments of the thigh and the hip joint (Fredet, 1899; Rouviere, 1967) have been suggested. However, these previous classifications of the branches of the internal iliac artery have not been used up to date because of deficiencies in the description of the arteries: for example, some arteries supply both intra and extrapelvic structures. Moreover, the size of the artery varies from one cadaver to another. A relatively simple classification has been described in which the internal iliac artery divides into anterior and posterior trunks (Carter, 1867; Sharpey et al, 1867; Wilson, 1868), from which various branches arise.

Adachi (1928) was the first to classify the internal iliac artery into five types (Figure 1), later updated by Ashley and Anson (1941). While, several studies on internal iliac artery branch variability in different populations using the Adachi classification types have been published (Table 1), it is often at variance with the observations from radiological studies (Merland and Chiras, 1981; Pelage et al, 1999). During dissection the existence of a sciatic artery has been observed, either in coexistence with or as a replacement of the inferior gluteal artery: this therefore modifies the internal iliac artery classification. It is important to update the internal iliac artery classification.

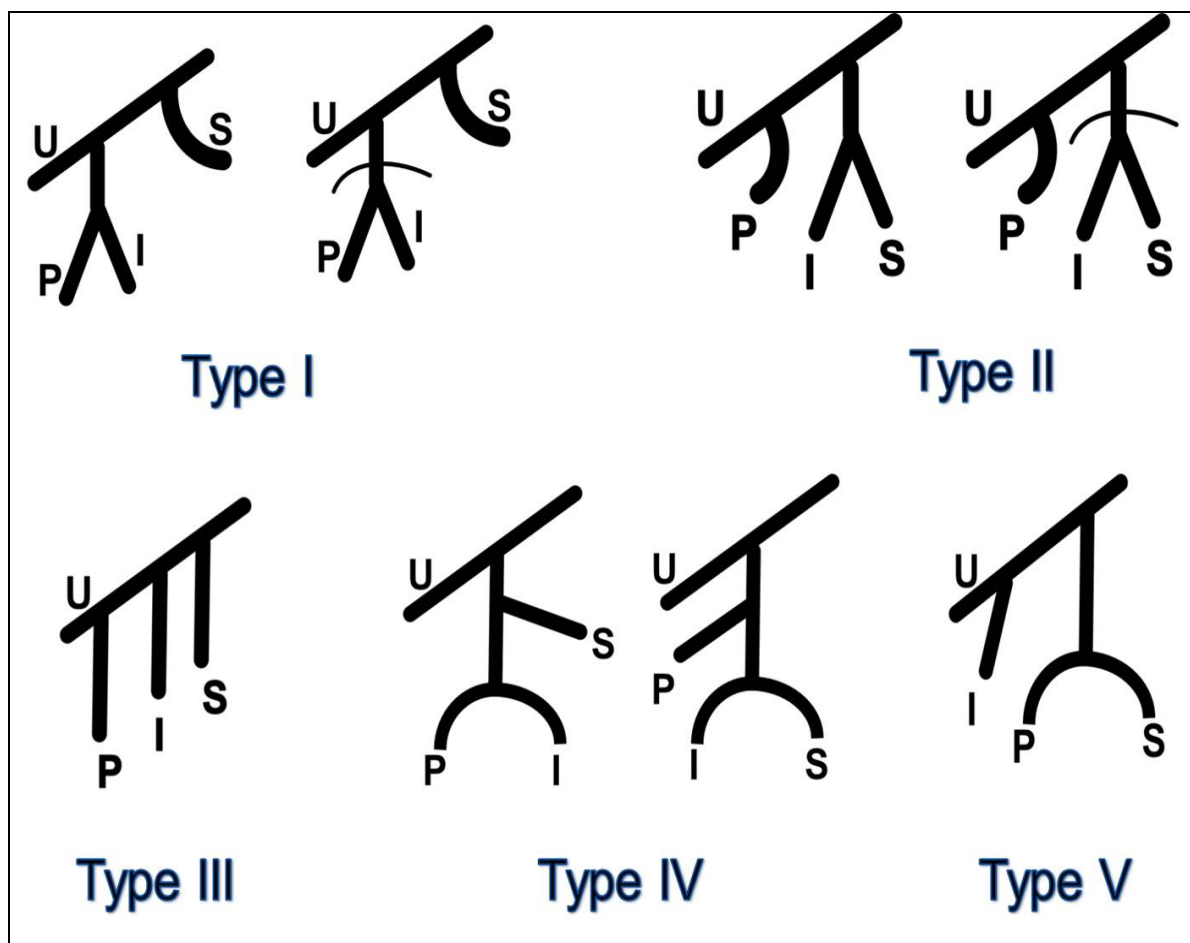


Figure 1- The internal iliac artery classification based on Adachi 1928 classification. Type I: the superior gluteal artery arises independently with the inferior gluteal and internal pudendal arteries arising from a common trunk which dividing inside (Type IA) or outside (Type IB) pelvic cavity. Type 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. Type III: the superior and inferior gluteal and internal pudendal arteries all arise from the internal iliac artery independently. Type IV: the superior and inferior gluteal and internal pudendal arteries arise from a common trunk. Type V: the internal pudendal and superior gluteal arteries arise from a common trunk with the inferior gluteal having a separate origin. (U. Umbilical artery, S. Superior gluteal artery, I. Inferior gluteal artery, P. Internal pudendal artery).

MATERIALS AND METHOD

Over a period of three years 342 hemipelvises from 171 cadavers (92 male, 79 female) were dissected to study the internal iliac artery and its branches. As well as noting the origin of all branches present a photographic record was taken of each specimen.

Once the anterior abdominal wall, foregut and hindgut had been dissected by undergraduates as part of their studies, a transverse section through or above L4 or L5 was made and followed by sagittal sectioning of the pelvis: the peritoneum was then carefully removed. In females removal of the vesico-uterine pouch revealed the deep structures. Clarification of the

broad ligament, as well as identification of the uterine tube and the ovary with its ligament was undertaken: these structures were released and reflected from the lateral pelvic wall. In males, the vas deferens was removed or reflected supero-anteriorly. At the level of the sacral promontory, the sigmoid colon was sectioned from the rectum at the rectosigmoidal junction: Waldeyer's fascia was incised and the rectum released from the pelvic wall.

After reflection of the pelvic viscera, the pelvic fascia was divided and removed from the pelvic wall. Subsequent to removal of the endopelvic fascia, the iliac system (venous and arterial) was exposed: the veins were carefully removed up to the level of formation of the common iliac vein.

Study	Type I	Type II	Type III	Type IV	Type V	Number of specimens
Lipshutz (1916)	51%*	24%	17%	7%**	0%	181
Adachi (1928)	51.2%	23.1%	18.2%	4.1%	0.8%	121
Tsukamoto (1929)	56.5%	8.4%	22%	12.9%	0%	287
Miyaji (1935)	79.4%	11.7%	9.5%	4.2%	0%	179
Arai (1936)	52.4%	19.4 %	24%	4.2%	0%	500
Hoshiai (1938)	55.1%	16.1%	26.1%	2,6%	0%	379
Ashley and Anson (1941)	58.1%	17.3%	9.6%	7.7%	0%	260
Suzuki (1951)	53.2%	18.8%	24.1%	3.7%	0.2%	490
Yasukawa (1954)	53.7%	18.4%	23.9%	4%	0%	544
Braithwaite (1952)	58.5%	15.3 %	22.5 %	3.6 %	0%	169
Fisher (1959)	50%	26%	16%	8%	0%	50
Roberts - Krishinger (1968)	50.9%	27%	14.4%	7.2%	0%	167
Morita et al (1974)	49.1%	22.5%	21.7%	6.7%	0%	267
Iwasaki et al (1987)	54.2%	19.5%	24.3%	2%	0%	251
Yamaki et al (1998)	58%	13.6%	22.8%	5.4%	.2%	645
Current study	36.1%	5.3%	34.8%	2.3%	0%	342

Table 1: Internal iliac artery classification based on series studies. *Type I of Lipshutz (1916) 40% exactly matches the Adachi classification whereas 11% Type V of Lipshutz (1916) classification is identical to Type IB of the Adachi classification which does not match Type V of Adachi classification, but Type I excluding the obturator artery. ** Type V has been found by Lipshutz (1916) to exactly match Type IV of Adachi.

Origin	Frequency	Incidence (%)
Type I	116	38.1
Type II	55	18.2
Type III	110	36.4
Type IV	7	2.3
NEW	14	4.6

Table 2: This study based on Adachi (1928) classification. Based on Lipshutz (1918) classification, 14 new patterns do not belong to any type of this classification. Observations based on 342 specimens.

RESULTS

Applying the Adachi (1928) classification system to the observations in the current study, Types I, II, III and IV were present in 38.4%, 18.2%, 36.4% and 2.3% of specimens respectively, with Type I being divided into IA (19.9%) and IB (18.5%) and Type II into IIA (6.3%) and IIB (11.9%). There were 14 internal iliac artery patterns which could not be assigned to any of the Adachi types (Table 2 and 3).

Type	Frequency	Incidence (%)
Type I A	60	19.9
Type I B	56	18.5
Type II A	19	6.3
Type II B	36	11.9
Type III	110	36.4
Type IV	7	2.3
NEW	14	4.6

Table 3: Adachi (1928) classification verifying subtype. Based on a modified Lipshutz classification via Adachi (1928), type I and type II is divided into subtype A and B. Observations based on 342 specimens.

Due to the observation of the coexistence of an incomplete form of an axial (sciatic) artery in

current study, in previous studies the sciatic artery could have been misclassified as the inferior gluteal artery when the inferior gluteal artery was either absent or arises in the gluteal region. This potential misidentification was present in 16.9% in the current study (Table 4).

Type	Frequency	Incidence (%)
Type I A	58	19.2
Type I B	51	16.9
Type II A	16	5.3
Type II B	105	34.8
Type III	7	2.3
FALS	51	16.9
NEW	14	4.6

Table 4: This study based on Adachi (1928) classification incidence. As Lipshutz identified the sciatic artery as inferior gluteal artery, some false patterns have been existed. False pattern of the sciatic artery has been identified as the inferior gluteal artery in case of the latter's absence or arising distally from either the previous artery or gluteopudendal trunk, therefore the latter trunk pretends as internal pudendal artery.

The Adachi (1928) classification system does not take into account the presence of a coexistent sciatic artery or absence of the inferior gluteal artery. These new pattern types have been included in the current study without altering the numerical classification of previous studies following the Adachi (1928) classification. These new patterns are divided into atypical type or atypical substitutive. The atypical Type I SA2, atypical Type III SA and atypical Type IV SA were observed to occur with a frequency of 0.7%, 0.3% and 1.0% respectively. The atypical substitutive Type IA was found in 2.0% and atypical substitutive Type IB in 1.3%. Furthermore, atypical substitutive Type IIA was found in 10.9% and atypical substitutive Type III in 5.3% (Table 5).

In Type I, the superior gluteal artery arises independently from the internal iliac artery, with the inferior gluteal and internal pudendal arteries arising from a gluteopudendal trunk dividing into Type IA above and Type IB below the pelvic floor. Type I was observed to occur in 36.1%, of which 19.2% were Type IA and 16.9% Type IB. In

addition, Type I has further subdivisions into three atypical (SA1, SA2 and SA3) and two substitutive types. In Type ISA1 the superior gluteal and sciatic arteries arise from the internal iliac artery, while the inferior gluteal and internal pudendal arteries arise from a gluteopudendal trunk dividing into one of three forms: Type IA above and Type IB below pelvic floor and Type IC in which the inferior gluteal and internal pudendal vessels arise independently. In Type I SA2, the superior gluteal artery arises independently from the internal iliac artery, whereas the inferior gluteal and internal pudendal arteries arise from a gluteopudendal trunk originating from the sciatic artery, which can be one of three forms: Type IA above and Type IB below pelvic floor, and Type IC the inferior gluteal and internal pudendal arteries arise independently from sciatic artery. This latter form was observed in 0.7% of specimens in the current study. In Type ISA3, the superior gluteal artery arises independently from the internal iliac artery, whereas the sciatic artery, inferior gluteal and internal pudendal arteries arise from a common trunk dividing inside the pelvis: no cases were observed in the current study.

In atypical substitutive Type IA, the superior gluteal artery is replaced by the sciatic artery arising independently from the internal iliac artery, whereas the inferior gluteal and internal pudendal arteries arise from a gluteopudendal trunk in one of two forms: substitutive Type I A1 above and Type I A2 below the pelvic floor, the latter occurring in 2% in the current study.

In atypical substitutive Type IB, the superior gluteal artery arises independently from the internal iliac artery, whereas the inferior gluteal is replaced by the sciatic artery arising with internal pudendal artery from a common trunk in one of two forms: Type I B1 above and Type I B2 below the pelvic floor, while Type I B3 is the internal pudendal artery arising from the sciatic artery. This latter type was present in 1.3% of specimens in the current study (Table 5).

In Type II, the superior and inferior gluteal arteries arise from common trunk, with the internal pudendal artery arising independently. The common gluteal trunk divides into one of two forms: Type IIA above and Type IIB below pelvic floor. In the current study the incidence of type II was 5.3%, all of which were Type IIA as Type IIB was not observed. In atypical substitutive Type II, the sciatic artery replaces either the superior or inferior gluteal arteries arising from a common trunk, again with the internal pudendal artery arising independently. As before the common gluteal trunk divides into one of two forms: Type II A1 above and Type II A2, the latter occurred in 10.9% in the current study.

Type	Frequency	Incidence (%)
Type I A	58	19.2
Type I B	51	16.9
Type II A	16	5.3
Type III	105	34.8
Type IV	7	2.3
Atypical substitutive Type I A	6	2.0
Atypical substitutive Type I B	4	1.3
Atypical substitutive Type II A	33	10.9
Atypical substitutive Type III	16	5.3
Atypical Type I SA2	2	0.7
Atypical Type III SA	1	0.3
Atypical Type IV SA	3	1.0

Table 5: Current study based on new IIA classification. According to the current study classification, the previous classifications types have not changed to avoid confusion. Further current types are clarified occurring at different rates. Observations based on 342 specimens.

In Type III, the superior and inferior gluteal and internal pudendal arteries arise independently from the internal iliac artery: it occurred in 34.8% of specimens in the current study. In atypical Type III SA, the superior and inferior gluteal and the internal pudendal arteries all coexist with a sciatic artery, which arises independently from the internal iliac artery: it occurred in 0.3% of specimens in the current study. In atypical substitutive Type III, the sciatic artery replaces either the superior or inferior gluteal arteries, with the internal pudendal artery arising from the

internal iliac artery independently (either directly or indirectly): it occurred in 5.3% of specimens. In Type IV, the superior and inferior gluteal and internal pudendal arteries arise from a common trunk of the internal iliac artery and was observed in 2.3% in the current study. In atypical Type IV SA, the superior and inferior gluteal and internal pudendal arteries coexist with a sciatic artery all arising from a common trunk of the internal iliac artery: this was not observed in the current study. In atypical substitutive Type IV, the sciatic artery

replaces either the superior or inferior gluteal artery and arises with the internal pudendal artery from a common trunk of the internal iliac artery: it was observed in 1% of specimens in the current study.

In Type V, the internal pudendal and superior gluteal arteries arise from a common trunk, with the inferior gluteal artery having a separate origin. No cases were observed of this type in the current study (Figure 2).

Type \ New pattern	New patterns of type I				New patterns of type II		New patterns of type III			New patterns of type IV			No new
Type I	Atypical Type I SA1	Atypical Type I SA2	Atypical Type SA3	Atypical substitutive Type I	Type II	Atypical substitutive Type II	Type III	Atypical type III SA	Atypical substitutive Type III	Type IV	Atypical type IV SA	Atypical substitutive type IV	Type V
A					A	A				A	A	A	A
B					B	B				B	B	B	B
		C	C			C							
			D			D							
			E										

Figure 2 - A revised classification of Adachi's (1928) classification of the internal iliac artery incorporating the coexistence of a sciatic artery and the absence of the superior or inferior gluteal artery and including the five types of Adachi's (1928) classification as well as the typical, atypical and atypical substitutive of its classification. (U. Umbilical artery, S. Superior gluteal artery, I. Inferior gluteal artery, P. Internal pudendal artery, Sc. Sciatic artery).

DISCUSSION

On the basis of the origin of the superior and inferior gluteal, and the internal pudendal arteries Adachi (1928) proposed a classification of the internal iliac artery into five types (Figure 1), which itself was a modification of the classification put forward by Lipshutz (1918) but excluded the obturator artery. Adachi's classification was later updated by Ashley and Anson (1941) who also included the umbilical artery to those used by Adachi. The more recent classification of Yamaki et al (1998) is a modification of Adachi's classification. Also,

Bilhim et al (2011) modified Adachi's classification in their study of 42 specimens using angio MR and digital angiography, angio computed topography. Nevertheless, after almost a century most studies (Adachi, 1928; Tsukamoto, 1929; Miyaji, 1935; Arai, 1936; Hoshiai, 1938; Ashley and Anson, 1941; Suzuki, 1951; Yasukawa, 1954; Braithwaite, 1952; Fischer, 1959; Roberts and Krishinger, 1968; Morita et al, 1974; Iwasaki et al, 1987; Yamaki et al, 1998; Naveen et al, 2011; Ramakrishnan et al, 2012) on the internal iliac artery are based on the Adachi classification

(Table 1). The Adachi (1928) classification has become the gold standard for the internal iliac artery as many authors follow it and assess vary incidence rate of each type, despite recent modifications and amendments.

By using the Adachi (1928) classification, many authors have not considered the possible presence of a sciatic artery as the obturator artery is excluded in the classification system. The inferior gluteal artery usually arises from the anterior trunk and supplies the sciatic nerve in gluteal region whereas the sciatic artery usually arises from the posterior trunk and supplies the sciatic nerve and classified into complete and incomplete form (Carter, 1867; Sharpey et al, 1867, Wilson, 1868; Bower et al, 1977; Williams, 1995). The incomplete form may confuse the radiologist in reporting the accurate information. The anterior division of internal iliac artery usually gives the inferior gluteal artery whereas the posterior division usually gives sciatic artery in

which both arteries pass below the piriformis. The possibility of sciatic artery and the inferior gluteal artery are either from the anterior or posterior division. Therefore, an anonymous artery arising from the posterior trunk can be classified as inferior gluteal artery depending on usual origin of obturator artery as from the anterior trunk due to delay of the primitive inferior gluteal artery development from the primitive anterior trunk. Whereas, the anonymous artery classified as a sciatic artery in case of the obturator artery arising from itself or external iliac system as well as femoral system due to embryological development of lower extremities based on sciatic artery and its branches (Primitive obturator artery supplying the medial part of the thigh in adult). The current study used the Adachi (1928) classification, but took into account the origin of the obturator artery to determine whether an artery was either the sciatic or inferior gluteal artery.

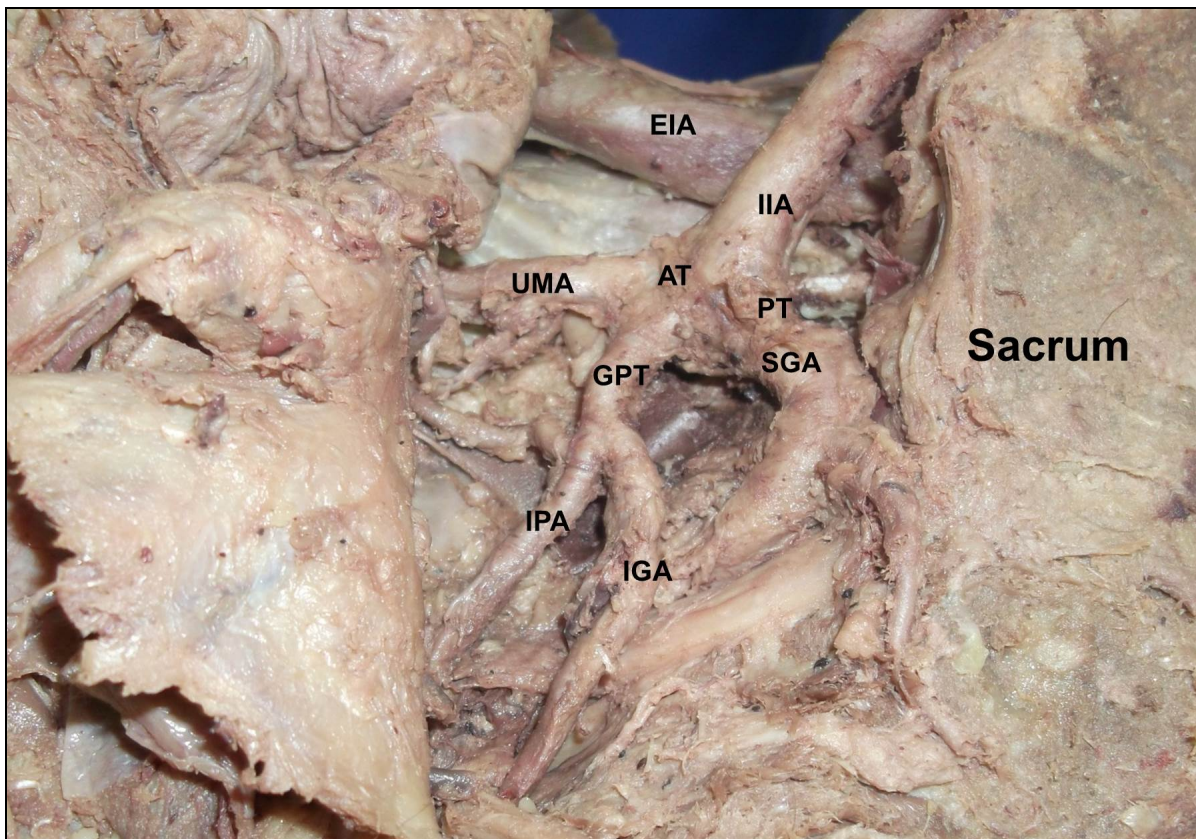


Figure 3 - The superior gluteal artery arises independently from the internal iliac artery whereas the inferior gluteal and internal pudendal arteries arising from a common trunk (referred as glueopudendal trunk) above the pelvic floor (Type IA). IIA. Internal iliac artery, EIA. External iliac artery, AT. Anterior trunk. PT. Posterior trunk, UMA. Umbilical artery, SGA. Superior gluteal artery, GPT. glueopudendal trunk, IGA. Inferior gluteal artery, IPA. Internal pudendal artery.

In the current study, the types of internal iliac artery had different incidences according to the

Adachi classification, with the presentation of a number of variations which did not fit into any of

the accepted types, suggesting that a revised and updated classification is required (Figure 2). In the current study, 65 internal iliac artery patterns could not be assigned to any type in Adachi (1928) classification due to the presence of a sciatic artery or absence of the inferior gluteal artery. It is possible that the authors have not correctly identified specific arteries, for example whether it is an incomplete form of the sciatic artery or the inferior gluteal artery, thus leading to misidentification (51 cases). Even so, there are 14 patterns which could not be classified due to the coexistence of a sciatic artery together with the superior and/or inferior gluteal artery and the internal pudendal artery (Table 4). Types I, II, III and IV occurred with incidences of 38.1%, 18.2%, 36.4% and 2.3% respectively (Table 2). These incidences would probably be similar for authors who identified the incomplete sciatic artery as the inferior gluteal artery in cases when the latter is absent, whereas the new type in which previous authors were unable to classify occur in 4.6% (Table 2). Type I is subdivided into IA, which occurs in 19.9%, and IB, which occurs in 18.5%; whereas Type II is subdivided into IIA, which occurs in 6.3%, and IIB, which occurs in 11.9% (Table 3). The Adachi (1928) classification, therefore fails to include cases in which there is coexistence of a sciatic artery and absence of the inferior gluteal artery. The revised classification includes atypical or substitutive types, whereby an atypical type is coexistence of the sciatic artery with the superior or inferior gluteal artery and the substitution type is the replacement of either the superior or inferior gluteal arteries by a sciatic artery.

Based on misidentification of persistent sciatic artery, the new patterns of type I are twelve patterns are classified under atypical type I and atypical substitutive type I. the new patterns of type II are four patterns classified under atypical substitutive type II in which there is no atypical type II. Similar to type I, the new patterns of type III are three patterns are classified under atypical type III and atypical substitutive type III as well as the type IV includes four new patterns classified under atypical type IV and atypical substitutive type IV. In contrast, there is no new pattern of type V (Figure 2).

Using the revised internal iliac classification system, the most common occurrence is Type I, with the second and third most common types being Type III and the atypical substitutive Type II A respectively (Figure 3). On the basis of the current observations Type IIA and atypical substitutive Type III have the fourth highest incidences. The fifth, sixth and seventh highest incidences are Type IV, atypical substitutive Type IA and atypical substitutive Type IB respectively.

Atypical Type I SA2, atypical Type III SA and atypical Type IV SA were observed to have an incidence of less than 1%, while Type IIB, atypical Type I SA1, atypical Type I SA3, atypical Type IV SA and Type IV were not observed in the current study (Table 5). Therefore, it would be useful to be able to compare the patterns observed in the present study with those in previous studies.

Comparing studies of internal iliac arteries classification in different populations, the incidence of the various divisions is variable (Table 1). The current observation that the most common and second most common are Type I and Type III has also been reported by others (Tsukamoto, 1929; Aria, 1936; Hoshiai, 1938; Suzuki, 1951; Yasukawa, 1954; Braithwaite, 1952; Iwasaki et al, 1987; Yamaki et al, 1998; Naveen et al, 2011; Ramakrishnan et al, 2012; Vishnumukkala et al, 2013). However, it is in disagreement with second that have reported the Type II is the second most common type seen (Lipshutz, 1916; Miyaji, 1935; Adachi, 1928; Ashley and Anson, 1941; Fischer, 1959; Roberts and Krishinger, 1968; Morita et al, 1974).

This is the first study which introduces coexistence of the sciatic artery and absent of either the superior or inferior gluteal artery into the classification of the internal iliac artery and thus revises the original Adachi classification. With coexistence of sciatic artery, there is a new organization of pelvic arteries.

With the revised internal iliac artery classification, the organization of the major internal iliac branches can be determined by pelvic angiography and thus avoid unnecessary embolization or embolectomy as well as non-mandatory ligation during surgical procedures. This should lead to a decrease in the risk of iatrogenic fault as well as limit postsurgical complications.

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