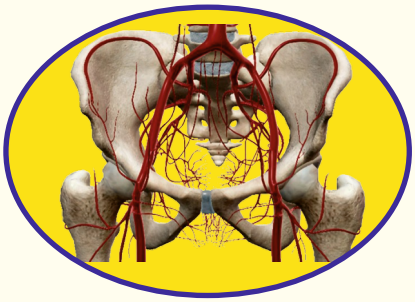
DISCUSSION



CHAPTER 6

DISCUSSION

6.1 ORIGIN OF INTERNAL ILIAC ARTERY

Internal iliac artery begins at the common iliac bifurcation, at the level of lumbosacral intervertebral disc, anterior to the sacroiliac joint. In our study the origin of the internal iliac artery was determined according to its association with vertebrae which established the vertebral level of origin, horizontal distance from the point of origin to the mid sagittal plane was observed & its relationship with the osteoarticular elements in vicinity which is Sacroiliac joint was also mentioned.

6.1.1 Vertebral levels of origin of the internal iliac artery

In our study the most common vertebral level of origin was at lumbosacral articulation level, which was 46% (23/50) of the sample. Similar finding were also observed by Pavan P Havaldar (2014), in which the most common site of origin of the internal iliac artery was at the level of the lumbosacral intervertebral disc found in 30 specimens (60%) & in study by Ibsen Henric Ongidi (2021)it was 24/57 (42.1%) cases .

In study by Sumathilatha Sakthivelavan (2014) & Lipshutz (1918), 81% (94) specimens & 83.3% (120) specimens respectively had origin between L5 & S1and it was above this level in 22 (19%) & 24 (16.7%) specimens respectively.

In another study of Naveen NS (2011) & H. Mamatha (2015), they both observed that the origin of the internal iliac artery was at the level of the S1 vertebra in the majority 58.3% (35) of the cases& 72 % (36) cases respectively and between L5 & S1, it was 40% (24) cases & 24% (12) cases which was not similar to our study.

Higher origin of the internal Iliac Artery above L5 level was observed in our study in 12% (6) cases & other studies like Pavan P Havaldar(2014), Ibsen Henric Ongidi(2021)

also reported origin at this vertebral level in 16% (8) & 14% (8) cases while other studies like Lipshutz(1918), Naveen NS(2011), H. Mamatha(2015) & Sakthivelavan (2014) didn't found such higher origin. Ibsen even report one case with origin from L4 level which was not observed by any authors.

In our study higher origin of the internal iliac artery between L4& L5 was observed only in male specimen & this was 27.3% of total male specimen while comparing it with females, origin of internal iliac artery at this level was not found in any female cadavers which established a well-marked tendency in females to bifurcate at a lower vertebral level. In 85.7% female specimen of our study, origin was below the L5 vertebral level. In 39.3% female specimens origin was at S1 level while in male it was 13.6%. Thompson states that the length of the common iliac artery is somewhat greater in females and that there is tendency in females to bifurcate at a lower vertebral level.

It was also observed that the level of variability in female was also less than male similar finding was also reported by Popa Oana(2014).

In the present study bilateral asymmetry was also observed in vertebral level of origin of internal iliac artery in many cases as shown in Figure 5.1 also, in which on the right side origin was higher between L4& L5 while on the left it was between L5 & S1. Lipshutz (1918) states that there was tendency for the left common iliac artery to bifurcate at a lower level than the right; this similar finding was also observed in few cases of our study.

The origin level of the internal iliac arteries determines both their path and direction, and especially their length, being particularly important when practicing a ligature on the artery

Table: 6.1 Origin of internal iliac artery at various vertebral levels from various authors

S.No	Authors	Sample Size	L4	B/W L4 & L5	L5	B/W L5 & S1	S1
1	Lipshutz (1918)	144	-	-	16.7% (24)	83.3% (120)	-
2	Naveen (2011)	60	-	-	1.7% (1)	40% (24)	58.3% (35)
3	Pavan Havaldar (2014)	50	-	16% (8)	20% (10)	60% (30)	4% 2
4	Sakthivelavan (2014)	116	-	-	19% (22)	81% (94)	-
5	H. Mamatha (2015)	50	-	-	4% (2)	24% (12)	72% (36)
6	Ibsen Henric Ongidi (2021)	57	1.8% (1)	14% (8)	36.8% (21)	42.1% (24)	5.3% (3)
7	Present study (2022)	50	-	12% 06	14% 07	46% 23	28% 14

6.1.2 Distance of origin of the internal iliac artery to the midsagittal plane

In the present study the horizontal distance from the origin of the internal iliac artery to the mid-sagittal plane varies from 23.65mm to 43.26mm with average of 33.42 ±4.83 mm while comparing our study with the study by Ibsen Henric Ongidi (2021), it was observed that the average distance of the internal iliac artery from the mid-sagittal plane of the pelvis was 31.47 mm ± 7.85 & it varies from 15.34mm to 46.05mm. In the study of C. Fatu (2006), it ranged between 29 to 36 mm.

It was also observed that there is a variation in the distance of origin of the internal iliac artery to the midsagittal plane in relation to gender. In the case of male mean value was 32.84± 5.59 mm and in female 33.88±4.18 mm. Such findings were also observed by C. Fatu (2006) & this is explained as probably an adaptive mechanism of the vascularization of the female pelvis & reflects in particular the post pubertal development of the female pelvis according to Kamina (1981)

However in the study of Ibsen Henric Ongidi(2021), there was no such finding, which might be due to small sample size of female cadavers (9) in their study which limited the ability of this study to determine sex differences in this variable.

There was one more observation that average distance from the midsagittal plane was more on left side than right. On the right side mean value was calculated as32.27± 4.75 mm, and on the left 34.57 ±4.72mm.However no significant difference between left and right sides of the pelvis was mentioned in other studies.

Alternative reference points have been used to define the level of internal iliac artery origin. In a similar study Terek et al. (2004) studied the left and right sides of 22 fresh Turkish female cadavers and recorded the distance of the posterior division of the internal iliac artery from the sacral promontory and the pelvic midline. The only significant left–right difference was the distance from the sacral promontory to the posterior division of internal iliac artery was significantly shorter on the right side compared to the left (p=0.018, Mann–Whitney U-test).

6.1.3 Relation of internal iliac artery with sacroliac joint

Sacroiliac joint is the present in the vicinity of internal iliac artery. According to Gray's internal iliac artery begins at the common iliac bifurcation anterior to the sacroiliac joint, which is an important landmark. Present study shows that the internal iliac artery predominantly (68%) lies at a position medial to the sacroiliac joint. It was related directly anterior to the joint in 28% cases & in one female specimen internal iliac artery lies lateral to the sacroiliac joint on both sides forming 4% of the cases. Similar findings were found in the study of Ibsen Henric Ongidi (2021) in which internal iliac artery lies medial to the sacroiliac joint in most cases 37/57 (64.9%), in 18/57 cases (31.6%) it was directly anterior & in 3.5% cases it was in lateral relation with the joint.

According to C. Fatu (2006), the internal iliac artery's origin is at the level of the sacroiliac joint with insignificant differences to the right or left. However, in males the origin is medial to the sacroiliac joint, while in females it is at the same level.

Mohammadbaigi et al.(2019) in a review of literature reports that, the internal iliac artery has an anterior relation to the sacroiliac joint in most cases. The immediate relation of the internal iliac artery and its branches with the sacroiliac joint make it susceptible to injury during trauma like pelvic fractures etc. or in surgical procedures leading to iatrogenic injury of the joint. Surgeons operating on the pelvis and sacrum should be acquainted with these distinctive relations of the artery with the sacroiliac joint.

Table: 6.2 Relation of internal iliac artery with sacroiliac joint from various authors

S.No	Authors	Sample Size	Medial to sacroiliac joint	Anterior to sacroiliac joint	Lateral to sacroiliac joint
1	C.Fatu (2006)	100	Males	Females	--
2	Ibsen Henric Ongidi (2021)	57	64.9% (37)	31.6% (18)	3.5% (2)
3	Present study (2022)	50	68% (34)	28% (14)	4% (2)

6.2 MORPHOMETRY OF INTERNAL ILIAC ARTERY

The morphometry of internal iliac artery was studied by measuring its length & diameter.

6.2.1 Length of the internal iliac artery

The length of the internal iliac artery was measured from the point of its origin at the bifurcation of the common iliac artery to its terminal branching point. As observed in the previous section that the origin of artery varies with in 2 to 3 vertebral level & similarly level of termination of artery was also highly variable which leads to considerable variation in the length of the artery. However Lipshutz (1918) states that the lower level of bifurcation of abdominal aorta or lower origin of common iliac artery did not lead to shortening of length of the iliac artery, in such cases origin & division of latter vessels occur at lower level.

In our study the length of the internal iliac artery varies extremely, shortest being 11.21 mm and longest being 66.37 mm with average value of 38.16 $\pm$11.22 mm. This correlate with the observations of Naveen (2011) in which length of artery range from 13 to 54 mm with average value of 37 $\pm$ 4.62 mm. Similar finding was also observed by Sakthivelavan (2014) having mean length of 37 with range from 23 to 71 mm. A very wide range has also been reported by various authors which was summarized in the table no.6.4

In the present study majority of specimen 44% (22) had length of internal iliac artery between 30 – 40 mm, These observations also correlate with the observations of Lipshutz (1918), & Pawan (2014) in which majority of specimens 37.6%(67) ranged from 35 to 45 mm and 46%(23) between 30 to 50mm. Sakthivelavan(2014) also found 67% of specimens between 25 to 42 mm. Although in study by C. Fatu (2006) majority of specimens 40% lie within the range of 50-60mm as summarized in Table 6.3

Table: 6.3 Frequencies of Length of internal iliac artery reported by different studies

S.No	Authors	Length of IIA (mm)	No. of Specimen	Percentage
1.	Lipshutz (1918)	**15 -25**	24	**13.5%**
		25-35	50	**28.1%**
		35-45	67	**37.6%**
		45-55	20	**11.2%**
		55-67	17	**9.6%**
			178	
2	C.Fatu (2006)	**20-30**	6	6**%**
		30-40	20	20**%**
		40-50	25	25**%**
		50-60	24	24**%**
		60-70	8	8**%**
		70 -80	10	10**%**
		80 -90	07	07**%**
			100	
3	Pavan Havaldar (2014)	**10-30**	11	**22%**
		30-50	23	**46%**
		50-70	16	**32%**
			50	
4	Sakthivelavan (2014)	**25-42**	78	**67%**
5.	Present study (2022)	**10 -20**	02	4%
		20 -30	11	22%
		30-40	22	44%
		40-50	09	18%
		50-60	04	8%
		60-70	02	4%

Minimum measure of the length of internal iliac artery was reported in our study as 11.21mm (Figure 5.3). However Bergman(1988) , Naveen(2011) , Pavan Havldar(2014) , Ibsen Henric(2021) observed length to be as short as 12mm, 13mm, 15mm & 16.42mm respectively in their studies.

Maximum measure of the length of internal iliac artery was reported by Ibsen Henric as 91.80 mm followed by 90mm in study of C. Fatu (2006) & Quain (1908) and then 75mm & 71mm by Bergman (1988) & Sakthivelavan (2014) respectively. In the present study longest length was observed as 66.37mm. Bleich(2007), Naveen(2011) & Yuvaraj Maria(2018) observed 52mm, 54mm, 54mm as maximum value of the length of internal iliac artery respectively.

Yuvaraj (2018) compared the length of right & left internal iliac artery which ranged from 2.4 cm to 5.4 cm with mean length of 3.943cm ± 0.859cm on right side, whereas on the left side it ranged from 2.7cm to 4.7cm with average length of 3.610cm ± 0.626cm. The P valve calculated as 0.0914, shows that the differences were statistically not significant between the lengths of internal iliac artery of both sides. Similar findings was also reported by Ibsen in which p-values = 0.470 between the left and right sides of the pelvis
which was not statistically significant. Although Shafiroff et al.(1959) reported that the internal iliac artery on the right side was often longer than that of the left side, and length of the common iliac artery was inversely proportional to it.

Jusoh et al.(2010) observed in 34 pelvic halves of 17 cadavers that the distance from the bifurcation of common iliac artery to the beginning of the anterior division of internal iliac artery was within the range of 10–60 mm and to the posterior division was 0–60 mm.

Table: 6.4 Length of internal iliac artery from various authors

SNo	Author		Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation
1	Quain (1908)		13	90	36.8	0.6
2	Adachi (1928)		-	-	44.3	1.32
3	Bergman (1988)		12	75	-	-
4	C.Fatu (2006)		20	90	49	3.34
5	Bleich et al (2007)	Right	0	49	27.0	10.1
		Left	0	52	26.8	10.7
6	Naveen (2011)		13	54	37	4.62
7	Sakthivelavan (2014)		23	71	37	-
8	Pavan Havaldar (2014)		15	70	-	-
9	Yuvaraj Maria (2018)	Right	24	54	39.43	0.859
		Left	27	47	36.10	0.629
10	Ibsen Henric Ongidi (2021)	Right	16.43	91.80	38.52	16.96
		Left	16.42	58.68	35.80	10.67
		Male	18.32	81.75	36.86	11.83
		Female	16.42	91.80	38.59	23.59
		Overall Average	16.42	91.80	36.97	14.12
11	Present study (2022)	Right	13.87	66.37	38.54	10.89
		Left	11.21	65.62	37.79	11.77
		Male	28.12	56.16	39.54	8.28
		Female	11.21	66.37	37.08	13.14
		Overall Average	11.21	66.37	38.16	11.22

In the present study the length of internal iliac artery was measured on embalmed formalin fixed adult human pelvic halves, there was no fresh unembalmed specimen.

Bleich et al.(2007) observed a notable difference in the length of internal iliac artery in fresh versus embalmed specimens in the 54 female cadavers (17 embalmed 37 unembalmed ; average age 79.6±12.7 years) (Table 6.6). The probable cause of this variation in vascular dimensions was either shrinking during embalming, distortion of tissue structure due to formalin fixation or the stretching of fresh tissues, was not explained.

Table: 6.5 Comparison of the length (mm) of the left and right internal iliac arteries in embalmed and unembalmed specimens. Adapted from Bleich et al. (2007)

Side	Cadaver Type	Total	**Length of internal iliac artery (mm)**			P value
			Range	Mean ± SD	Median	
Right	Embalmed	17	0-31	38.59 ± 4.93	24.5	P<0.002
	Fresh	37	0-49	38.59 ± 4.93	29.5	
	Total	54	0-49	38.59 ± 4.93	27.5	
Left	Embalmed	17	0-38	21.80 ± 11.6	24	P<0.001
	Fresh	37	7-52	29.0 ± 9.6	29.5	
	Total	54	0-52	26.8 ± 10.7	27	

Fatu (2006) compared the data with similar studies in the literature on different ethnic groups (English, Japanese) & found that the data shows minor differences in the length of the internal iliac artery in Romanian patients (49±3.34 mm) compared to the Japanese persons (44.3±1.32 mm) (Adachi, 1928), and significant differences compared to the English persons (36.8±0.6 mm) (Quain, 1908) as shown in Table 6.7

According to the present study, the length of the artery in Indian population ranged between 11.21 and 66.37mm. The mean value was 38.16±11.22mm without major

differences between two sides. These value matches with previous study by Naveen et al. (2011) in south Indian population (37±4.62mm).

Thus conclude that the length of the internal iliac artery varies in different races.

Table: 6.6 Comparison of the length (mm) in different ethnic groups

SNo.	Length of IIA (mm)	Quain (English)	Adachi (Japanese)	Fatu (Romanians)
1.	11-13	07	-	-
2.	14 -20	16	2	1
3.	21-30	-	7	5
4.	31-40	195	36	20
5.	41-50	57	26	25
6.	51-60	-	18	24
7.	61-70	18	5	8
8.	71-80	-	4	10
9.	81-90	4	1	7
	Mean ± SD	**36.8 ± 0.6**	**44.3 ± 1.32**	**49 ± 3.34**

6.2.2 Diameter of the internal iliac artery

External diameter of the artery was measured at the middle segment between the origin and termination. Unlike the length of artery, the caliber was not dependent on the origin level of the internal iliac artery.

In our study the diameter of the internal iliac artery varies from 3.63mm to 8.45mm, similar findings was also observed by Adachi (1928) in which it ranged from 5mm to 8mm. C. Fatu (2006) reported larger calibers than those observed in previous studies with value ranging between 4mm to 11mm. Ibsen henric (2021) also mentioned a very broad range of external diameter of artery, narrowest being 3.52mm & widest being 12.46mm.

Popa Oana(2014) studied the diameter of internal iliac artery through cadaveric dissections, Doppler ultrasound, simple angiography, angio CT (3D and 2D reconstructions) & observed a range between 2.5mm to 9.8mm.

Popa Oana(2014) also compared the caliber of male & female cases on both right & left sides & found that in Females dimension varies from 3.9mm to 6.9mm while males have a wider range of 2.5mm to 9.8mm. Thus conclude that in females arterial diameter variability was smaller as compared to males. However in our study no significant difference in arterial caliber between male & female was found. Similar to our findings, Ibsen henric (2021) also noticed negligible discrepancy in the average values of males and females.

Mean value with standard deviation of diameter of internal iliac artery in the present study was calculated as 6.83 $\pm$1.24 mm. This correlates with the mean value reported by Ibsen henric (2021) which was 7.32 $\pm$1.69 mm. Yuvaraj Maria (2018) observed the mean value of caliber thickness of artery as 4.85 $\pm$0.60 mm, which was not close to our study.

Table: 6.7 Diameter of internal iliac artery from various authors

SNo	Study		Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation
1	Adachi (1928)		5	8	-	-
2	C.Fatu (2006)		4	11	-	-
3	Popa Oana (2014)	Male Right	3	9.8	-	-
		Male Left	2.5	9.6	-	-
		Female Right	3.9	6.9	-	-
		Female Left	3.9	6.6	-	-
4	Yuvaraj Maria (2018)		-	-	4.85	0.60
5	Ibsen Henric Ongidi (2021)	Right	4.34	9.66	7.16	1.50
		Left	3.52	12.46	7.51	1.83
		Male	3.52	12.46	7.42	1.68
		Female	4.34	9.23	6.90	1.62
		Overall Average	3.52	12.46	7.32	1.69
6	Present study (2022)	Right	3.63	8.45	6.81	1.26
		Left	3.97	8.39	6.85	1.25
		Male	3.63	8.45	7.01	1.37
		Female	4.15	8.27	6.69	1.13
		Overall Average	3.63	8.45	6.83	1.24

6.3 TERMINATION OF INTERNAL ILIAC ARTERY

Termination of internal iliac artery, by dividing into anterior and posterior division or branches, occurs in the pelvic cavity at the superior margin of the greater sciatic foramen. In our study the termination of the internal iliac artery was explained & compared by identifying the level of termination and the pattern by which it terminates into further branches.

6.3.1 Distance from Greater Sciatic Foramen (GSF)

According to Gray's, the internal iliac artery divides at the level of superior edge of greater sciatic foramen. Although in the present study it has been noticed that the division of internal iliac artery occurs proximal to the greater sciatic foramen. To determine the level of division, distance was measured from the superior margin of the greater sciatic foramen to the point of division of artery into anterior and posterior trunk or branches. Various Studies observed this variable & their findings were tabulated in table 6.7

In the present study distance from the point of division of artery varies from 2.5 cm above to 1cm below the superior border of Greater Sciatic Foramen. These findings were also correlate with the study of H. Mamatha (2015) & Pavan Havaldar (2014) in which distance extend from 3.5cm above to 1cm below & 3cm above to 2cm below the upper border of Greater Sciatic Foramen respectively.

In 72% (36) specimens the division of internal iliac artery took place above the Greater Sciatic Foramen in our study, similar finding was also found by Pavan Havaldar (2014) in which division was above in 68% (34) cases. However in the study of Naveen (2011) & H. Mamatha(2015) 100% (60) & 98% (49) specimens respectively are above the superior border of Greater Sciatic Foramen. On the contrary Sakthivelavan (2014) mentioned that the termination of internal iliac artery was at a highly variable position between lumbosacral articulation and greater sciatic foramen in 34.5% (40) specimens.

Sakthivelavan (2014) observed that in 65.5% (76) specimens, the level of division of internal iliac artery was at the level of superior border of greater sciatic foramen. In our study 24% (12) cases were found at this level. Pavan Havaldar (2014) also reported 14% (7) specimens at this level. Not a single case was noticed by H. Mamatha(2015) & Naveen(2011) in which termination was at the level of superior border of greater sciatic foramen.

In the current study 2 cases (4%) were found in which level of division took place below the upper border of greater sciatic foramen, in one case it was 0.5 cm below & in another it was 1 cm below. Similar to our study H. Mamatha(2015) report a single case (2%) 1cm below the upper border of GSF. However Pawan Havaldar(2014) mentioned a much more cases (18%) having the division level below the upper border of GSF which were 8% (4) specimen below 0.5cm, 6% (3) specimen 1cm below & 4% (2) specimens 2 cm below . On the contrary Naveen(2011) & Sakthivelavan (2014) did not found any specimen having division level below this.

Ibsen Henric Ongidi (2021) established the level of termination by associating the point of division of internal iliac artery with vertebral level & it was found that termination of internal iliac artery varies from L5/S1 junction at the brim of pelvis to S2 level in pelvic cavity.

Table: 6.8 The distance of the level of division of the internal iliac artery in respect to greater sciatic foramen reported by various studies

SNo.	Distance from Greater Sciatic Foramen (GSF)	Naveen (2011)	Pavan Havaldar (2014)	Sakthivelavan (2014)	H. Mamatha (2015)	Present Study (2020)
1.	5.5cm above GSF	6.6% (4)	-		-	-
2.	4cm above GSF	13.2% (8)	-		-	-
3.	3.5cm above GSF	6.6% (4)	-	34.5% (40)	16% (8)	-
4.	3 cm above GSF	30.7% (18)	2% (1)		18% (9)	-
5.	2.5cm above GSF	19.8% (12)	4% (2)		36% (18)	8% (4)
6.	2 cm above GSF	23.1% (14)	18% (9)		28% (14)	12% (6)
7.	1.5cm above GSF	-	8% (4)		-	14% (7)
8.	1cm above GSF	-	18% (9)		-	22% (11)
9.	0.5cm above GSF	-	18% (9)		-	16% (8)
10.	At upper border of GSF	-	14% (7)	65.5% (76)	-	24% (12)
11.	0.5cm below GSF	-	8% (4)	-	-	2% (1)
12	1 cm below GSF	-	6% (3)	-	2% (1)	2% (1)
13	2 cm below GSF	-	4% (2)	-	-	-

6.3.2 Mode of Termination of internal iliac artery

The usual pattern of termination of the internal iliac artery was by branching into the anterior and posterior division. In our study, 80% of the specimen shows this pattern of termination. Similar to our observation Sakthivelavan (2014) & Ibsen henric (2021) report 79.3% & 77.2% cases of bifurcation of internal iliac artery into anterior and posterior division respectively.

We observed other patterns such as trifurcation which was of two types. In one type trifurcation of trunk into anterior division, posterior division and a common trunk of inferior gluteal artery (IGA) & internal pudendal artery (IPA) and in other type trifurcation into iliolumbar artery, anterior & posterior division, found in 6% & 4% cases respectively in our study.

Other studies also report such cases of trifurcation, in these cases iliolumbar takes origin from bifurcation point of internal iliac artery and converts it into trifurcation. Ibsen henric (2021) report 3.5% such cases. Rusu et al (2010) classify such cases into Level D origin of iliolumbar artery which was found in 3.75% of cases.

In the present study another pattern of ramification into multiple branches was also found in 10% of cases. Our findings correlate with Ibsen henric, 2021 (10.5%). However Sakthivelavan (2014) mentioned 20.7% cases in which internal iliac artery terminated by giving rise to its principal branches directly without dividing into two trunks.

Based on a radiological review of 197 cases Pelage et al (1999) established a classification of the internal iliac artery reporting that it terminated as two main trunks (anterior and posterior) in 77% of cases and into three main trunks in 14% of cases including posterior branches, a common trunk of the internal pudendal and inferior gluteal artery and genitourinary branches. Although, Yamaki et al (1998) reported that the artery divided into a common trunk with the superior gluteal artery instead of the genitourinary branches (80%).

In addition, Pelage et al (1999) stated that in 3% of cases the internal iliac artery has four or more terminal divisions, in 4% of cases the internal iliac artery remains as a single main trunk, while in 2% of cases the internal iliac artery had no systematic termination.

The occurrence of such patterns could be explained by differential patterning during embryological development. The variant patterns can influence vascular interventions done to control bleeding in intractable pelvic hemorrhage. Surgeons attempting to ligate the anterior division of the IIA selectively should be aware of these variant branching patterns.

Table: 6.9 Various patterns of Termination of internal iliac artery

SNo.	**Termination patterns**	Pelage et al (1999)	Sakthivelavan (2014)	Ibsen Henric (2021)	**Present Study (2020)**
1.	Bifurcation into anterior and posterior Division	77%	79.3% (92)	77.2% (44)	80% (40)
2.	Trifurcation into posterior division, Common Trunk of IGA & IPA and anterior division	14%	-	-	6% (3)
3.	Trifurcation into posterior division, IG trunk and SVA	-	-	8.8% (5)	-
4.	Trifurcation into iliolumbar, anterior & posterior division	-	-	3.5% (2)	4% (2)
5.	Ramifies into four or more branches	3%	20.7% (24)	10.5% (6)	10% (5)

6.4 TYPE OF BRANCHING PATTERN OF INTERNAL ILIAC ARTERY ACCORDING TO ADACHI'S CLASSIFICATION

Branching pattern of internal iliac artery was classified into 5 types in which Type I, Type II & Type IV were further sub divided into two type a & b, according to widely accepted classifications by Adachi 1928 (Fig. 4.8).

In our study Type Ia was the most common finding. The order of incidence of Types in the present study was I > III > II >V instead of I > II > III >IV>V by Adachi's classification.

Similar order of incidence of types was reported by Pavan Havaldar (2014) only among studies mentioned in Table 6.11

In the present study Type IIb and Type IV was not found in any of the specimens. However Type V was found in 2% of specimens which was very rare in other studies. Pavan Havaldar (2014) & Vishnumukkala(2013) also reported a single case of Type V similar to our study.

In the present study frequency of occurrence of type II was very less 10% than that of type III 24%. This was against the findings of Adachi (1928) and many other studies as shown in Table 6.11. However similar finding was also reported by Ramakrishnan (2012), Talalwah(2014), Sakthivelavan (2014), Ibsen Henric (2021), Vishnumukkala (2013) .& Jastschinski (1891).

Jastschinski(1891) grouped pattern of origin of large-calibre vessels into 4 types, and ordered numerically based upon their frequency of observation. The main differences in the Adachi system compared to that of Jastschinski (1891a) was that the Jastschinski Types II and III swapped positions due to the relative predominance of Jastschinski Type III over Type II in the Adachi study. These differences are might be due to variability in the vasculature among different ethnic groups.

According to Adachi(1928), the type I pattern was found in 51.2% of the cases, type II in 23%, type III in 18% and type IV in 4.1% of the cases. In contrast, Fatu et al (2006)

found type I pattern in 60 out of 100 cases, type II in 20 cases, type III in 10 cases, type IV in one case and type V was found in 8 cases. Fatu report the maximum incidence of type V pattern among all the studies.

From a study conducted by Braithwaite1952, type I arrangement was seen in 58.5 % of cases, type III in 22.5 % and type II in 15.3 %. The type IV was less frequent and occurred in 3.86 % of specimens. According to a study by Naveen et al. from 60 cadavers, the type Ia pattern of Adachi was observed in 76.9% of the cases followed by types III in 6 (9.9%) cases, type II & type Ib in 4 (6.6%) of cases & the type IV and V pattern of Adachi were not observed.

Recent studies on Indian cadavers (Shivakumar et al. 2010; Naveen et al. 2011; Ramakrishnan et al.2012; Vishnumukkala et al. 2013; Sakthivelavan 2014, Pavan Havaldar 2014 & Present study 2022) suggest that the Indian population may have a higher percentage of type 1 variants as compared to the Western/Japanese population. As depicted in Table 6.11.

Lipshutz 1918 also reported that there was a tendency for types I and II to be more common on the right side with types III, IV, and V being more common on the left. However such significant comparison between right & left sides was not reported by any author and in our study also.

Table 6.10 Incidence of variations in branching pattern of internal iliac artery from different authors according to Adachi's 1928 classification system into 5 main type

SNo	Author	Year	Sample Size	Adachi's 1928 classification system (%)					
				I	II	III	IV	V	Other
1	Jastschinski	1891	396	38	24	28	9	-	-
2	Lipshutz	1918	181	51	24	17	7	-	-
3	Adachi	1928	121	51.2	23.1	18.2	4.1	0.8	2.5
4	Tsukamoto	1929	287	56.5	8.4	22.0	12.9	-	-
5	Miyaji	1935	179	70.4	11.7	9.5	8.4	-	-
6	Aria	1936	500	52.4	19.4	24.0	4.2	-	-
7	Hoshiai	1938	379	55.1	16.1	26.1	2.6	-	-
8	Ashley & Anson	1941	260	58.1	17.3	9.6	7.7	-	7.3
9	Suzuki	1951	490	53.2	18.8	24.1	3.7	0.2	-
10	Braithwaite	1952	169	58.5	15.3	22.5	3.6	-	-
11	Yasukawa	1954	544	53.7	18.4	23.9	4.0	-	-
12	Shafiroff et al.	1959	150	50	20	18	12	-	-
13	Fischer	1959	50	50	26	16	8	0	0
14	Roberts &Krishingner	1967	167	51	26.8	14.4	7.2	0	0
15	Morita	1974	267	49.1	22.5	21.7	6.7	0	-
16	Lwasaki	1987	251	54.2	19.5	24.3	2	0	-
17	Yamaki	1998	645	58	13.6	22.8	5.4	0.2	-
18	Fatu et al.	2006	100	60	20	10	1	8	1

19	Shivakumar et al.	2010	40	89	11	00	00	00	-
20	Naveen et al.	2011	60	83.5	6.6	9.9	00	00	-
21	Ramakrishnan et al.	2012	50	60	8	30	2	00	-
22	Vishnumukkala et al. (2013)	2013	45	66.7	2.2	24.4	4.4	2.2	-
23	Talalwah	2014	342	36.1	5.3	34.8	2.3	-	
24	Sakthivelavan	2014	116	63.2	15.8	21	-	-	-
25	Pavan Havaldar	2014	50	52	2	34	0	2	10
26	Chongtham (fetal)	2017	44	34.1	13.6	22.7	29.5	00	--
27	Ibsen Henric	2021	57	68.4	7.0	21.1	3.6	-	-
28	Present Study	2022	50	64	10	24	-	2	-

6.5 OBTURATOR ARTERY

The obturator artery presents considerable variation in its origin, size and distribution. Indeed, Lipshutz (1918) commented that "Probably no artery in the human body of proportionate size has so voluminous a literature as the obturator artery," a fact which most likely still holds true.

In our study all the rare variant origin of other branches of internal iliac artery like Superior Vesical artery (Figure 5.25), inferior gluteal artery (Figure 5.21), iliolumbar artery (Figure 5.24) were associated with variant origin & course of obturator artery.

The origin point of the obturator artery was highly variable and has been studied in detail due to its clinical significance in pelvic and abdominal wall surgery.
Out of 50 pelvic halves studied, 31 pelvises (62%) showed variations in the origin

In the present study obturator artery was most frequently a direct branch of the anterior division of the internal iliac artery, in 19 specimens (38%). In most of the studies, majority of cases shows the same site of origin of obturator artery; however incidence varies from 35% cases of Tirupathirao (2013) to 61% cases of Mangala M Pai (2009) as shown in Table 6.11

Sakthivel (2015), Ramakrishnan (2012), Braithwaite (1952) reported incidence of origin of obturator artery similar to our study as 36.67%, 40%, 41.4% respectively.

Parsons and keith (1897), Pick Ashely & Anson (1942), Braithwaite (1952), mentioned the origin of obturator artery from other branches of anterior division also like separately from Inferior gluteal artery, internal pudendal artery and from Common Trunk of IGA & IPA. However no such site of origin was reported by our study.

Table 6.11: Frequency reported by various authors on the origin of obturator artery from the anterior division of internal iliac artery

SNo	Author	Sample Size	As a separate branch	Inferior Gluteal Artery	Internal Pudendal Artery	Common Trunk of IGA & IPA	Total from Anterior division
1	Parsons and keith (1897)	55	39.3%	3.2%	3.2%	8.2%	**53.9%**
2	Pick Ashely & Anson (1942)	320	42.6%	5.5%	3.7%	10.1%	**61.9%**
3	Braithwaite (1952)	169	41.4%	4.7%	3.8%	10%	**59.9%**
4	Mangala M Pai (2009)	98	60.2%	-	-	-	**60.2%**
5	Sharmishta Biswas (2010)	56	44.6%	-	-	-	**44.6%**
6	Ramakrishnan (2012)	50	40%	-	18%	18%	**76%**
7	Sakthivel (2015)	60	36.67%,	-	-	-	**36.67%,**
8	Tirupathirao et al., (2013)	45	35.55%	4.44%	4.44%	13.33%	**57.76%**
9	Akshara Rajive et al (2015)	50	54%	2%	2%	-	**58%**
10	Nataraj, Havaldar (2017)	50	40%	32%			**72**%
11	Yuvaraj Maria (2018)	80	45%	-	-	-	45%
12	Present Study (2022)	50	38%	-	-	-	38%

In the present study obturator artery arise from posterior division of internal iliac artery in 26% of specimens either as a separate branch in 16% cases, with Superior Gluteal Artery (6%), or with Iliolumbar Artery (4%).

Similar findings was also reported by Yuvaraj Maria (2018) in which site of origin from posterior division was 28% (as a separate branch in 20%, 5% & 3% from Superior Gluteal & Iliolumbar Artery respectively).

Sharmishta Biswas (2010) also observed 28.6% cases from posterior division similar to our study in which maximum 16.1% was from superior gluteal.

In the present study only 4% cases had origin with iliolumbar artery which co relates with the findings of most of the studies except Ramakrishnan (2012), who reported 10% cases of origin of obturator with iliolumbar artery.

Table 6.12: Incidence of obturator artery originating from the posterior division of internal iliac artery by various authors

SNo	Author	Sample Size	As a separate branch	With Superior Gluteal Artery	With Iliolumbar Artery	Total from Posterior division
1	Parsons and keith (1897)	55	-	8%	4.9%	**12.9**%
2	Pick Ashely & Anson (1942)	320	-	6.4%	1.8%	**7.9**%
3	Braithwaite (1952)	169	-	10%	3.5%	**13.5**%
4	Mangala M Pai (2009)	98	7.20%	10.20%	1%	**18.40**%
5	Sharmishta Biswas (2010)	56	12.50%	16.1%	-	**28.6**%
6	Ramakrishnan (2012)	50	-	14%	10%	**24**%
7	Sakthivel (2015)	60	11.67%	15%	3.33%	**30**%
8	Tirupathirao (2013)	45	-	4.44%	2.22%	**6.66**%
9	Akshara Rajive (2015)	50	10%	2%	-	**12**%
10	Yuvaraj Maria (2018)	80	20%	5%	3%	**28**%
11	Present Study (2022)	50	16%	6%	4%	**26%**

Obturator Artery was found arising from external iliac artery or its branch inferior epigastric artery in 36% of cases in the present study.

There was a low incidence of the obturator artery arising directly from the external iliac artery with studies reporting frequencies of 1.1% (Braithwaite 1952) to 8.8% (Thirupathi rao et al., 2013) as compared to the incidence of the obturator artery originating from the inferior epigastric artery with studies reporting average frequency as 21.4%

Table 6.13:Frequency of obturator artery originating from the external iliac artery by different authors

SNo	Author	Sample Size	Inferior Epigastric Artery	Direct from external Iliac Artery
1	Parsons and keith (1897)	55	25%	1.6%
2	Pick Ashely & Anson (1942)	320	21.3%	0.9%
3	Braithwaite (1952)	169	19.5%	1.1%
4	Mangala M Pai (2009)	98	14.3%	5.10%
5	Sharmishta Biswas (2010)	56	23.2%	3.6%
6	Sakthivel (2015)	60	25%	8.33%
7	Tirupathirao et al., (2013)	45	26.66%	8.88%
8	Akshara Rajive et al (2015)	50	22%	4%
9	Amudalapalli (2015)	50	26%	8%
10	Nataraj, Havaldar (2017)	50	6%	2%
11	Yuvaraj Maria (2018)	80	22%	5%
12	Present Study (2022)	50	26%	10%

6.6 INFERIOR GLUTEAL ARTERY

In the present study origin of Inferior gluteal artery was from anterior division in majority of cases (90%) which is either independently from anterior division or through a common trunk with Internal Pudendal artery.

In majority of case 64% site of origin was through a common trunk with Internal Pudendal artery which corresponds with Type 1 Adachi classification of branching pattern of internal iliac artery.

However it may arise from the posterior trunk with the superior gluteal artery in 8% cases of present study which corresponds with Type II Adachi classification. Adachi report 23.1% such cases. Lipshutz (1916) mentioned that the inferior gluteal artery arise with the superior gluteal artery, superior to piriformis in 24% cases and this course variation was noticed to be associated with a high variability of the obturator artery arising from the external iliac artery.

Naguib et al 2008 mentioned that inferior gluteal artery arise independently from the anterior trunk in 85% of the specimens and from the posterior trunk in 15%. However, it arise from a common trunk either with the superior gluteal or internal pudendal arteries (Cruveilhier 1871; Sappey 1876) in 24% or in 40% respectively

In the present study a single case was found in which inferior gluteal artery arise from obturator artery or from a common trunk with obturator artery which was arising from posterior division of the internal iliac artery which was a very unusual variant as shown in Figure 5.21. Although Ashwini et al (2011) report a case where obturator artery was given off from inferior gluteal artery which was a branch from posterior division. Previously, Lipshutz (1916) reported this phenomenon in 3.5% of specimens.

Variation in the inferior gluteal artery branches could present with other vascular anomalies such as the obturator artery arising from it rather than its usual origin from the internal iliac artery. In these cases the IGA is the chief blood supply for the medial thigh compartment.

6.7 ILIOLUMBAR ARTERY

In our study, we observed that the origin of the Iliolumbar Artery was from the posterior division in 52% (26), 38% (19) from the trunk of the internal iliac artery, 4% (2) from the single trunk with obturator artery from posterior division, and 6% (3) it was absent. The posterior division of the internal iliac artery was the most common site of origin.

Valchkevich Dzmitry et al (2020), Waseem Al Talalwah et al (2014) & Teli CG et al (2013), observed that the origin of iliolumbar Artery was from the posterior division in 73.3%(22) 77.90% & 80%(32) respectively, a finding which was similar with our study.

While in other studies of Parul et al (2021), Ravi Shankar Gadagi et al (2018), Turan Koç et al (2016), Kiray A et al (2010), Yuvaraj Maria Francis (2018), Rusu MC et al (2010), the iliolumbar artery originated from trunk of IIA in 66.66% (16), 36.67%(11), 57.14%(12), 71.4% (30), 75%, 52.50% respectively - a finding which was different from our study.

A comparison of variations with respect to the origin of the iliolumbar artery (ILA), with different studies is tabulated in table 2.

In our study we found origin of ILA mainly from either posterior division of IIA or from the trunk of IIA. There were no branches coming from the common iliac, external iliac or gluteal arteries as has been reported by various other authors.

Several authors have classified the origin of ILA differently. Rusu et al (2010) classified the ILA origin into different levels; Level A: ILA from the CIA. Level B: ILA from the CIA bifurcation. Level C: ILA from the main trunk of the IIA. Level D: ILA from the origin of the posterior division of the IIA. Level E: ILA from the posterior division of the IIA. In our study, type 1 corresponds to level E category whereas type 2 corresponds to level C category. The atypical type 3 in which ILA was arising from single trunk with obturator artery from posterior division did not correspond to any of the above Rusu et al (2010) levels of classification & was not reported by any other study.

Table 6.14: Various mode of origin of iliolumbar artery by different authors

SNo	Author	Sample Size	Trunk	Posterior Division	Lateral sacral artery	Obturator Artery	Superior Gluteal Artery	Common Iliac Artery	External Iliac Artery
1	Chen (1999)		96.30%	-	-	-	-	3.70%	-
2	Rusu (2010)	30	52.50%	32.50%	-	-	-	8.75%	-
3	Kiray A(2010)	42	71.4% (30)	19% (8)	-	-	-	4.8% (2)	-
4	Teli Chanrika (2013)	40	20% (8)	80% (32)	-	-	-	-	-
5	Waseem Al Talalwah (2014)	342	13.80%	77.90%	-	-	0.70%	2%	0.30%
6	Turan Koç (2016)	21	57.14% (12)	23.8% (5)	-	-	-	-	-
7	Ravi Shankar (2018)	30	36.67% (11)	23.33% (7)	-	-	-	13.33% (4)	-
8	Yuvaraj Maria (2018)	80	75%	25%	-	-	-	-	-
9	Valchkevich Dzmitry (2020)	30	16.6% (5)	73.3% (22)	3.3% (1)	3.3% (1)	3.3% (1)	-	-
10	Parul (2021)	24	66.66% (16)	29.17% (7)	4.16% (1)	-	-	-	-
11	Present study (2022)	50	38% (19)	52% (26)	-	4% (2)	-	-	-

In one cadaver, on both sides, it was observed that the iliolumbar artery was taking the double origin from two different points, one from trunk & other from posterior division of IIA. Turan Koç et al (2016) & Amaç Kiray (2010) also reported such cases in 4 & 2 (4.8%) specimens respectively.

In our study we also observed absence of iliolumbar artery in 3 specimens (6%). So far very few reports have been documented on the absence of iliolumbar artery. Ravi Shankar Gadagi (2018), Lipshutz (1918) and Al Talalwah (2014) reported the absence of ILA in 8 specimens (26.67%), 5 subjects and 4.7% respectively. In case ILA was absent, it was replaced by fourth lumbar artery (Lipshutz 1918)

Table 6.15: Number of Iliolumbar artery present in the pelvic half reported by various Authors

SNo.	Author	Sample Size	Single origin	Double origin from 2 Different point	Absent
1	Kiray A (2010)	42	95.24%	4.8% (2)	-
2	Waseem Al Talalwah (2014)	342	95.3%	-	4.70%
3	Turan Koç (2016)	21	80.6%	19.4% (4)	-
4	Ravi Shankar (2018)	30	73.33%	-	26.67% (8)
5	Present study (2022)	50	90%	4% (2)	6% (3)

6.8 SUPERIOR VESICAL ARTERY

Superior vesical artery often arises from the anterior division of internal iliac artery and umbilical artery, in the present study in a single cadaver on the left side the superior vesical artery was observed arising from obturator artery which was also having an aberrant course & origin from external iliac artery instead of internal iliac artery as illustrated in Figure 5.25. While on the right side of same cadaver the superior vesical artery arises from usual anterior division of internal iliac artery. In this case blood supply of bladder was derived from external iliac artery via obturator.

Similar rare variants in origin have also been reported following a study of 353 Japanese cadavers (706 pelvic halves), Kawai et al. (2008) reported a rare variant in which the inferior epigastric arose from a common trunk, with the obturator artery and either the superior vesical artery or both the superior and inferior vesical arteries arising from the same arterial trunk.

Bergman (1988) reported the origin of superior vesical artery from uterine artery (9%), vesicodeferential (9%), and the obturator arteries (4.4%).

Parsons and Keith (1897) reported on 58 observations of the superior vesical artery. In 44 cases (75.9%) it arose from the hypogastric trunk; in two of these cases the artery was duplicated, in nine cases (15.5%) it arose from the anterior division of the internal iliac artery and in one of these it was duplicated, in four cases (6.9%) it arose from the internal iliac artery, and in one case it arose from the hypogastric trunk in common with the middle rectal artery.

Lipshutz (1918) reported the superior vesical artery to arise as a common trunk with the uterine. Similarly, Pelage et al. (1999) studied 375 uterine arteries in 197 patients and reported three cases (1%) in which the vesical artery found originating from a common trunk with the uterine artery; it subsequently coursed downward and medially to reach the lateral part of the bladder where it gave off three terminal branches.

In our study superior vesical artery arises as a single branch as well as multiple branches from anterior division of internal iliac artery. In majority of the cases 68% superior vesical artery arises as a two branches. Similar number of superior vesical artery was also observed in majority by the study of Levi (1902) and Dubreuil-Chambardel (1925) in 70% & 74% specimens respectively.

Levi (1902) and Dubreuil-Chambardel (1925) describe that the number of superior vesical artery varies from one to five. This finding differed from that of older research, in which superior vesical artery reported as a single branch.

Ashley and Anson (1941) studied 66 cadaveric pelvic halves, and reported that the superior vesical arteries were commonly two to three in number and all were derived from the umbilical artery.

Talawah (2014) states that on each side, the vesical arteries are two or less in number in females but two or more in males. Similar observation was reported by Reddy et al 2007 that in males, the superior vesical artery arises from the anterior division of the internal iliac artery as three or four branches.

Table 6.16 Number of Superior vesical artery arising from internal iliac artery reported by various authors

S. No.	**Number of SVA**	Levi (1902)	Dubreuil-Chambardel (1925)	Present Study (2022)
1	Single Branch	10 %	9 %	18 %
2	Two	70 %	74 %	68 %
3	Three	12 %	9 %	10 %
4	Four	8 %	6 %	4 %
5	Five	-	2 %	--