

MORPHOLOGY OF LUMBAR PLEXUS AND ITS CLINICAL SIGNIFICANCE

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ABSTRACT

Background and Objectives: Looking to the applied significance of lumbar plexus in the form of its involvement in various injuries and entrapment, it is imperative to have a thorough knowledge about its formation, branching pattern and variations.

Materials and Methods: The study was performed on 30 formalin embalmed cadavers in the department of anatomy, Government Medical College, Patiala. The muscles of the posterior abdominal wall were exposed. The fibers of psoas major muscle were dissected from the transverse processes of lumbar vertebrae and the nerves of lumbar plexus were exposed.

Results: The variable origin of iliohypogastric nerve was found in 8.33% cases. It was not found in 8 specimens. Ilioinguinal nerve was not seen in 14.97% cases. Variations in morphological origin of genitofemoral nerve were seen in 13.36% cases and in case of femoral nerve, variations were in 43.32% cases. Lateral femoral cutaneous nerve was seen arising from femoral nerve in 8.33% cases and was not found in 16.67% cases. Psoas minor muscle was found unilaterally in 1 cadaver on the right side and bilaterally in 2 cadavers.

Conclusion: Knowledge of the anatomy of the lumbar plexus is essential for the surgeon who wishes to perform a surgical intervention to this plexus.

KEY WORDS: Lumbar Plexus, Psoas Major, Ilioinguinal Nerve, Iliohypogastric Nerve, Femoral Nerve, Obturator Nerve, Lateral Femoral Cutaneous Nerve, Genitofemoral Nerve.

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INTRODUCTION

Variations are principally due to the variable genetic composition, which is an inheritance carried over from an ancestral origin. Most of the anatomical variations are benign and are due to the errors of embryological development [1]. The posterior abdominal wall contains the

origin of lumbar plexus and numerous autonomic plexuses and ganglia, which lie close to the abdominal aorta and its branches. The anterior divisions of the lumbar nerves (rami anteriores) increase in size from above downward. They are joined, near their origins, by gray rami communicantes from the lumbar ganglia of the

sympathetic trunk. The nerves pass obliquely outward behind the Psoas major, or between its fasciculi, distributing filaments to it and the Quadratus lumborum. The first three and the greater part of the fourth are connected together in this situation by anastomotic loops, and form the lumbar plexus. The smaller part of the fourth joins with the fifth to form the lumbosacral trunk, which assists in the formation of the sacral plexus. The fourth nerve is named the nervus furcalis, from the fact that it is subdivided between the two plexuses [2]. The third lumbar root may sometimes give a branch to the furcal nerve and this situation is called a "prefixed plexus". If the fifth lumbar root participates in the formation of the furcal nerve, the plexus is called a "postfixed plexus" [3].

The well-protected structure and safe location give the plexus more security. Lumbar plexopathies are therefore less common peripheral nerve lesions affecting the lower extremities. Knowledge of the anatomy of the lumbar plexus is essential for the surgeon who wishes to perform a surgical intervention to this plexus or surrounding structures and the posterior approach to reach this region is quite difficult [4].

The mode in which the plexus is arranged varies in different subjects. It differs from the brachial plexus in not forming an intricate interlacement, but the several nerves of distribution arise from one or more of the spinal nerves, in the following manner: the first lumbar nerve, frequently supplemented by a twig from the last thoracic, splits into an upper and lower branch; the upper and larger branch divides into the iliohypogastric and ilioinguinal nerves; the lower and smaller branch unites with a branch of the second lumbar to form the genitofemoral nerve. The remainder of the second nerve, and the third and fourth nerves, divide into ventral and dorsal divisions. The ventral division of the second unites with the ventral divisions of the third and fourth nerves to form the obturator nerve. The dorsal divisions of the second and third nerves divide into two branches, a smaller branch from each uniting to form the lateral femoral cutaneous nerve, and a larger branch from each joining with the dorsal division of the fourth nerve to form the femoral

nerve. The accessory obturator, when it exists, is formed by the union of two small branches given off from the third and fourth nerves [2].

The purpose of this study is to describe the anatomical variations in the origin of nerves of lumbar plexus. Comparing our findings to the previously described variations, we will also suggest possible clinical implications. The branches of the lumbar plexus may be injured during certain surgical procedures, particularly in the lower abdominal region (appendectomy, inguinal hernia repair, iliac crest bone graft harvesting and gynecologic procedures through transverse incision). After such operations, several clinical conditions may be encountered such as meralgia paraesthetica, groin pain and testicular pain in which the LFCN, ilioinguinal and the genitofemoral nerves are mostly involved. Thus, a better knowledge of the regional anatomy and its variations is essential for preventing from the lesions of the branches of the lumbar plexus. Awareness of the possibility of encountering multiple variations at once may prevent from having postoperative complications [5]. Absence of the iliohypogastric nerve may also have implications for the likelihood and presentation of nerve damage in this region during surgical procedures such as inguinal herniotomy. Although, with its multi-segmental innervation from most commonly L2 and L3 and less commonly L1 and L2, the differentiation between radiculopathy and peripheral neuropathy affecting the lateral femoral cutaneous nerve as in meralgia paraesthetica where patients report numbness, paraesthesias, pain, an/or hyperaesthesia in the anterolateral thigh should be made by the clinician without difficulty, this may be less easily done in the small percentage of patients where the nerve derives solely from the L2 nerve [6].

Ontogeny: Limb muscles are innervated by the branches of the ventral primary rami of the spinal nerves C5 through T1 (for the upper limb) and L4 through S3 (for the lower limb). Once the motor axons arrive at the base of the limb bud, they mix in a specific pattern to form the brachial plexus of the upper limb and the lumbosacral plexus of the lower limb. This zone thus constitutes the decision-making region for

the axons. The identities of the factors that control the formation of the brachial and lumbosacral plexus are not well known, but hepatocyte growth factor has been implicated as a trophic factor.

Once the axons have sorted out in the plexus, the growth cones continue into the limb bud, presumably traveling along permissive pathways that lead in the general direction of the appropriate muscle compartment. Over the last part of an axon's path, from the part where it leaves its major nerve trunk to the point where it innervates a specific muscle, axonal path finding is probably regulated by cues produced by the muscle itself [7].

This study aims to record variations in origin of various nerves of lumbar plexus, to compile the findings and to analyse the clinical aspects related to variations so recorded and to compare the study to previous studies.

MATERIALS AND METHODS

The study was done during routine educational dissection of 30 formalin embalmed human vcadavers in the department of anatomy, Government Medical College, Patiala over a period of 3 years. There were no signs of trauma, surgery or wound scars in the abdominal regions of any of the cadavers. The muscles of the posterior abdominal wall were exposed by removing their fascial coverings. While doing so, injury to the vessels and nerves related to the muscles was avoided. The fibres of psoas major muscle were then meticulously detached from the intervertebral discs and vertebral bodies. The genitofemoral nerve on the anterior surface of psoas was traced through that muscle to the lumbar nerves. The removal of psoas from the transverse processes of the lumbar vertebrae was carefully completed, disentangling the ventral rami of the lumbar nerves from its substance. The nerves and their branches were exposed.

OBSERVATIONS

The formation and distribution of the lumbar plexus was analysed using cadavers. The present study was conducted on 30 embalmed adult human cadavers in the Department of Anatomy, Government Medical College, Patiala.

The material for this study comprised of 60 lumbar plexuses. Both the sides of the abdomen of these adult human cadavers were dissected to compare the morphology of lumbar plexus. Out of the 30 cadavers, 22 were male and 8 were female cadavers.

Table 1: Sex distribution of specimens.

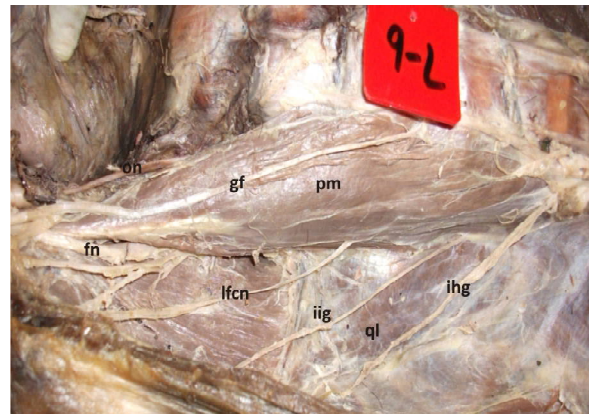
Sex	No. of specimens	Percentage
Male	22	73.33
Female	8	26.67

Out of total 60 lumbar plexuses studied, 30(50%) belonged to the right side and 30(50%) belonged to the left side. Any variations in the formation of the lumbar plexus were observed in all the specimens.

Formation: It was found that lumbar plexus was mainly formed by ventral rami of T12 to L4. T12 was contributing in 5 specimens. It's contribution was seen bilaterally in 2 cadavers and unilaterally in 1 cadaver. L1, L2, L3 was a constant feature in the formation of Lumbar plexus whereas L4 was contributing in 52 specimens out of 60 specimens.

Relation to psoas major muscle (Fig. 1): In all the specimens, it was found that genitofemoral nerve, if present was passing anterior to the psoas major muscle. The obturator nerve emerged from the medial border of the muscle in all cases. Rest of the nerves were passing through the substance of the muscle and were emerging from its lateral border.

Fig. 1: Lateral femoral cutaneous nerve passing through the substance of psoas major muscle and emerging from its lateral border.



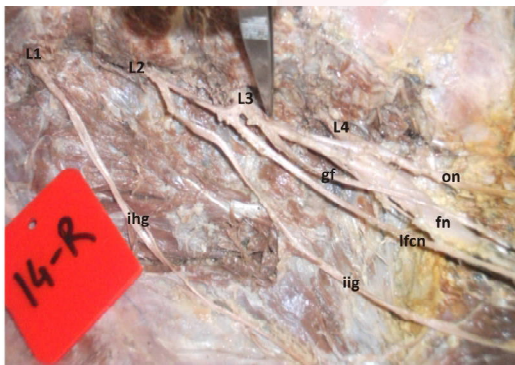
ihg –iliohypogastric nerve, iig-ilioinguinal nerve, gf- genitofemoral nerve, fn- femoral nerve, on- obturator nerve, lfcn- lateral femoral cutaneous nerve, pm- psoas major, ql- quadratus lumborum

Relation to Quadratus lumborum muscle: In the study conducted, no nerve was found in direct relation to Quadratus lumborum muscle. Portion of the psoas major muscle separated the nerves from Quadratus lumborum muscle.

Ilioypogastric Nerve: The origin of ilioypogastric nerve varied from T12 & L1 (5 specimens) or L1 alone (47 specimens). It was not found in 8 specimens. Out of these, in 3 cadavers, it was absent bilaterally whereas in 1 cadaver, it was not found on left side and in another, it was absent on right side.

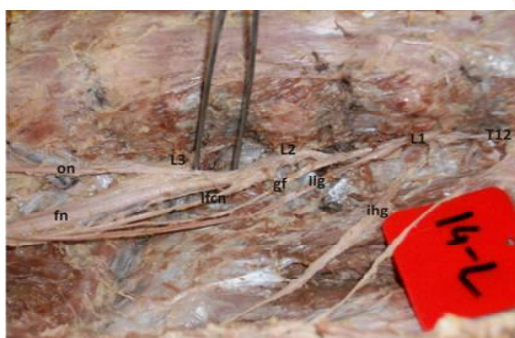
In maximum number of specimens, the morphological root value of nerve was L1 (Figure 2). This was found bilaterally in 21 cadavers and unilaterally in 5 out of which in 3 cadavers, it was found arising from L1 on right side and in 2, on left side. In 2 cadavers, this nerve was found to arise from T12, L1 on both the sides and one left side in one cadaver(Figure3).

Fig. 2: LFCN arising from L2 and L3 nerve roots.



ihg –iliohypogastric nerve, iig-ilioinguinal nerve,gf- genitofemoral nerve, fn- femoral nerve,on- obturator nerve, ifcn- lateral femoral cutaneous nerve

Fig. 3: T12 joined L1 and gave out Ilioypogastric nerve. L1 after joining with T12 divided into 2 branches- Ilioinguinal nerve and the other one further divided into Genitofemoral nerve and a branch which completed the loop with L2. L2 gave rise to Lateral femoral cutaneous nerve and then joined with L3 forming a trunk which divided into obturator and femoral nerves.



ihg –iliohypogastric nerve, iig-ilioinguinal nerve,gf- genitofemoral nerve, fn- femoral nerve,on- obturator nerve, ifcn- lateral femoral cutaneous nerve

Table 2: Variations in the origin of the iliohypogastric nerve.

Origin	T12 and L1		L 1		Not found	
	L	R	L	R	L	R
Side						
% age	5	3.33	38.3	40	6.67	6.67

Ilioinguinal Nerve: The origin of ilioinguinal nerve varied from T12, L1 (5 specimens) or L1 (44 specimens) or L1, 2 (1 specimen) or L2 (1 specimen). No contribution to this nerve was seen from L3. It was found absent in 9 specimens. Out of these, in 4 cadavers, it was bilaterally absent whereas in 1 cadaver, it was absent only on left side.

The morphological root value of the nerve was L1 was in 20 cadavers bilaterally and, it was seen arising from L1 only on right side in 3 cadavers and on left side in 1 cadaver.

Ilioinguinal nerve was found arising bilaterally from T12 & L1 in 2 cadavers and on the left side in one cadaver (fig 3) and from L2 in another specimen (fig 2). In 1 cadaver, it was seen arising from L1 & L2 only on left side.

TABLE 3: VARIATIONS IN THE ORIGIN OF ILIOINGUINAL NERVE.

Origin	T12 & L1		L1		L1&L2		L2		Not found	
	L	R	L	R	L	R	L	R	L	R
Side										
% age	5	3.33	35	38.3	1.66	0	0	1.66	8.3	6.67

Genitofemoral Nerve: The origin of genitofemoral nerve varied from T12, L1(2 specimens) or L1 alone(1 specimen) or L1, L2 (45specimens) or L1, L2, L3(2 specimens) or L2 (2 specimens) or L2, 3(1 specimen). The nerve was not found bilaterally in 3 cadavers and unilaterally in 1 cadaver on right side.

The morphological root value of the nerve was L1 & L2 in 45 specimens. This was found bilaterally in 22 cadavers and only on right side in 1 cadaver.

In 2 specimens, the nerve was seen arising from T12 & L1 unilaterally on the left side in a cadaver (Figure 3) and on the right side in another cadaver.

In 1 cadaver, the nerve arose from L1, L2, L3 bilaterally.

In another cadaver, it arose from L2, L3 on the right side (Fig 2). In 1 specimen, the morphological root value of the nerve was L1 on the left side and in1 cadaver, it was L2 on both sides.

Table 4: Variations in the origin of genitofemoral nerve.

Origin	T12&L1		L1		L1&L2		L2		L2&L3		L1,2,3		Not found	
Side	L	R	L	R	L	R	L	R	L	R	L	R	L	R
% age	1.67	1.67	1.67	0	36.67	38.33	1.67	1.67	0	1.67	1.67	1.67	5	6.67

Femoral Nerve: Origin of the femoral nerve varied from T12, L1, L2, L3 (2 specimens)(figure 3). The origin also varied from L1, L2, L3(5 specimens) or L1, 2, 3, 4 (18 specimens) or L2, 3(1 specimen) or L2, 3, 4 (34 specimens) .

Morphological root value of femoral nerve was L2, L3, L4 in maximum number of cases . In 16 cadavers, this origin was bilateral and in 1, it arose from L2, L3, L4 only on left side (Fig 2) and in another, only on the right side.

The femoral nerve was seen arising from L1, L2, L3, L4 in 18 specimens. This origin was bilateral in 7 cadavers. In 1 cadaver, it was seen arising from L1,2,3,4 only on right side and in another cadaver, it was seen on left side.

Morphological root value of the nerve was L1, L2, L3 in 5 specimens. It was found to arise from L1, L2, L3 bilaterally in 2 cadavers and on right side in 1 specimen.

In one specimen, the root value of the nerve was found to be L2, L3 only on the right side.

Table 5: Variations in the origin of the Femoral nerve.

Origin	T12, L1, 2, 3		L1, 2, 3		L1, 2, 3, 4		L2, 3		L2, 3, 4	
Side	L	R	L	R	L	R	L	R	L	R
% age	3.33	0	3.33	5	16.66	13.33	0	1.67	28.3	28.3

Lateral Femoral Cutaneous Nerve of the Thigh: Generally described as arising from posterior division of L2 and L3 roots, in the current study Lateral femoral cutaneous nerve arose from these roots only in 28 lumbar plexuses(Figure 2). The nerve was not found in 10 plexuses. It arose from L1, 2 in 8 lumbar plexuses. It was found to arise from L1, 2, 3 roots in 6 plexuses and solely from L3 in 1 plexus. In 5 specimens, the nerve was found to arise from the femoral nerve itself.

Table 6: variations in the origin of lateral femoral cutaneous nerve of thigh

Origin	T12, L1, L2		L1, 2		L1, 2, 3		L2, 3		Femoral nerve		L3		Not Found	
Side	L	R	L	R	L	R	L	R	L	R	L	R	L	R
% age	3.33	0	6.67	6.67	5	5	21.67	25	5	3.33	1.67	0	6.67	10

Obturator Nerve: Origin of the nerve varied from t12, l1, 2, 3 (2 specimens)(figure 3); l1, 2, 3 (7specimens); l1, 2, 3, 4, (16 specimens); l2, 3 (3 specimens); l2, 3, 4 (32 specimens) .

Morphological root value of the nerve was found to be L2, L3, L4 in maximum number of cases. It arose from L2, L3, L4 bilaterally in 15 cadavers and unilaterally on the left side in specimen and on the right side in 1 specimen (Figure 2).

It was seen to arise L1, L2, L3 bilaterally in three cadavers and unilaterally on the right side in 1 cadaver.

Root value of the nerve was found to be L2, L3 on the right side in one cadaver and on left side in 2 cadavers.

Table 7: Variations in the origin of the obturator nerve.

Origin	T12, L1, 2, 3		L1, 2, 3		L1, 2, 3, 4		L2, 3		L2, 3, 4	
Side	L	R	L	R	L	R	L	R	L	R
% age	3.33	0	5	6.67	13.33	13.33	3.33	1.67	26.66	26.66

In 2 out of 60 lumbar plexuses dissected, an unusual pattern of lumbar plexus was observed. The plexuses were prefixed as there was a contribution from T12 and the nerves were forming loops as shown in figure 3. T12 joined L1 and gave out Iliohypogastric nerve. L1 after joining with T12 divided into 2 branches- Ilioinguinal nerve and the other one further divided into Genitofemoral nerve and a branch which completed the loop with L2. L2 gave rise to Lateral femoral cutaneous nerve and then joined with L3 forming a trunk which divided into obturator and femoral nerves.

Psoas minor muscle was found unilaterally in 1 cadaver on the right side and bilaterally in 2 cadavers . The muscle was found anterior to psoas major (Figure 4).

Fig. 4: Psoas minor muscle.



DISCUSSION

Iliohypogastric Nerve: In our study, the nerve was not found in 13.34% of lumbar plexuses. A study found absence of the iliohypogastric nerve in 7 of the 34 cases and in two of the cadavers, the ilioinguinal and iliohypogastric nerves were

conjoined as they exited through the substance of the psoas major musculature[8]. In the present study, in 78.33%, the morphological root value of the iliohypogastric nerve was L1. Another study found the iliohypogastric nerve arising from L1 alone in 32%[9].

Ilioinguinal Nerve: Bergman reported 10 different types of formation of the ilioinguinal nerve. According to the classification of Bergman, the ilioinguinal nerve arises from a common root with a ratio of 86.5% (mostly from L1, rarely from L2), while 11% arises from two different segments (T12 and L1, L1 and L2, or L2 and L3)[10]. Another study found the ilioinguinal nerve receiving fibres from L1 only in slightly more than half (51.5%) of cases, receiving fibres from T12 only in 3.5 % of the cases, and from T12 and L1 in 38.3%. In 6.6% of the cases, it was not found[9]. In the present study, the ilioinguinal nerve was seen arising from T12 & L1 in 8.33%, from L1 alone in 73.33%, from L1 & L2 in 1.67%, from L2 alone in 1.66% of plexuses. It was found absent in 14.97% cases.

Genitofemoral Nerve: In the present study, the origin of the genitofemoral nerve varied from T12 & L1 in 3.33%, L1 in 1.67%, L1 & L2 in 75%, L1, L2, L3 in 3.33%, , L2 alone in 3.33%, L2 & L3 in 1.67% out of 60 lumbar plexuses. It was not found in 11.67% plexuses

In a study stated that the Genitofemoral nerve arises as a single root in 80% and as a double root in 20%, of the cases. He also claimed that these roots may originate from L1 and L2, or L2 and L3. As compared to the present study, he did not find the origin of this nerve from T12[10].

Another study found that the genitofemoral nerve was originating from the ventral ramus of L2 on the right side of a 35 year old female cadaver [11].

Femoral Nerve: A study found a contribution from the first lumbar nerve to the femoral nerve in 60 per cent of the plexuses that they classified as prefixed [12].

Another study described a complex bilateral variation in the formation of lumbar plexus in a 32 year old male cadaver. On the left side the plexus was postfixed and located posterior to the psoas major muscle. The femoral nerve was

formed by the union of anterior rami of the second, third, fourth and fifth lumbar spinal nerves. On the right side, the lumbar plexus was prefixed. The femoral nerve formed by branches from the first, second, third and fifth lumbar spinal nerves [13].

In the present study, the femoral nerve was found to arise from T12, L1, L2, L3 in 3.33%, L1, L2, L3 in 8.33%, L1, L2, L3, L4 in 30% lumbar plexuses. The normal morphological root value of the nerve, that is L2, L3, L4 was present only in 56.67% cases. In 1 specimen, it arose from L2 & L3.

Lateral Cutaneous Femoral Nerve: The LFCN originates directly from the lumbar plexus and may be derived from several different combinations of lumbar nerves, including L2 and L3, L1 and L2, L2 alone and L3 alone [14]. In our study, LFCN arose from femoral nerve in 8.3% of plexuses.

In another study, it was reported that in 22 (36.7%) of 60 plexuses, the lateral femoral cutaneous nerve arose from L1 and L2; in one plexus (1.7%), the nerve arose solely from L2 and in 6 plexuses (10%), it arose directly from the femoral nerve, making for a total of 48.3% variation for the lateral femoral cutaneous nerve [15]. In the current study, the nerve derived its segmental innervations from segments other than L2 and L3 in 53.3% of plexuses.

A study was done on 200 cadavers. In 24 cases, the lateral femoral cutaneous nerve arose from L1 and L2, and even solely from the second or third lumbar nerve [16]. Erbil et al reported in a case that the lateral cutaneous nerve of the thigh was formed by the union of the anterior rami of the first and second lumbar spinal nerves [13]. In the present study the morphological root value of the nerve was L1 & L2 in 8(13.33%) and L3 alone in 1(1.66%) lumbar plexuses.

Obturator Nerve: Bardeen and Elting found that when the plexus was prefixed, the obturator nerve usually also received fibres from L1, and when it was postfixed, it usually received fibres from L5[12].

In a series of 228 plexuses, the Obturator nerve arose from the third and fourth lumbar nerves in 175, and from the second through the fourth lumbar in only 23; in the remainder it arose

from the first through the fourth lumbar twice, from third through fifth 10 times, from the third alone 3 times, from the fourth alone 12 times, and from fourth and fifth 3 times[17].

In the present study, the normal morphological root value of the obturator nerve, that is, L2, L3, L4 was found in 53.32% of plexuses. The obturator nerve was found to arise from T12, L1, L2, L3 in 3.33%, from L1,2 in 5%, from L1, L2, L3 in 11.67%, L1, L2, L3, L4 in 26.67% of lumbar plexuses.

Accessory Obturator Nerve: Bardeen and Elting expressed the opinion the accessory obturator nerve is more commonly associated with prefixed than with other types of plexuses and found it in less than 10% of cases arising most commonly from the third and fourth lumbar[12].

A study described the Accessory Obturator nerve in 4 or 5 times in 9 or 10 bodies[18]. Horwitz found the accessory obturator nerve arising most commonly from either the obturator or femoral, rather than the divisions of the plexus, but described the origin in remaining cases as being most commonly from L3, about half as frequently from L3 and L4, and sometimes from L2 alone, L2 and L3, or L4 alone[17].

No accessory obturator nerve was found in the present study.

In a study Schmidt also described the plexus of Martin and Gunther, which he found in seven bodies. In one of the two plexuses, a considerable branch came from the union of communicating loops of the first three lumbar nerves before the third joins the fourth, and lower down united with the Anterior Crural[19].

CONCLUSION

The present study was conducted on 60 lumbar plexuses. Prefixation was seen in 5 lumbar plexuses. 13.34% of investigated lumbar plexuses demonstrated absence of iliohypogastric nerve and 14.97% showed absence of ilioinguinal nerve.

The morphological root value of ilioinguinal nerve(L1) was found in 78.3% and that of iliohypogastric nerve was found in 73.3% of lumbar plexuses. Genitofemoral nerve was absent in 11.67% cases and in the rest, 13.33% showed

variant origin. Femoral nerve showed variant origin in 43.37% of plexuses. Thus, it was seen that all the nerves of lumbar plexus showed variable origin from the lumbar nerves. The knowledge of these variations is of utmost importance to the clinicians, surgeons and anaesthesiologists.

Conflicts of Interests: None

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