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Original Article

A cadaveric study of the anatomical variations of the lumbar plexus with clinical implications

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ABSTRACT

Introduction: The main objective was to study the normal and abnormal lumbar plexus.
Material and methods: We analyzed 131 lumbar plexuses from 68 embalmed cadavers at the Cadaveric Surgical Training Center, Faculty of Medicine, Chiang Mai University in the period between April 2012 and June 2013. Morphometric measurements were taken.
Results: The lumbar plexus was located within psoas major muscle (100.0%). The iliohypogastric nerve originated from the ventral rami of L_1 (96.5%) followed by the ilioinguinal nerve (90.1%). The genitofemoral nerves originated from the ventral rami of L_1 and L_2 (98.5%). The lateral femoral cutaneous nerves (LFCN) originated from the ventral rami of L_2 and L_3 (84.0%). The femoral and obturator nerves originated from ventral rami of L_2–L_3–L_4 (100.0%). The distance between the origin of LFCN to L_3 transverse process was at an average 1.96 ± 0.67 cm. The distance from nerve to L_4 transverse process was above L_3 and between L_3 and L_4 transverse process at an average 2.8 ± 1.63 cm. The distance between femoral nerve to L_3 and L_4 transverse process was inferior to L_4 transverse process at an average of 5.13 ± 2.18 cm and 2.53 ± 2.26 cm, respectively. The distance between obturator nerve to L_3 and L_4 transverse process was found inferior to L_4 transverse process at an average 5.42 ± 1.73 cm and 2.75 ± 1.75 cm, respectively.
Discussion: The knowledge of anatomical variations of LP may be important for administration of local anaesthetic agents and avoid any inadvertent injuries.

1. Introduction

Lumbar plexus (LP) is formed by the ventral rami of the spinal nerves level L_1–L_4 and related to the psoas major muscles. The nerves that emerge from the spinal cord divide into anterior and posterior divisions and unite forming six branches of lumbar plexus i.e. iliohypogastric, ilioinguinal, genitofemoral, lateral femoral cutaneous, femoral and obturator nerves.[1–3] The LP is located on the posterior abdominal wall. The LP is very complex and often varied.

Variations of the origin and branches of the LP bear immense clinical importance. Lesions of the lumbar plexus are most commonly iatrogenic but maybe due to birth trauma, hematoma, entrapment in fibrous or muscular bands, tumors (both intrinsic and extrinsic), or wounds such as those incurred by a sharp object or gunshot.[4] Lumbar plexopathies are therefore less common peripheral nerve lesion affecting the lower extremities groin region and abdominal wall muscle.[2,5] Compression syndrome of the femoral nerve is termed as neuralgia paresthetica.[6] Furthermore, the anatomical knowledge of LP may help anesthesiologists to know the exact location of the nerves and its branches and this may result in better treatment. Understanding normal anatomy of lumbar plexus is also important for administration of local anesthetic agents especially during sacroiliac and groin surgery. The local anesthetic drug is administered to LP nerve group (i.e. lumbar plexus block).[7,8]

It is used in treating children and adults who experience chronic groin pain. Performing LP block is uncommon in lower extremity surgery because it is a difficult technique with a high risk. The

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difficulty in performing such nerve block is attributed to the fact that the nerves in this area are separated unlike performing spinal block or epidural block which is much easier. On the other hand, this kind of nerve block is less risky than performing spinal block and epidural block. This method has lower risk as it does not affect the patient's blood pressure and patient may experience numbness only in the operated leg.

Administration of local anesthetic may be a failure in the presence of anomalous LP and its branches. Anloague and Huijbregts studied variations in the anatomy of lumbar plexus and its clinical importance.[3] It was found that iliohypogastric and ilioinguinal nerves were formed from spinal nerve L_1. On few occasions, iliohypogastric nerve may be absent but only ilioinguinal nerve may be found.[3,9]

Genitofemoral nerve may divide into genital and femoral branches in the psoas major muscle before emerging out at the anterior border of this muscle.[10] Lateral femoral cutaneous nerve may divide into two branches before passing deep to inguinal ligament or received communicating branch from femoral nerve instead.[11,12]

Femoral nerve was observed to separate into superior and inferior branches before traversing inferior to the inguinal ligament.[13,14] The knowledge of origin and variations of the lumbar plexus may be important for anatomists, anesthetists, and surgeons to avoid iatrogenic lumbar plexus injury.

The present study aimed to dissect, identify and describe the anatomical variations in the lumbar plexus with respect to their origin and its branches and we firmly believe that it would be beneficial to neurologists, anesthesiologists and clinicians for proper diagnosis and treatment.

2. Materials and methods

2.1. Cadaveric specimens

The cadavers were obtained from the Cadaveric Surgical Training Center, Faculty of Medicine, Chiang Mai University in the period between April 2012 and June 2013. Prior ethical approval was sought from institutional ethical committee. The study was carried out on 131 lumbar plexuses from 68 embalmed cadavers of known sex and age at the time of decease and without any pathology and abnormality of abdomen. The age of the cadavers ranged from 38 to 85 years. No specimen with any pathology and abnormality of abdomen and posterior abdominal wall was included.

2.2. Dissection procedure

The posterior abdominal wall and its structures were carefully dissected in the cadavers. Psoas major muscle was exposed in order to study the anatomical location of LP, trace their branches and note their relationship to the lateral femoral cutaneous (LFCN), femoral and obturator nerves.

2.3. Morphometric measurements

Morphometric measurements were taken for distance between the three branches and transverse processes of L_3 to L_4 vertebrae. A Vernier caliper was used (Fig. 1). Two independent observers took the measurements in order to avoid any bias and error.

2.4. Statistical analysis

We evaluated the data by using descriptive statistical analysis using Chi-square test.

3. Results

The study was carried out on LP spinal nerve roots from 68 cadavers; with 131 lumbar plexuses available (5 cadavers had 1 lumbar plexus for this study). The details of the 6 branches of lumbar plexuses were shown in Table 1. Eighty-three iliohypogastric nerves (96.5%) were composed of root L_1 with three nerves of T_{12} uniting with L_1 (3.5%). The sensory area was supplied by

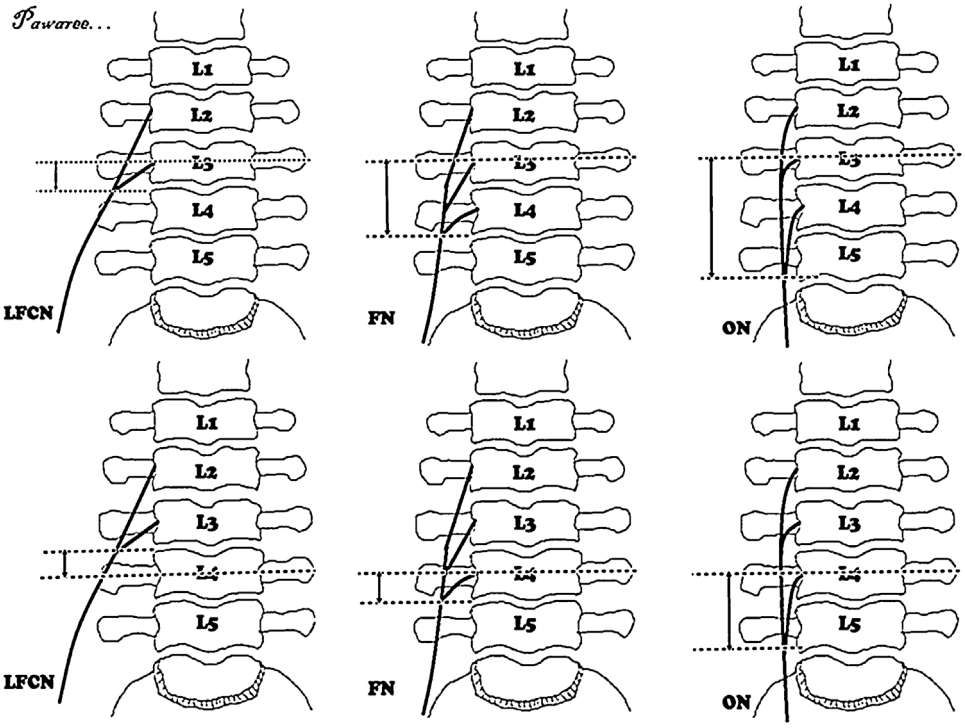

Fig. 1. Measurement of the distance between lateral femoral cutaneous, femoral and obturator nerve with the transverse process of L_3 and L_4 vertebrae.

Table 1
Showing the 6 branches of lumbar plexus nerve roots.

Nerve	Nerve derived from	*N*	Percentage of plexuses
Iliohypogastric nerve	T_{12}–L_1	3	3.5
	L_1	83	96.5
Ilioinguinal nerve	T_{12}–L_1	5	3.8
	L_1	118	90.1
	L_1–L_2	5	3.8
	L_2	1	0.8
	L_2–L_3	2	1.5
Genitofemoral nerve	L_2	1	0.8
	L_1–L_2	129	98.5
	L_2–L_3	1	0.8
Lateral femoral cutaneous nerve	L_2	4	3.05
	L_2–L_3	110	84.0
	L_2–L_3–L_4	17	13.0
Femoral nerve	L_2–L_3–L_4	131	100.0
Obturator nerve	L_2–L_3–L_4	131	100.0

subcostal nerve instead. Ilioinguinal nerve was formed by L_1 root in 118 plexuses (90.1%). Genitofemoral nerve was formed from the union of L_1–L_2 roots (98.5%). In addition, this nerve was formed by one L_1 root joined to the L_1–L_3 roots. Additional variation in 33 plexuses (25.2%) was also observed.

Lateral femoral cutaneous nerve was formed by the union of L_2–L_3 root (84.0%), with four of them emerging from the L_2 root. The union of L_2–L_3–L_4 roots formed another type of LFCN branches and its was observed in 54 plexuses (41.2%). These nerve variations were of two patterns i.e. receiving the communicating branches from femoral nerve, in 17 plexuses from 54 (Fig. 2). This nerve divided itself into two branches before traversing inferior to the inguinal ligament in 27 plexuses from 54 (Fig. 3). In all 131 plexuses, femoral nerve was formed by the union of L_2–L_3–L_4 roots in 36 lumbar plexuses (27.5%). Division of femoral nerves were split by the psoas major muscle belly (27.5%) (Fig. 4). In all 131 plexuses, every obturator nerve was formed by the union of L_2–L_3–L_4 roots. Out of these, twelve accessory obturator nerves (9.2%) were from the union of L_3–L_4 roots.

The variation of the six branches of LP were analyzed by Chi-square test. While comparing the anatomical variation of the six branches of LP between left and right sides, we found no significant differences between the sides ($P > 0.05$). Psoas minor muscle was discovered in 75 cadavers (57.25%). Anomalous origin of iliohypogastric (34.35%), genitofemoral (25.2%), LFCN (41.2%), and femoral nerves (27.5%) were observed.

The gaps between LFCN, femoral and obturator nerves related to L_3 and L_4 transverse processes were shown in Table 2. The gap

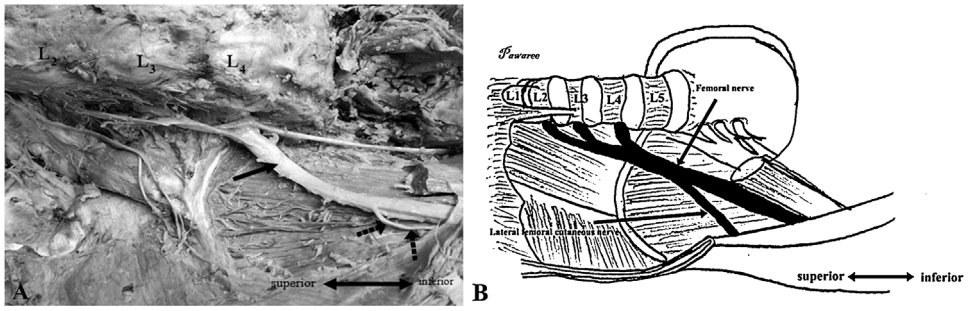

Fig. 2. Right lumbar plexus: variation of lateral femoral cutaneous nerve (dashed arrows). It arose directly from the femoral nerve (arrow).

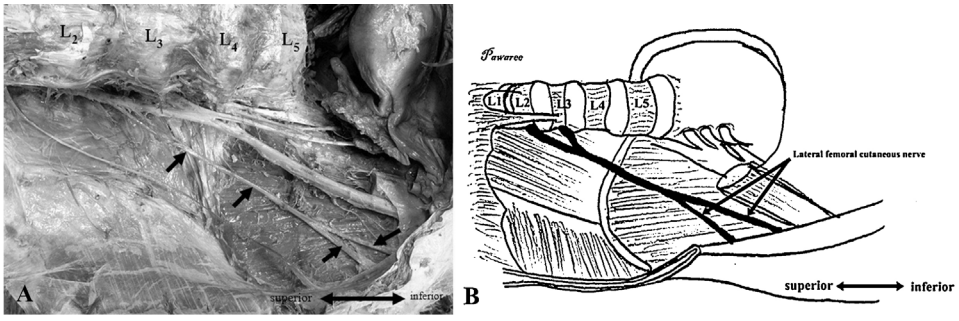

Fig. 3. Right lumbar plexus: bifurcation of the lateral femoral cutaneous nerve prior to exiting the pelvic cavity (arrows).

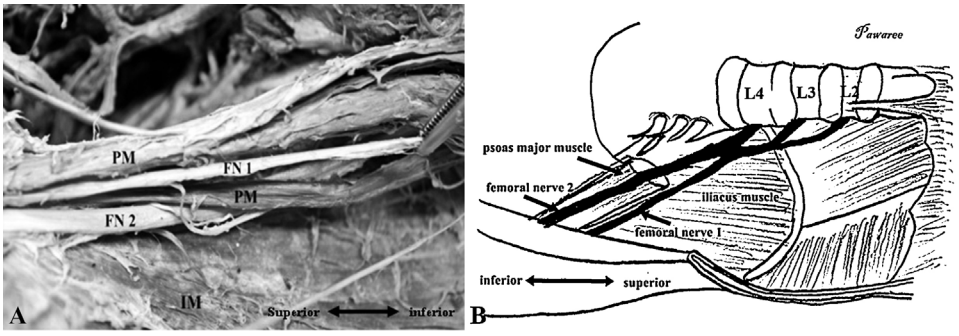

Fig. 4. Left lumbar plexus: division of femoral nerves (FN 1, FN 2) were split by the psoas major muscle belly. (PM = psoas major muscle, IM = iliacus muscle.)

Table 2
The distance between lateral femoral cutaneous, femoral and obturator nerves as related to the transverse process of L_3 and L_4 vertebrae.

Position of nerve origin	L_3 transverse process (cm) (Mean ± SD)			L_4 transverse process (cm) (Mean ± SD)		
	Lateral femoral cutaneous	Femoral	Obturator	Lateral femoral cutaneous	Femoral	Obturator
Above L_3	1.96 ± 0.67	–	–	2.8 ± 1.63[a]	–	–
Between L_3 and L_4	1.87 ± 0.95	–	–	2.8 ± 1.63[a]	–	–
Below L_4	7.28 ± 1.14	5.13 ± 2.18	5.42 ± 1.73	4.81 ± 1.28	2.53 ± 2.26	2.75 ± 1.75

[a] The measured value of the position above the L_3 and L_4 transverse process.

between the origin of LFCN to L_3 transverse process was at an average 1.96 ± 0.67 cm on both sides. The gap between nerves to L_4 transverse process was above the L_3 and between L_3 and L_4 transverse process at an average 2.8 ± 1.63 cm on both sides. The gap between femoral nerve to L_3 and L_4 transverse process was inferior to L_4 transverse process at an average of 5.13 ± 2.18 cm and 2.53 ± 2.26 cm on both sides, respectively. The distance between obturator nerve to L_3 and L_4 transverse process was found inferior to L_4 transverse process at an average 5.42 ± 1.73 cm and 2.75 ± 1.75 cm on both sides, respectively. To compare the location of nerve joining, average and gaps between LFCN, femoral and obturator nerves as related to L_3 and L_4, Chi-square analysis was used. No significant difference ($P > 0.05$) was found at the joining location.

4. Discussion

An extant search of literature revealed several anatomical variations in the lumbar plexus. Six peripheral branches were described in various studies. The lumbar plexus lay within the substance of the psoas major muscle.[7,15–17]

The lumbar plexus plays an important role in regional anesthesia, especially in sacroiliac and pelvic region surgery. Lumbar plexus block is a useful technique, especially in the management of chronic pain and in the provision of surgical analgesia for adults and children.[2] The origin of the iliohypogastric and ilioinguinal nerves significantly differs from the description in standard anatomical texts.[9] It has been previously stated that the iliohypogastric and ilioinguinal nerves are derived from L_1 and occasionally from T_{12}.[7,9,10]

According to past studies, ilioinguinal nerve originated from L_2 and L_3 in 10% cases[9] whereas in the present study we found the incidence in 1.5% cases. Earlier research results showed sensory components that composed these nerves encompassing a region of the spinal cord extending from T_{11} to L_3.[9] However, communication between the genitofemoral, ilioinguinal or iliohypogastric nerves (as well as the lateral femoral cutaneous nerve) was common and resulted in sensory overlap.[9] In a previous study, 20.6% of the LP had absence of iliohypogastric nerve.[3] In the present study, we found it to be present in 34.35% cases. The genitofemoral nerve, divided into genital and femoral branches prior to emerging from the psoas major 25.2%[7] was different from the present study. Another past study found it to be 26.5%.[3]

The genital and femoral branches were pierced apart by the psoas muscle in 42% cases.[10] Variability of the terminal course and distribution of the ilioinguinal and genitofemoral nerves were observed in cadaveric studies.[5,10] The anatomical variation of these nerves should be taken into account in the examination and treatment of chronic groin pain.[10] In 10% cases, the LFCN originated directly from the femoral nerve,[7] while Analoague and Huijbregts found it to be present in 17.6% cases.[3] Uzmansel et al.[18] reported origin of LFCN from the femoral nerve above the inguinal ligament. Astik and Dave[13] found origin of LFCN from the femoral nerve above the inguinal ligament in 4 plexuses. In the present study, we found the variations in 41.22% cases.

The anatomical variations of the LFCN and the relation of the course of this nerve and meralgia paresthetica.[12] In addition, origin of LFCN from femoral nerve may have impact on the clinical efficacy of lumbar plexus block.[13] Several variations of the femoral nerve were described previously. Variant slips of the iliacus and psoas major muscles split the femoral nerve into 2 or 3 separate slips in 35.5%,[3] 7%,[6] and 2.2% cases.[19] Rao et al.[20] noticed that the femoral nerve split in order to enclose both the variant slips of psoas major and iliacus muscles in their case report. Kirchmair et al.[17] observed in 13 of 61 plexuses, the femoral nerve to exhibit the ramification into 2 or 3 branches which came out of the psoas major muscle. Jakubowicz[21] reported splitting of the femoral nerve by lateral fibers of psoas major muscle in 2.5% and by muscle fibers of iliacus in 2.5% cases. Astik and Dave[13] found splitting of the femoral nerve into two slips by muscular slip of psoas major in 3 plexuses and by accessory iliacus slip in 2 plexuses. We observed splitting of the femoral nerve into two slips by muscular slip of psoas major in 36 plexuses and iliacus slip in one plexus. These variations which cause tension of the femoral nerve. An amount of caution should be borne in mind for treating patients with referred pain to their hip and knee joints.[13]

Earlier researchers studied the branching of the femoral nerve in the abdominal cavity superior to the inguinal ligament and found that the method of administering local anesthetic through a point 2–3 cm caudal to the inguinal ligament and 1–2 cm lateral to the femoral artery would affect either the anterior or posterior branch only, with an incomplete block. Such anatomical knowledge may be important during nerve block procedures. We found presence of the accessory obturator nerve in 9.2%. Regarding other studies, 8.8% were reported by Analoague and Huijbregts,[3] 12.5% by Akkya,[22] and 12% by Sim and Webb.[7]

The presence of the obturator nerve has clinical consequences for accessory obturator nerve and may hinder the success obturator nerve block.[7,22] The anatomical variation of the LP can be explained on the embryological basis. Yasar et al.[16] investigated morphological structure and variations of lumbar plexus in human fetuses found them to be similar to the LP in adults.

5. Conclusion

The LP is composed of complex and variable structures interrelated to their surroundings and any injury to them may also involve the surrounding structures. The present study revealed basic anatomical knowledge concerning the origin and variation in the branches of LP. The results of the study may be beneficial for clinicians treating patients with lumbar plexopathies and anesthesiologists performing successful block in the LP.

Conflicts of interest

The authors have none to declare.

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