Surgical and Radiologic Anatomy (2019) 41:125–132
https://doi.org/10.1007/s00276-018-2111-4

ORIGINAL ARTICLE

Anatomical variations of the principal nutrient pedicle for iliac crest graft: the ilio-lumbar artery

G. Sankaranarayanan[1] · S. S. S. N. Rajasekhar[1]

Received: 14 July 2018 / Accepted: 24 September 2018 / Published online: 12 October 2018

Abstract

Purpose The purpose of this study is to observe the origin, course, length, diameter and termination of the ilio-lumbar artery (ILA) and its variations in south Indian population.

Materials and methods The study was carried out in 34 sides in 19 cadavers (R-18, L-16) used for routine dissection for undergraduate students during the period of 2017–2018 in Department of Anatomy, JIPMER, Puducherry. On each side of the pelvis, the origin, length, diameter, course of the ILA and its relations to the surrounding anatomical structures was observed and documented.

Results Out of 34 formalin-fixed pelvis halves of human cadavers, the ILA originated from the common iliac artery (CIA), the trunk of the internal iliac artery (IIA) and posterior division of IIA in around 0%, 61.76%, and 38.23% of the cases, respectively. In all the cadavers, the ILA passes in between the obturator nerve anteriorly and the lumbosacral trunk posteriorly and ILA terminates by giving iliac and lumbar arteries medial to the psoas major muscle.

Conclusions In our study, we observed that the mean distance between the origin of ILA and the bifurcation of the CIA is significantly less than the study done previously. The knowledge about the variations in the origin, course, length, diameter, and termination of ILA is very important to the surgeon to avoid iatrogenic injury during surgeries in lumbosacral region and moreover, it will be easy to access the ILA for clamping or embolization. A similar study can be done with more sample size in different population to increase the knowledge base regarding ILA anatomy.

Keywords Common iliac artery · Ilio-lumbar artery · Ilium · Internal iliac artery

Introduction

Ilio-lumbar artery (ILA) is one of the three branches of the posterior division of the internal iliac artery (IIA) [17, 21]. ILA passes supero-laterally behind the obturator nerve (ON) and external iliac vessels. Further, the ILA passes in front of the sacroiliac joint and lumbosacral trunk (LST). It finally reaches the medial side of the psoas major, where it gives off its terminal branches namely, iliac and lumbar arteries [19, 21]. The lumbar branch ascends up behind the psoas major muscle to supply the psoas major and quadratus lumborum and anastomose with the fourth lumbar artery. The ILA also gives a spinal branch, which passes into the vertebral foramen between the fifth lumbar and first sacral vertebrae to supply the cauda equina. The iliac branch enters and supplies the iliacus muscle and the iliac bone (Ilio-lumbar artery of Haller) [13]. During its course through the iliacus muscle, the ILA anastomose with the circumflex iliac, gluteal and external branch of the epigastric arteries to supply the gluteal and abdominal muscles. The iliac crest will be supplied by the arteries such as ilio-lumbar, superior gluteal, deep circumflex iliac and fourth lumbar [3, 8, 21]. Among them, the ilio-lumbar artery is an ideal pedicle for vascularized bone graft [21]. The knowledge about the arterial supply to the iliac bone is useful in the radiological embolization through the ILA [14]. Hemorrhage is the most common cause of morbidity in gynecological surgeries [4, 5]. If the internal iliac artery (IIA) is ligated proximal to the origin of ILA, it leads to buttock claudication and necrosis [2]. So, the knowledge about the origin and course of the ILA is essential to surgeons to avoid the iatrogenic vascular hemorrhage in the regional surgeries Moreover, it will be easy to access the ILA for clamping or embolization. The aim of the present

✉ S. S. S. N. Rajasekhar
sekhar5883@gmail.com

[1] Department of Anatomy, JIPMER, Puducherry, India

study was to observe the origin, course, length, diameter, and termination of the ILA and its variations.

Materials and methods

Ilio-lumbar artery was observed in 19 formalin-embalmed cadavers that are used for dissection and teaching the undergraduate students in the Department of Anatomy, JIPMER, Puducherry, India, during the period of 2017–2018. The cadavers were voluntarily donated and with age ranging from 45 to 70 years. Among them, 15 were male and 4 were female.

Following evisceration of the abdominal and pelvic cavity, posterior wall of the pelvis was dissected to identify the CIA and IIA. The IIA was dissected to observe the anterior and posterior divisions. Internal iliac veins and its tributaries were carefully dissected away from the arteries. Branches of the posterior division of the IIA was dissected. ILA was dissected from its origin to its termination. The course and the relations of the ILA were observed. The following parameters of ILA were noted.

1. Site of origin of Ilio-lumbar artery.
2. The length of ILA.
3. The diameter of ILA.
4. The distance between the origin of ILA and the bifurcation of common iliac artery (CIA).
5. The course and relations of Ilio-lumbar artery with Obturator nerve (ON) and Lumbosacral trunk (LST).
6. The termination of ILA.

Figures 1, 2, 3 and 4 show the schematic diagrams of the measurements taken from CIA, IIA, and ILA. Figures 5 and 6 show the photograph of dissection of origin and divisions of internal iliac artery and its branches.

Results

The Ilio-lumbar artery was found to be arising from the trunk of IIA as well as from the posterior division of IIA. The distance from the site of origin of ILA and bifurcation of CIA was observed to be in the range of 11–30 mm in majority of the cases. The length of ILA ranged between 2.96 and 20.25 mm with mean of 13.85 ± 4.7 mm when ILA originated from posterior division of IIA. The length of ILA ranged between 5.21 and 23.97 mm with mean of 15.72 ± 5.11 mm when ILA originated as the direct branch from the trunk of IIA. However, the difference was statistically insignificant. The diameter of ILA ranged between 1.12 and 1.26 mm with mean of $1.21 \text{ mm} \pm 0.04$ mm when ILA originated from the posterior division of IIA. The

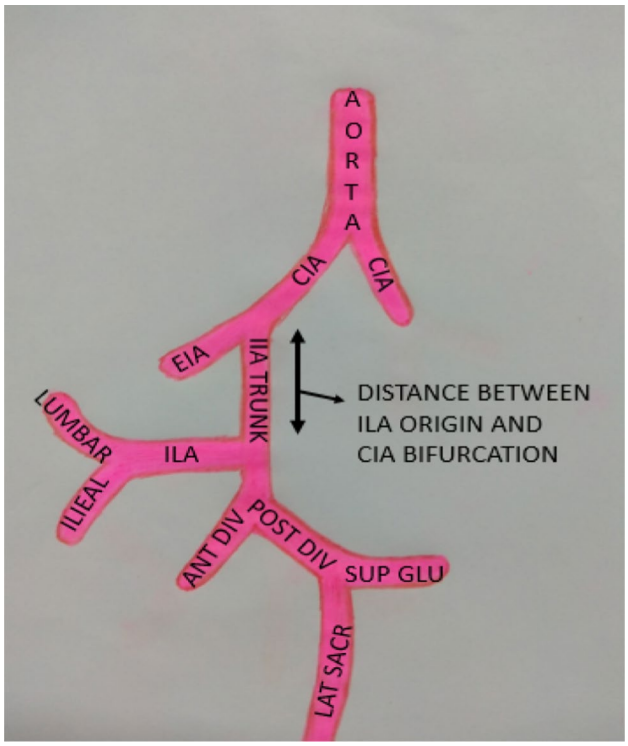

Fig. 1 Distance between bifurcation of CIA and the origin of ILA from the trunk of IIA. *CIA* common iliac artery, *ILA* ilio-lumbar artery, *EIA* external iliac artery, *IIA* internal iliac artery

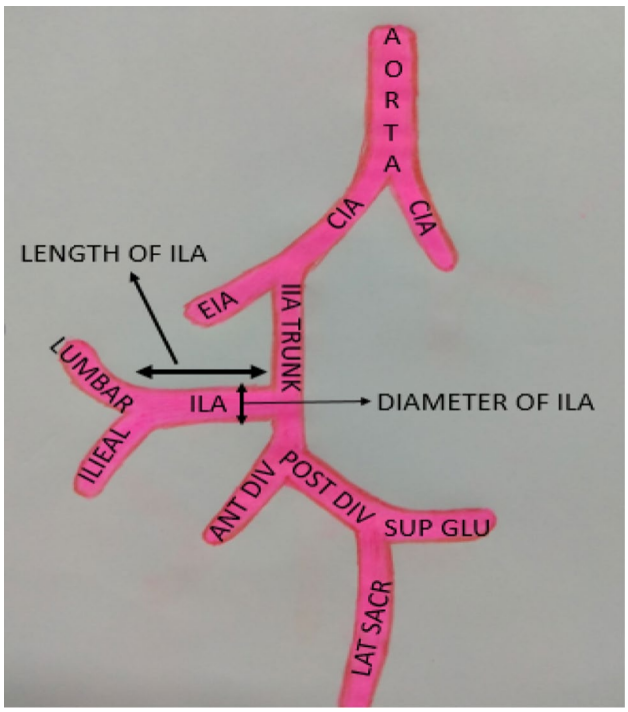

Fig. 2 Length and diameter of the ILA when it is arising from the trunk of internal iliac artery. *CIA* common iliac artery, *ILA* ilio-lumbar artery, *EIA* external iliac artery, *IIA* internal iliac artery

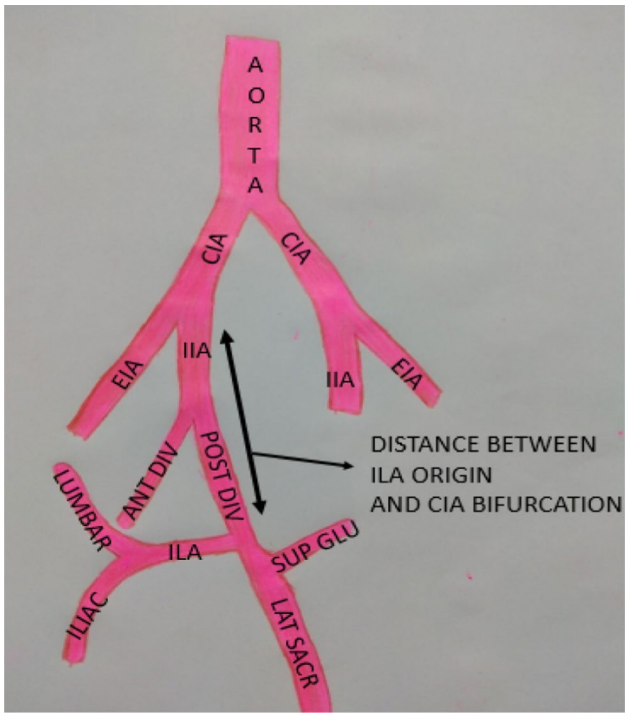

Fig. 3 Distance between the bifurcation of CIA and the origin of ILA when ILA is arising from PD of IIA. *CIA* common iliac artery, *ILA* ilio-lumbar artery, *EIA* external iliac artery, *IIA* internal iliac artery

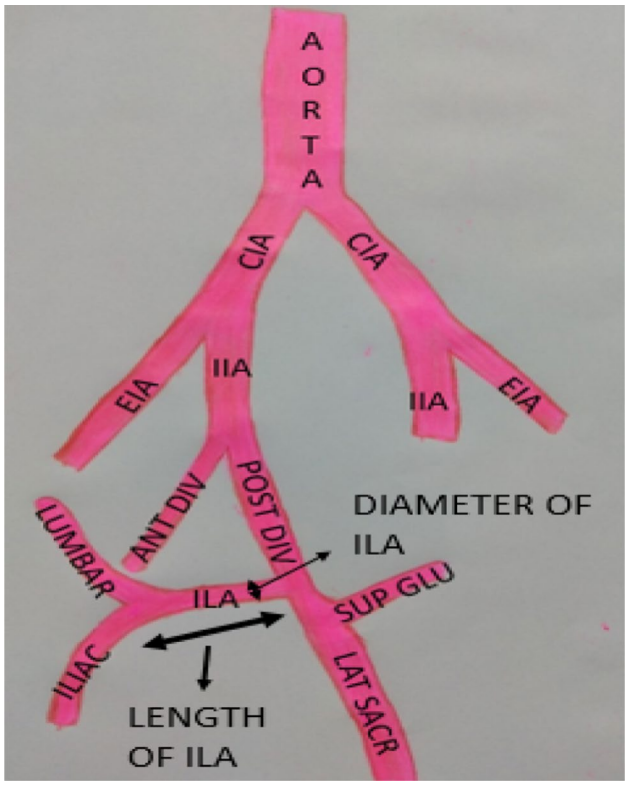

Fig. 4 Length and diameter of ILA when it is arising from the PD of IIA. *CIA* common iliac artery, *ILA* ilio-lumbar artery, *EIA* external iliac artery, *IIA* internal iliac artery

diameter of ILA ranged between 1.86 and 1.99 mm with the mean of 1.92 mm ± 0.04 mm when ILA originated from the trunk of IIA. However, the difference was statistically insignificant. In all the specimens used for the study the relationship between ILA, ON, LST was constant, ON was anterior to ILA and LST was posterior to ILA. Morphometric parameters of ILA such as length, diameter, site of origin, distance between the site of origin of ILA and bifurcation of CIA are shown in (Table 1).

Branching pattern and connections of ILA: when ILA arose from the posterior division and trunk of IIA, it passed laterally in between ON anteriorly and LST posteriorly in all cases. On reaching behind the psoas major muscle, ILA was divided into then ilial and lumbar branches. Lumbar branch ascended up behind the psoas major muscle and supplied it. The further course of the lumbar branch could not be dissected. After supplying the ilacus, the ilial branch passed behind it towards the iliac crest to supply it. Further course of the ilial branch was not dissected. In all the specimens, the initial course of the branches of ILA was observed until which they could be dissected and discerned, and it was found that there were no communications with the other arteries or any other anatomical variations.

The following measurements were analyzed with respect to the site of origin, length, and diameter of ILA.

1. Length of ILA from its origin to its terminal divisions when the ILA is arising from the trunk of the IIA.
2. Length of ILA from its origin to its terminal divisions when ILA is arising from the PD of IIA.
3. Distance between the bifurcation of CIA and the origin of ILA when ILA is arising from the trunk of IIA
4. Distance between the bifurcation of CIA and the origin of ILA when ILA is arising from PD of IIA.

The relationship between the site of origin of ILA and length of ILA is summarized in (Table 2). The association between the length of ILA and the distance between the origin of ILA and bifurcation of CIA is summarized in (Table 3). The association between the diameter of ILA and the site of origin of ILA is summarized in (Table 4).

Discussion

The luminal diameter and the length of the Ilio-lumbar artery are crucial for its preference as component of vascularized bone graft of iliac crest for the reconstruction of mandibular injuries [3]. Knowledge about the site of origin is essential to avoid iatrogenic injuries to the ILA during surgery. During

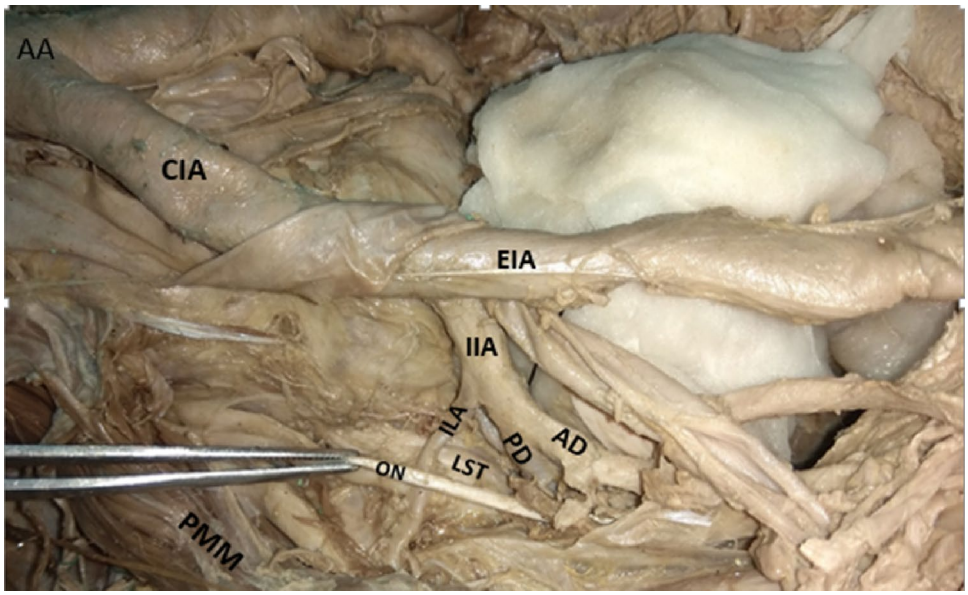

Fig. 5 Origin of ILA from the trunk of the internal iliac artery. *AA* abdominal aorta, *CIA* common iliac artery, *EIA* external iliac artery, *IIA* internal iliac artery, *AD* anterior division, *PD* posterior division, *ILA* ilio-lumbar artery, *ON* obturator nerve, *LST* lumbosacral trunk, PMM psoas major muscle

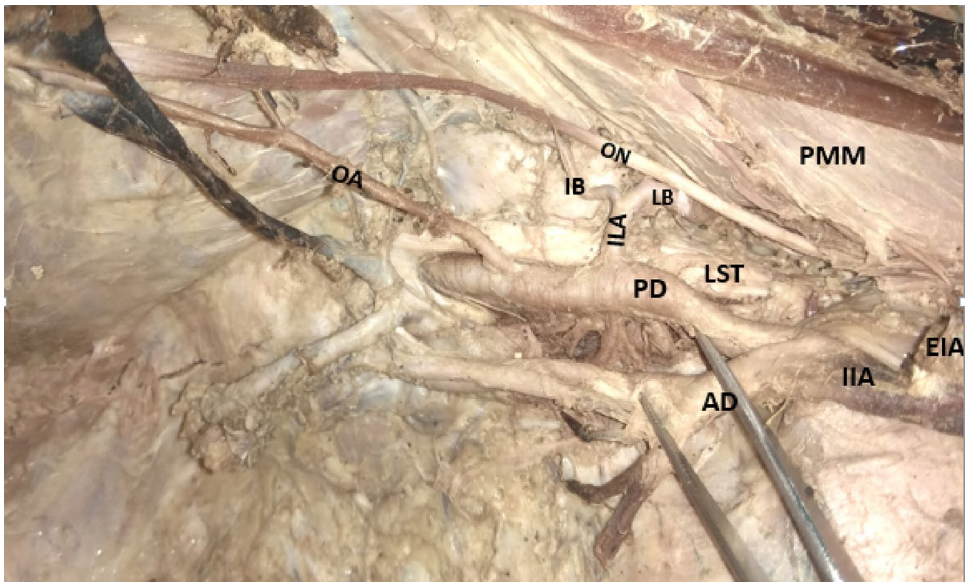

Fig. 6 Origin of ILA from the posterior division of the internal iliac artery. *EIA* external iliac artery, *IIA* internal iliac artery, *AD* anterior division, *PD* posterior division, *ILA* ilio-lumbar artery, *LB* lumbar branch, *IB* iliac branch, *ON* obturator nerve, *OA* obturator artery, PMM psoas major muscle, *LST* lumbosacral trunk

surgical procedures such as paramedian lumbar micro discectomy of L5-S1 intervertebral disc, inadvertent injury to ILA has been reported [6]. Hemorrhage is the most common cause of morbidity in gynecological surgeries [4, 5]. If the IIA is ligated proximal to the origin of ILA then it leads to the buttock claudication and necrosis [2]. Hence, the knowledge of variant anatomy of site of origin of ILA is important. In the present study we observed the site of origin, length and diameter of ILA.

In the present study, the origin of ILA from IIA was observed in 61.76% of the cases which is similar to the observation made by Bleich et al (62.25%) [2]. The percentage of origin of ILA from the posterior division of IIA observed in the present study (38.24%) was not similar to any previously reported findings, but was nearer to the finding reported by Rusu et al (32.5%) [14].

Length of IL

In the present study, the mean length of ILA when the ILA arose from the P.D. of IIA was 13.85 ± 4.7 mm and the mean length of ILA when it originated from the trunk of IIA was 15.72 ± 5.11 mm. The overall mean length of ILA was 13.18 ± 6.59 mm. The mean length of ILA was reported as 12.2 ± 5.5 mm by Teli et al. [19] and 13.2 ± 5.5 mm by Kiray et al. [10]. Souza et al. [15] reported that the mean length

Table 1 Results of length, diameter of ILA, distance between origin of ILA and bifurcation of CIA, relations and termination of ILA in 34 dissected halves of pelvis in the present study

Sl. no.	Origin	Length of ILA (mm)	Diameter of ILA (mm)	Distance B/W ILA origin and cia bifurcation (mm)	Relation of surrounding anatomical structure (ANT → POST)
1	PD of IIA	14.07	1.22	42.25	ON → ILA → LST
2	Trunk of IIA	11.72	1.86	26.60	ON → ILA → LST
3	Trunk of IIA	05.21	1.98	09.86	ON → ILA → LST
4	Trunk of IIA	16.86	1.88	19.07	ON → ILA → LST
5	Trunk of IIA	23.97	1.99	16.26	ON → ILA → LST
6	Trunk of IIA	17.30	1.86	17.30	ON → ILA → LST
7	Trunk of IIA	10.90	1.96	30.66	ON → ILA → LST
8	Trunk of IIA	17.50	1.94	25.56	ON → ILA → LST
9	PD of IIA	20.25	1.23	31.30	ON → ILA → LST
10	PD of IIA	17.95	1.20	29.64	ON → ILA → LST
11	Trunk of IIA	13.75	1.94	23.06	ON → ILA → LST
12	PD of IIA	02.96	1.12	34.16	ON → ILA → LST
13	Trunk of IIA	17.95	1.92	30.81	ON → ILA → LST
14	Trunk of IIA	22.42	1.94	20.57	ON → ILA → LST
15	PD of IIA	07.44	1.16	39.23	ON → ILA → LST
16	PD of IIA	07.27	1.14	42.15	ON → ILA → LST
17	PD of IIA	19.60	1.26	29.47	ON → ILA → LST
18	Trunk of IIA	22.52	1.92	13.11	ON → ILA → LST
19	Trunk of IIA	20.86	1.88	20.02	ON → ILA → LST
20	Trunk of IIA	11.00	1.89	13.37	ON → ILA → LST
21	PD of IIA	10.21	1.24	30.67	ON → ILA → LST
22	Trunk of IIA	12.36	1.94	26.72	ON → ILA → LST
23	Trunk of IIA	13.72	1.97	28.32	ON → ILA → LST
24	PD of IIA	14.32	1.26	26.16	ON → ILA → LST
25	Trunk of IIA	13.62	1.96	30.02	ON → ILA → LST
26	PD of IIA	10.26	1.22	13.11	ON → ILA → LST
27	PD of IIA	19.20	1.24	14.12	ON → ILA → LST
28	PD of IIA	16.62	1.24	12.02	ON → ILA → LST
29	PD of IIA	15.02	1.23	14.01	ON → ILA → LST
30	PD of IIA	16.72	1.26	16.01	ON → ILA → LST
31	PD of IIA	14.02	1.24	13.01	ON → ILA → LST
32	PD of IIA	12.12	1.20	11.01	ON → ILA → LST
33	PD of IIA	16.01	1.17	12.09	ON → ILA → LST
34	PD of IIA	15.36	1.22	10.90	ON → ILA → LST

ON obturator nerve, *LST* lumbosacral trunk, *ILA* ilio-lumbar artery, *CIA* common iliac artery, *IIA* internal iliac artery, *PD of IIA* posterior division of internal iliac artery

Table 2 Relationship between site of origin of ILA and the length of ILA

S. no.	Origin	Number of specimen	Range (mm)	Mean length (mm)	Stand deviation	*p* value
1	Posterior division of IIA	18	2.96–20.25	13.85	4.7	0.27
2	Trunk of IIA	16	5.21–23.97	15.72	5.11	

ILA ilio-lumbar artery, *CIA* common iliac artery, *IIA* internal iliac artery

of the ILA was 14.7 ± 8.2 mm. However, Chen et al. [3] reported the mean length of 22 ± 7 mm which is significantly higher than the mean length reported by other authors. The mean length in the present study similar to reports by Kiray et al. and Souza et al. In the present study, the mean length of the ILA when it is arising from the trunk of the IIA was

greater compared to the mean length of the ILA when it was arising from the posterior division of the IIA. However, the difference was statistically insignificant.

Diameter of ILA

In the present study, the mean diameter of ILA arising from posterior division IIA was found to be 1.21 ± 0.04 mm, whereas, the mean diameter of ILA arising from trunk of IIA was found to be 1.92 ± 0.04 mm. The overall mean diameter of ILA is 1.54 ± 0.36 mm. Chen et al. [3] reported a mean diameter of 2.7 ± 0.6 mm and Bleich et al. [2] reported a mean diameter of ILA 4.6 mm. A mean diameter of 3.7 ± 0.7 mm was reported by Kiray et al. [10] and a mean diameter of 3.5 ± 0.5 mm was reported by Teli et al. [19]. Koc et al. [11] reported that the diameter of ILA originating from the trunk of IIA was lesser than the diameter of ILA originating from posterior division of IIA. However, in the present study, the mean diameter of ILA originating from the trunk of IIA was greater than the mean diameter of ILA originating from posterior division of IIA, contrary to the report by Koc et al. [11]. However, the difference was statistically insignificant.

Site of origin of ILA

The origin of ILA from IIA was reported by most of the authors [2, 3, 7, 10, 11, 14, 15, 19]. Relatively less number of authors reported the origin of ILA from the posterior division of IIA [10, 11, 14, 15, 19]. Very few authors have reported the origin of ILA from CIA [3, 10, 14]. Percentage distribution of origin of ILA from three different sites reported by various authors is summarized in Table 5.

Table 3 Association between the length of ILA and the distance between the origin of ILA and bifurcation of CIA

S. no	Range of distance B/W ILA origin to CIA bifurcation (mm)	No. of pelvic sides observed in that range	Mean length of ILA (mm)	Stand. deviation of length of ILA
1	1–10	1	2.96	–
2	11–20	14	10.97	2.71
3	20–30	10	15.97	1.22
4	30–40	7	19.74	1.6
5	40–50	2	23.24	1.02

ILA ilio-lumbar artery, *CIA* common iliac artery, *IIA* internal iliac artery

Table 4 Association between the diameter of ILA and the site of origin of ILA

S. no.	Origin	Number of specimens	Range (mm)	Mean diameter (mm)	Stand. deviation	*p* value
1	Posterior division of IIA	18	1.12–1.26	1.21	0.04	1.77
2	Trunk of IIA	16	1.86–1.99	1.92	0.04	

ILA ilio-lumbar artery, *CIA* common Iliac artery, *IIA* internal iliac artery

Table 5 Percentage distribution of ILA's origin at three different sites in various studies

Sl. no	Author	ILA from CIA (%)	ILA from IIA (%)	ILA from posterior division of IIA (%)
1	Chen et al. [3]	3.7	96.3	–
2	Bleich et al. [2]	–	62.25	–
3	Rusu et al. [14]	8.75	52.5	32.5
4	Kiray et al [10]	4.8	71.4	19
5	Teli et al [19]	0	20	80
6	Havaldar et al. [7]	–	18	–
7	Souza et al. [15]	0	12	88
8	Koc et al. [11]	0	70.6	29.4
9	Talawah et al. [1]	2	13.8	77.9
10	Present study	0	61.76	38.24

ILA ilio-lumbar artery, *CIA* common iliac artery, *IIA* internal iliac artery

In the present study, the origin of ILA was from the trunk of an internal iliac artery in 61.76% of cases, the origin of ILA was from the posterior division of IIA in 38.23% of cases and origin of ILA from the CIA was not encountered. So in our study, we found that in majority of cases, the origin of ILA was from the trunk of the IIA and our findings were consistent with the observations made by Koc et al. [11] and Kiray et al. [10].

Distance between the ILA origin and CIA bifurcation

Kiray et al. [10] reported that the mean distance between the ILA origin and CIA bifurcation was 28.7 ± 12.6 mm and Souza et al. [15] reported the mean distance of 56.5 ± 16 mm. In a study done by Teli et al. [19], the mean distance between the origin of ILA and the bifurcation of the CIA was 38.7 ± 10.6 mm. In our study, the mean distance between the origin of ILA and the bifurcation of the CIA was 18.29 ± 10.57 mm. So, the mean distance between the origin of ILA and the bifurcation of the CIA in our study is less than the study done by Teli et al. [19]. Majority of the cases in the present study showed that the distance between the origin of ILA and the bifurcation of the CIA fell within the range of 11–20 mm and the mean length of the ILA was 10.97 ± 2.71 mm in such cases.

Relationship of ILA to the surrounding structures

ILA passing between ON and LST was reported by Chen et al. [3], Kiray et al. [10], Souza et al. [15] and Koc et al. [11], whereas, ILA passing between the L4 and L5 root of LST was reported by Rusu et al. [14]. In present study, the ILA coursed between ON and LST which is similar to all findings reported by majority of the authors except Rusu et al. where the relationship was different. Comparison of various parameters of ILA between the present study and the previous studies is depicted in (Table 6). Kiray et al. [10], Teli et al. [19], and Souza et al. [15] in their study measured the distance between the origin of ILA and the lower margin of fifth lumbar vertebra. In the present study, we didn't measure the above-said distance but considered the distance of origin of ILA from CIA bifurcation. This is because we believe that the relationship between the origin of ILA and lower margin of L5 vertebra in a cadaveric study is subjective and more prone for error as the position of ILA will be disturbed during its dissection.

In all cases, ILA passes in between the ON anteriorly and the LST, posteriorly. In all cases, ILA terminated by giving iliac and lumbar arteries medial to the psoas major muscle.

In the third week of development, the umbilical artery is connected to the dorsal branch of the abdominal aorta, the

Table 6 Comparison of various parameters studied by different authors with the present study

Sl. no	Author	Origin of ILA is from	Length of ILA (mm)	Distance of ILA origin from CIA bifurcation (mm)	Relations to the surrounding structures	Other parameters
1	Chen et al. [3]	IIA	22 ± 7	–	ILA passes Behind the ON	Diameter of ILA = 2.7 ± 0.6 mm
2	Bleich et al. [2]	IIA	–	–	–	Diameter of ILA = 4.6 (2–9) mm
3	Rusu et al. [14]	IIA	–	–	ILA passing b/w L4 & L5 root of LS trunk	1. ILA from bifurcation of CIA and IIA was 2.5% and 3.75%
4	Kiray et al. [10]	IIA	13.2 ± 5.5	28.7 ± 12.6	In major cases ILA passing b/w ON and LS trunk	1. Diameter of ILA = 3.7 ± 0.7 mm 2. Distance b/w ILA origin and lower margin of L5 = 43.2 ± 12.6 mm
5	Teli et al. [19]	PD of IIA	–	38.7 ± 10.6	–	1. Diameter of ILA = 3.5 ± 0.5 mm 2. Distance b/w ILA origin and lower margin of L5 = 43.2 ± 11.6 mm
6	Havaldar et al. [7]	IIA	–	–	–	–
7	Souza et al. [15]	PD of IIA	14.7 ± 8.2	56.5 ± 16	ILA passing b/w ON and LS trunk	1. Distance b/w ILA origin and sacral promontory = 71 ± 15 mm
8	Koc et al. [11]	IIA	–	–	LB passing anterior to LS trunk, ON and FN	1. Diameter of ILA originating from IIA < Diameter of ILA originating from P.D of IIA 2. Double ILA was seen in 4.8% cases
9	Present study	IIA	13.18 ± 6.59	18.29 ± 10.57	ILA passing b/w ON and LS trunk	1. Diameter of ILA originating from IIA (1.92 ± 0.04 mm) > Diameter of ILA originating from P.D of IIA (1.21 ± 0.04 mm)

ILA ilio-lumbar artery, *PD* posterior division, *LB* lumbar branch, *CIA* common iliac artery, *ON* obturator nerve, *FN* femoral nerve, *IIA* internal iliac artery, LS trunk lumbosacral trunk, L5 lumbar vertebra

CIA in the form of the plexus. The portion of the umbilical artery proximal to this plexus gives rise to the IIA and superior vesical artery. The portion of the umbilical artery distal to this plexus gives rise to the median umbilical ligament. The blood from the abdominal aorta flows into the umbilical artery through the plexus in the caudal direction leading to caudal migration of the umbilical artery. This caudal migration may be responsible for the variations in the branches of the IIA [9, 12, 16, 18].

Awareness about the possible variations in the course of ILA is important as it is susceptible to injury during the surgical approach for L5–S1 lateral disc excision [6], spinopelvic fixation in case of neuropathic scoliosis [19], anterior and midline posterior approach to sacroiliac joint [11, 19, 20] and lumbosacral spinal surgery [11]. Moreover, the chances of ILA injury is more in open book injury/shearing fracture [22] and posterior pelvic fracture [19].

Conclusion

In our study, we observed that the length and diameter of ILA was greater when the ILA was arising from the trunk of IIA compared to that of the origin from the posterior division of IIA. Greater length of ILA will facilitate an easier access and utilization of ILA for clamping and embolization. The mean distance between the origin of ILA and the bifurcation of CIA was significantly less than that reported in the previous studies. The knowledge about the variations in the origin, course and termination of ILA is very important to the surgeon to avoid iatrogenic injury to the ILA during lumbosacral region surgeries. A similar study can be done with more sample size in a different population to increase the knowledge base regarding ILA anatomy.

Author contributions SG: data collection, data analysis. RSSSN: protocol/project development, manuscript writing/editing.

Compliance with ethical standards

Conflict of interest Authors declare no conflict of interest.

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