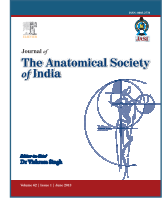




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## Original article

# Lumbar plexus and its variations

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## KEY WORDS

Lumbar plexus block, Variations, Prefixation, Retroperitoneal, Supracristal plane.

## ABSTRACT

**Introduction:** Looking to the applied significance of lumbar plexus in the form of its involvement in various injuries, direct or iatrogenic and entrapment, it is imperative to have a thorough knowledge about its formation, branching pattern, and variations. Tubbs et al referred to the lumbar plexus as a 'no man's land' because of relative inaccessibility of this region and there is infrequency in operating on retroperitoneal structures by neurosurgeons. However, a recent increase in retroperitoneal laparoscopic surgeries inspired us to revisit the anatomy of lumbar plexus. **Material and methods:** The study was conducted on 30 formalin embalmed cadavers available in the Department of Anatomy, RMC, PIMS, Loni, Maharashtra. Thorough dissection was performed to observe the formation of branches of lumbar plexus and measurements were taken from the adjacent bony landmarks. **Result:** Bilateral prefixation of the lumbar plexus was found in one cadaver bilaterally. Ilioinguinal and iliohypogastric nerves were arising by a common stem in 11.66% of cases; in the remaining ones, they were having separate origins. In majority, 81.6% of the genitofemoral nerve pierced the medial third of the anterior surface of the psoas major muscle. Accessory obturator nerve was observed in 3 cases (5%) of 60 plexuses. The site of formation of femoral nerve was 5 cm inferior to the iliac crest in 71.6% of instances. The formation of obturator nerve was found to vary from the level of supracristal plane to 3.5 cm inferior to the plane; in 58.3%, it was 3 cm below the plane. **Conclusion:** The measurements given in this study will help the surgeon to avoid iatrogenic nerve injury as well as to assess them during lumbar plexus block.

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## 1. Introduction

Lumbar plexus blockade (LPB) is a useful technique in provision of surgical anesthesia for lower limb orthopedic surgeries, muscle biopsies, and skin graft harvesting.<sup>1</sup> Continuous LPB after hip<sup>2</sup> and knee joint<sup>3</sup> arthroplasties is a safe and effective technique in management of postoperative pain during physical therapy and hospital stay.<sup>2,3</sup> A successful block depends upon appropriate placement of the needle and an ideal distribution of the local anesthetic. Improper placement of needle may result in postoperative nerve injury of the branches of lumbar plexus (LP) recorded up to 1.9%,<sup>4</sup> and 2% in laparoscopic hernioplasties.<sup>5,6</sup> Accurate measurements of relationship of the branches of LP to the

adjoining bony landmarks aid the surgeon to perform safe and successful LP blocks. Further anatomical variations of LP must be considered at the time of LPB to avoid nerve damage and maximize the success rate.

The LP, which is one of the main nervous pathways supplying the lower limb, is located retroperitoneally within the posterior part of psoas major muscle. It is formed by the first three and most of the fourth lumbar ventral rami with or without a contribution from the twelfth thoracic ventral ramus. Of the main branches, the iliohypogastric (IH) (L1), ilioinguinal (II) (L1), lateral femoral cutaneous nerve (LFCN) (L2-3 dorsal), and the femoral (L2-4 dorsal) appear in that order from above downward, at the lateral border of the psoas major muscle, the genitofemoral (GF) (L1-2) appears

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on the anterior surface, and the obturator nerve (ON) (L2–4 ventral) emerges along the medial border of the muscle. The same is the position of accessory ON if present. These branches have both a sensory and motor component, except the LFCN, which as the name implies does not have a somatic motor component. The pattern of formation of LP is altered if the plexus is prefixed or postfixed, that is, fiber contribution is moved cranially or caudally, respectively.<sup>1,7–10</sup>

## 2. Material and methods

Thirty (twenty-four males and six females) adult human cadavers, embalmed in neutral formalin, were dissected bilaterally. All preserved cadavers were Indians, ranging in age from 30 years to 68 years. Following the removal of abdominal viscera and peritoneum, the LP was exposed by an anterior approach. The branches were identified as they pierced the anterior, medial, and lateral borders of the psoas major muscle. Measurements were made from these nerves to the adjoining bony points e.g., the center of anterior superior iliac spine (ASIS), iliac crest, inguinal ligament, and supracristal plane. The fibers of psoas major were then meticulously dissected at their origin from the lateral surface of the lumbar vertebra and the branches of the LP were traced till their roots at the intervertebral foramen.

The measurements were made with the help of thread and the ruler with the markings in millimeters. The cadavers used were having a normal anatomy of this region and free from any spinal or retroperitoneal anomalies. There were no signs of surgery, wound scars, or trauma in the abdominal regions of any of the cadavers.

## 3. Results

In the present series, the LP was located in the posterior one-third of the psoas major muscle. Most frequent variations were found in IH, LFCN, and GF nerve. Sexual dimorphism was not considered because of small sample size of female cadavers. No significant difference was found comparing the sides of the cadavers.

### 3.1 Formation of branches of lumbar plexus

Eight of sixty (13.3%) investigated LP showed contribution of T-12 in the formation of plexus.

Iliohypogastric and ilioinguinal nerves were separate at origin (the level of L1) in 53 (88.33%) out of 60 plexuses investigated. In seven cases (11.66%), there was a common stem for these nerves which after traversing a mean distance of 6 cm within the substance of psoas major divided into IH and II nerves. The IH nerve was the thinnest in diameter. We did not find the absence of IH nerve in any of the plexuses. These nerves were 1.5 cm apart all along their course across the quadratus lumborum, on the posterior abdominal wall and

were in posterior relation of the kidneys on their respective sides.

The GF nerve pierced the middle third of psoas major at the L3–4 vertebral level, in 49 (81.66%) out of 60 sides, whereas in the rest, it pierced the upper third of the muscle. The nerve was observed as a single stem in 47 (78.3%) sides at its emergence from the psoas major. This single stem divided into genital and femoral branches at a mean distance of 5.5 cm above the inguinal ligament (IL). In 13 (21.7%) cases, GF bifurcated within the substance of psoas into genital and femoral branch, the femoral branch lying medial to the genital. These branches pierced the psoas major muscle at a very variable distance. In one case, GF had its origin solely from L2, rest in all cases, it arose from the L1–L2 ventral division. However, in prefixed plexus, the fibers shifted cranially.

Lateral femoral cutaneous nerve arose from L2 and L3 in all except prefixed plexus. In seven (11.6%) cases, at first the nerve was bound to the femoral nerve (FN) and therefore termed the anterior external femoral cutaneous nerve (Fig. 1). The LFCN acquired an oblique course over iliacus muscle, posterior to the cecum on the right and to the sigmoid colon on the left side. The LFCN traversed to the thigh by passing through the IL in 41 (68.3%) and under the IL in 19 (31%) of cases. In none of the cases did the nerve pass through the bony canal at the ASIS. The LFCN exited the pelvis in four different modes (Table 1).

**Table 1 – Mode of emergence of the lateral femoral cutaneous nerve in relation to the anterior superior iliac spine.**

S. No.	Relation to ASIS	Number of cases observed of 60 cases	Percentage (%)
1	At ASIS	2	3.3
2	1 cm infero-medial to ASIS	47	78
3	2–3 cm infero-medial to ASIS	10	17
4	Lateral to ASIS	1	1.6

ASIS: Anterior superior iliac spine.



**Fig. 1 – Lumbar plexus of left side showing accessory obturator nerve (\*), femoral (a), obturator (b), genitofemoral (c), and lateral femoral cutaneous nerve (d).**

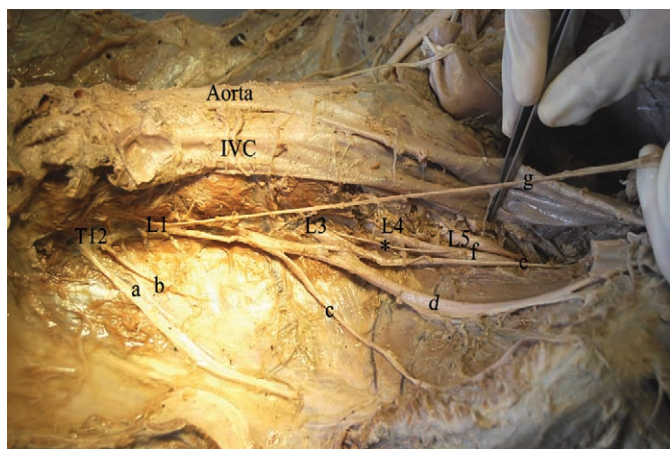
**Table 2 – Formation of femoral nerve in relation to the iliac crest.**

Formation of femoral nerve (distance inferior to iliac crest) in cm	No. of cases	Sides		Percentage (%)
		Right	Left	
1.5–2.5 cm below IC	3	2	1	5
3–5 cm below IC	8	3	5	13.3
5–6 cm below IC	49	25	24	81.66

IC: Iliac crest.

Femoral nerve, the largest branch of LP, had usual origin from L2, 3, 4 in all except once in prefixed plexus (Fig. 2). Interestingly, in one case, the L5 also contributed to the nerve (Fig. 3) along with its normal root value. The formation of FN in relation to the iliac crest is shown in Table 2. The FN emerges from the lateral surface of psoas major below the iliac crest at a variable distance from 3 cm to 6.5 cm, in 80% of cases, the nerve emerges at a distance of 6 cm inferior to iliac crest. The FN has an 8–10 cm oblique course within the pelvis on the iliacus muscle. On the right side, the FN is in posterior relation to the ileocecal junction and on the left side posterior to the sigmoid colon. After traversing the distance of 5 cm, the FN occupies the iliopsoas groove (lacuna musculorum), roofed by iliacus fascia in its pelvic course. In the groin, the FN travels in a rigid fibromuscular canal bound by the inguinal ligament, iliopsoas muscle, and iliacus fascia where it is liable to compression. Sometimes anomalous slip of psoas major may split the FN as seen in Fig. 4. The FN was the thickest in diameter.

The ON emerges at a variable distance from the level of iliac crest to 3.5 cm below the supracristal plane along the medial border of psoas major muscle. In 35 cases (58.33%), the ON was located 3–3.5 cm below the supracristal plane, in 22 (36.6%) cases, it was 2–3 cm below the iliac crest, and in 5%, the nerve was at the level of iliac crest. In one case, L5 also contributed fibers to the ON.



**Fig. 2 – Right lateral aspect showing the branches of prefixed lumbar plexus. Iliohypogastric (a), ilioinguinal (b), lateral femoral cutaneous nerve (c), femoral (d), obturator (e), lumbo-sacral trunk (f), genitofemoral (g), and the nervus furcalis (\*).**

### 3.2 Some interesting variations

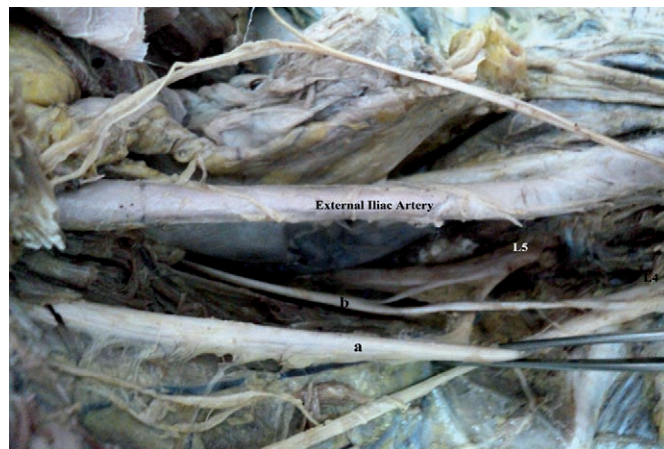
Prefixation was found only in one cadaver bilaterally, whereas we did not find any case of postfixation of LP (Fig. 2). The femoral and ON were formed 1 cm above the iliac crest in 3.3% of instances. The accessory ON was present in three cases (Fig. 1). An interesting intercommunication between the nerve roots L1, L2, and L3 was also observed.

### 4. Discussion

Although the detailed anatomy of lumbosacral plexus was first described by Longnecker,<sup>1</sup> variations in the formation and position of lumbosacral plexus were briefly presented by Hollinshead.<sup>8</sup> These variations have clinical implications during LPB for hip and knee arthroplasties,<sup>1</sup> inguinal herniorrhaphy, obstetric surgeries, appendicectomy,<sup>5,6,11</sup> femoral artery angiography,<sup>5</sup> and pelvic surgeries.<sup>2,6,11,12</sup> The posterior approach of the LPB is preferred over anterior by most of the anesthetists including Pandin et al as the stem of the branches of LP can be assessed easily within the substance of psoas major.<sup>13</sup>

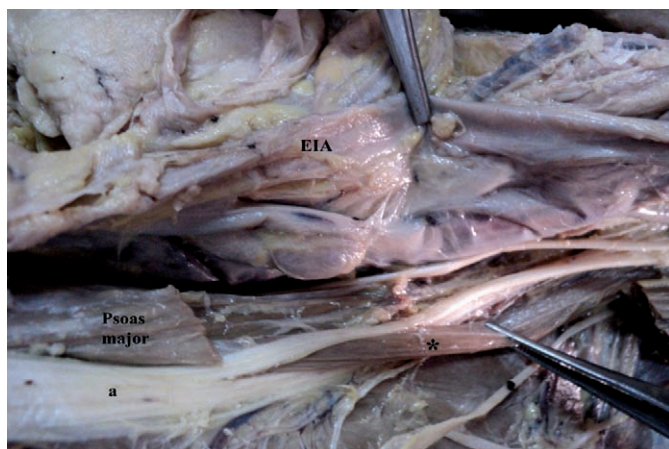
In the current study, the contribution of 12th thoracic nerve to the LP was observed in 7 (13.3%) of 60 cases. Hollinshead<sup>8</sup> performed a series of studies on 250 LP and reported this in 34%<sup>8</sup> and Woodburn found it in almost 50% of cases.<sup>14</sup>

Hollinshead<sup>8</sup> proposed that IH arose from T12 and L1 in 34%, we observed this in only 13.3%. In the present study, IH was arising from L1 in 86.6%, whereas Hollinshead recorded it in 32%. IH and II nerves rest on quadratus lumborum muscle, 1.5 cm apart, posterior to the kidney.<sup>8</sup> Interestingly, cases of renal subcapsular hematoma have been reported following LPB at L3 level.<sup>15</sup> The neuropathy of IH and II nerves is the second most common neuropathy after Pfannenstiel incision (3.7%) for obstetric and gynecologic surgeries.<sup>6</sup> Our findings coincide with those of Tubbs et al that the IH and II nerves were superior to the supracristal plane with a mean distance



**Fig. 3 – Lumbar plexus (left side) illustrating the contribution of L5 in the formation of femoral (a) and obturator (b) branches.**





**Fig. 4 – Left lateral aspect of plexus. The anomalous slips of psoas major muscle (\*) splitting the femoral nerve (a).**

of 4 cm and 5 cm, respectively,<sup>5</sup> and therefore Whiteside insisted on placing the laparoscopic trocar 2 cm above a line transversely drawn between the right and left ASIS to prevent iatrogenic nerve transection.<sup>11</sup>

Regarding origin, the GF nerve arose from L1–L2 in all instances except in prefixed plexus. In one case, the GF had its origin solely from L2. Anloague and Huijbrechts mentioned a similar finding in 2.9% cases.<sup>16</sup> Tubbs et al reported that the GF nerve always pierced the psoas muscle more or less in the midline, without mentioning the details<sup>5</sup>; in the present study, the nerve pierced the middle third of the psoas major in 81.6% at L3–L4 vertebra. Several authors (Standring et al, Hollinshead, Skandalakis) have described that the GF nerve sometimes divided into genital and femoral branches prior to emergence from the psoas major.<sup>7–9</sup> The prevalence of division of GF within the substance of psoas major is shown in Table 3. As the GF nerve is closely related to the lumbar sympathetic trunk (LST) after its emergence from the psoas major, it is often confused for the LST during the neurolytic sympathetic block leading to GF neuritis. The incidence is mentioned as high as 5–10% by Datta and Pai.<sup>17</sup>

Entrapment or pinching of LFCN at the level of IL leads to meralgia paresthetica, a condition characterized by pain, dysesthesia, and hyperesthesia in the anterolateral portion of the thigh.<sup>4,5,7,11,12,18,19</sup> Tubbs et al<sup>5</sup> observed that in 80.5% of cases, the nerve pierced the IL 1 cm medial to the ASIS, whereas Hadspodar reported the relation of LFCN 1–1.5 cm medial to the IL in 100% of cases.<sup>8</sup> Mattera et al performed an

extensive study on the relationship of LFCN to the ASIS in 64 groins. They concluded that in 50% of the cases, the nerve was at a distance of 1–20 mm from the ASIS, in 35.9% the LFCN contacted the ASIS, and in 14.1%, the distance was >20 mm from the ASIS.<sup>18</sup> Carai et al in their retrospective study on the LFCN suggested that in 87% of cases, the nerve was inferolateral to the ASIS.<sup>19</sup> Mattera et al observed that the LFCN passes 4 cm behind the ASIS over the iliac crest.<sup>18</sup> In our series, we did not find any cases with such characteristics. These variations in distance may affect the success of nerve decompression surgery for meralgia paresthetica.<sup>18,19</sup> Carai et al proposed that the LFCN traversing deep to the IL in 85.2% of cases is prone to associated traction between IL anteriorly and fascia iliaca posteriorly; on the other hand, when it runs through the IL, it is liable to the compression syndrome.<sup>19</sup>

The prevalence of anterior external femoral cutaneous nerve is widely studied by various authors in detail. According to Hollinshead, it varies from 18% to 65.3% of cases.<sup>8</sup> Hovelacque as cited by Mattera reported it in 20%, Mattera et al found this in only 1.6%,<sup>18</sup> Astik recorded it in 6.2% (4 plexuses) of 64 plexuses studied.<sup>20</sup> Anloague found it in 2.9%<sup>16</sup> and we observed this in 11.6% (7 of 60) of cases. The more medial course of this type of LFCN (five of seven were 3 cm inferomedial to the ASIS) may be responsible for missing the LFCN in the treatment of meralgia paresthetica. Astik and Dave described that LFCN blocks in these cases can also produce FN blocks<sup>20</sup>; the proposed theory supporting this fact is that lumbar roots are surrounded by a fascial sheath which extends around the branches and thus acts as an enclosed conduit for the spread of anesthetic agents.<sup>1</sup>

Femoral nerve, the largest outflow of the LP, traverses deep to the IL to the thigh.<sup>3,7–9,14,16,20</sup> In the current study, in 81.6% of cases, the FN is formed 5–6 cm inferior to the iliac crest, similar to the findings reported by Tubbs et al.<sup>5</sup> The femoral nerve block is performed 1 cm below the level of IL to provide analgesia for hip and knee joint surgeries.<sup>1,3,6,20</sup> The FN can also be damaged during femoral artery manipulation for angiography.<sup>5</sup> The FN palsy can also result due to the entrapment of the nerve at the IL for prolonged duration, during vaginal hysterectomy.<sup>4,6</sup> Bal et al described three such cases of neuropathy and concluded that during surgery, the angles of hip flexion and abduction should not exceed 45° to prevent nerve injury.<sup>21</sup> Bal et al mentioned femoral neuropathy following hemorrhoidectomy performed in lithotomy position due to excessive flexion of thigh and abduction and external rotation of hip.<sup>21</sup> The anomalous slips of the psoas major muscle split the FN as shown in Fig. 4, may cause tension on the nerve, and should be suspected in the patients of undiagnosed knee and hip joint pain.<sup>5</sup>

Hollinshead described a very variable origin of ON as arising from the third and fourth lumbar nerves in 175 (76.7%) of 228 plexuses.<sup>8</sup> These results are contradicted by Hollinshead who observed the nerve arising from the ventral division of L2, L3 and L4 spinal segments in all cases except where the plexus was prefixed.<sup>8</sup> In the present study, the similar findings were seen. The ON normally emerged at a mean distance of 3.5 cm below the suprascapular plane in our

**Table 3 – Reported prevalence of division of genitofemoral nerve within the psoas major muscle.**

Authors	Number of plexuses studied	Cases found	Percentage (%)
Tubbs et al <sup>5</sup>	22	0	0
Uzmanzel et al <sup>12</sup>	64	27	42
Anloague et al <sup>16</sup>	34	9	26.5
Present study	60	5	21.7

study, a little above the distance advocated by Tubbs et al as 5 cm inferior to plane.<sup>5</sup> Though the ON is well protected by the bony pelvis and the adjoining muscles, obturator neuropathy is the most common neuropathy observed after major gynecologic surgeries or pelvic trauma.<sup>6</sup> Four interesting anatomical variations in LP are reported by Uzmanse and Aktekin in a single female cadaver suggesting that multiple variations can be encountered at once and awareness of these may prevent postoperational complications.<sup>12</sup> Moro et al<sup>22</sup> and Tubbs et al<sup>5</sup> in their cadaveric study proposed the L4–L5 and the above zone as a safety zone for retroperitoneal endoscopic surgery, excluding the GF nerve.<sup>22</sup> We do agree with these studies for the LP block. However, a more medial modified posterior approach, closer to the nerve roots into the psoas compartment by Pandin et al, can be followed for a complete and successful LPB.<sup>13</sup>

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