The Morphological Aspects of Lumbar Plexus and Roots

An Anatomical Study

Lomber Pleksus ve Köklerin Morfolojik Özellikleri

Anatomik Çalışma

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Received : 09.02.2005
Accepted : 22.04.2005

ABSTRACT

OBJECTIVE: Although there are many reports on the anatomy of the lumbar plexus and knowledge of the morphological aspects of this plexus is of practical importance during the surgical and anaesthetical interventions, the thickness and length of the lumbar nerves and roots have not been studied in detail.

METHODS: The anatomy of the lumbar plexus and lumbar roots was investigated through dissection of 10 human anatomic specimens. The lumbar plexus was dissected bilaterally in 10 cadavers with the posterior approach and the lumbar roots and plexus were exposed entirely in all specimens. The course and sizes of the lumbar nerves and roots in the posterior wall of the abdomen relevant to soft tissue and bony landmarks are described. Six lumbar nerves and four lumbar roots were included in this work.

RESULTS: According to the morphometric measurements, L1 is the thinnest (4.1 mm) and L4 is the largest (5.5 mm) root of the lumbar plexus. The iliohypogastric nerve is the longest (210 mm) and the ilioinguinal nerve is the thinnest (1.2 mm) nerve of the lumbar plexus.

CONCLUSIONS: The lumbar plexus is located in the substance of the psoas major muscle in the posterior abdominal wall. Meticulous dissection and thorough knowledge of the anatomy are required for the appropriate exposure of the lumbar plexus.

KEY WORDS: Lumbar Plexus, Morphology, Lumbar root, Lumbar nerve

ÖZ

AMAÇ: Literatürde lomber pleksus'un anatomisi üzerine pek çok yayın olmakla birlikte ve bu pleksusa ait morfolojik bilgi cerrahi ve anesteziolojik girişimler yönünden önemli olmakla birlikte lomber köklerin ve sinirlerin uzunlukları ve kalınlıkları üzerine detaylı bir çalışma yapılmamıştır.

METODLAR: Lomber pleksus ve köklerin anatomisi 10 adet insan kadavrası üzerinde çalışıldı. Lomber pleksus bilateral olarak 10 kadavrada posterior yolla açıldı ve lomber pleksus ile kökler tümüyle ortaya kondu. Lomber sinirlerin ve köklerin karın arka duvarında seyri ve boyutları ve yumuşak dokular ve kemik yapılar ile ilişkisi tanımlandı. Bu çalışmaya lomber pleksus ile ilgili 4 lomber kök ve 6 lomber sinir dahil edildi.

BULGULAR: Morfometrik ölçümlere gore lomber omurgada, L1 (4,1 mm) en ince, L4 (5,5 mm) ise en kalın köktür. İliohipogastrik sinir (210 mm) lomber pleksus'un en uzun, ilioinguinal sinir (1,2 mm) ise en ince siniridir.

SONUÇ: Lomber pleksus karın arka duvarında ve psoas majör kasının içine yerleşmiştir. Lomber pleksusun uygun şekilde ortaya konması için dikkatli bir diseksiyon ve iyi bilgi gereklidir.

ANAHTAR SÖZCÜKLER: Lomber pleksus, Morfoloji, Lomber kök, Lomber sinir

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INTRODUCTION

The lumbar plexus, which is the upper component of lumbosacral plexus, is formed by the ventral rami of the first three nerves and the greater part of the 4th lumbar nerve with a communication from the 12th thoracic nerve. It is placed on the internal surface of the posterior abdominal wall, ventral to the transverse processes of the lumbar vertebrae (28, 29). 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.

A 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. Meanwhile, the literature contains some contradictions on the exact sizes of the lumbar nerves and the precise location of the plexus (9).

The goal of the study was to describe precisely the morphological features of the nerves and roots forming the plexus. Ten intact adult cadavers were dissected bilaterally and entire lumbar roots and nerves were exposed followed by morphological measurements.

MATERIAL AND METHODS

The study protocol was reviewed and approved by the research and ethics committee of our institution. The work was performed in the dissection room of the Department of Anatomy and 10 adult cadavers were used for the dissections. Seven of the cadavers were male and three female with a mean age of 28.

Twenty lumbar plexuses were explored from the 10 cadavers via the posterior approach. Our study consisted of two parts. The first part consisted of opening the thoracolumbar fascia after making a midline incision in the lumbar region. The posterior components of the spine including spinous processes, laminae and facet joints, were removed totally. We then reached the spinal cord and the dura was opened vertically avoiding any damage to the neural structures. The lumbar roots were explored and each root was measured precisely. In the second section, the lumbar plexus was completely exposed by meticulous dissection of the psoas major and quadratus lumborum muscles. The lumbar nerves which constitute the plexus were measured using some anatomical landmarks and the data recorded. The thickness and the length of each lumbar nerve were measured separately. The thickness of each nerve was measured at the L4 level. We used a posterior approach for both sections to obtain optimal exposure of the lumbar roots and plexus.

Each section of the study was documented by photograhy at the end of dissection.

All cadavers had a normal lumbosacral region.

RESULTS

After removal of the posterior components of the spine at the lumbar region, the spinal cord was observed with the lumbar roots originating from both sides (Figure 1). Following opening of the dura, the cauda equina and conus medullaris were seen (Figure 2). The lumbar plexus originated from the ventral rami of the first four lumbar roots (Figure 2)

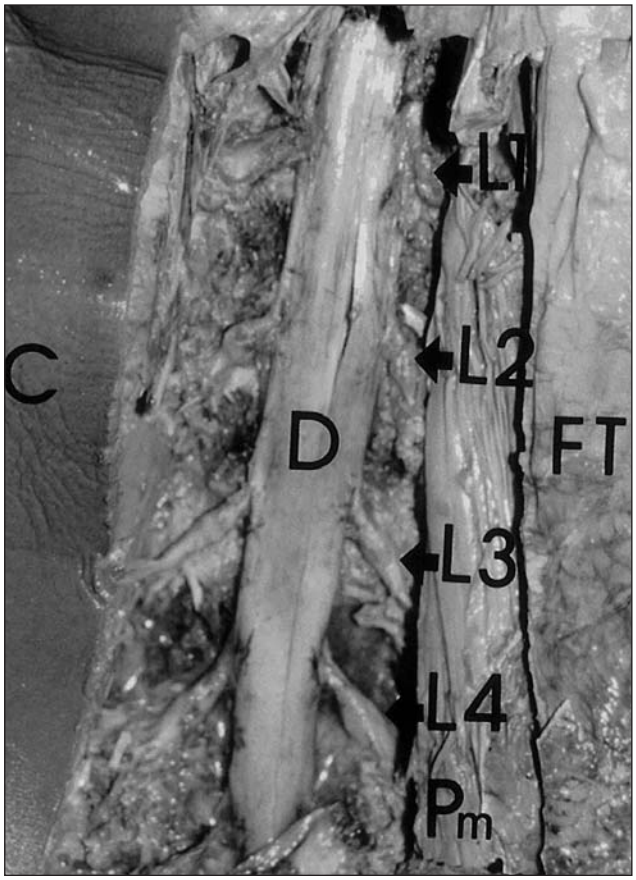

Figure 1: Exposure of the spinal cord before opening the dura. The posterior components of the lumbar spine were removed and the lumbar roots were exposed. L1: First lumbar root, L2: Second lumbar root, L3: Third lumbar root, L4: Fourth lumbar root, FT: Thoracolumbar fascia, D: Dura mater, C: Skin, Pm: Psoas major muscle

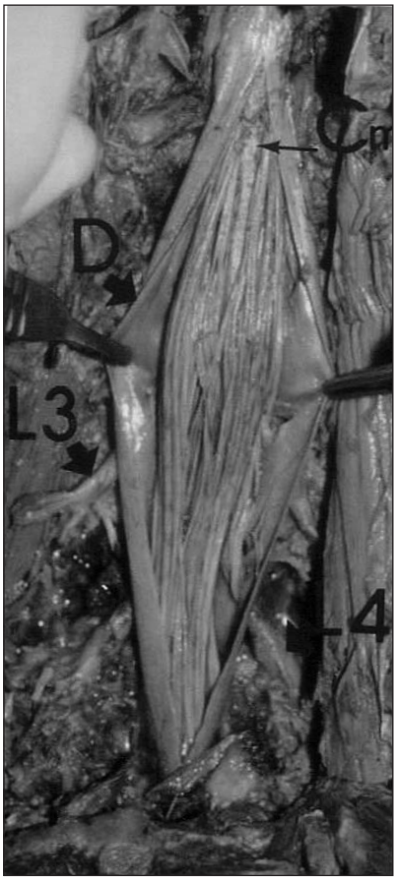

Figure 2: The exposure of cauda equina and conus medullaris after opening the dura. The lumbar roots originate from the both sides of dural sheath.
Cm: Conus medullaris, D: Dura mater, L3: Third lumbar root, L4: Fourth lumbar root

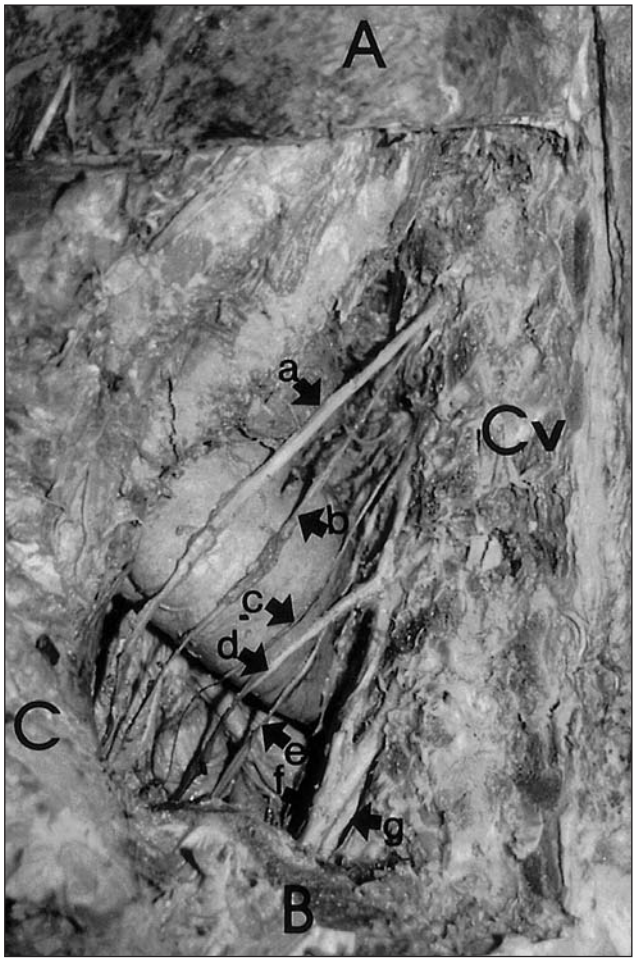

Figure 3: The view of the entire lumbar plexus after the removal of quadratus lumborum and psoas major muscles with the posterior approach. Note the left kidney deep to the plexus.
Cv: Vertebral column, A: Thoracolumbar fascia, B: Psoas major muscle, C: Quadratus lumborum muscle, a: Iliohypogastric nerve, b: Ilioinguinal nerve, c: Genitofemoral nerve, d: Lateral femoral cutaneous nerve, e: Obturator nerve, f: Femoral nerve, g: Lumbosacral trunk

and lied within and/or around the psoas major. It received a thin branch from the 12th thoracic root. The plexus had a triangular form and lied from the upper part of lumbar region to the pelvis. The six main lumbar nerves constituting the lumbar plexus were observed; iliohypogastric nerve, ilioinguinal nerve, genitofemoral nerve, lateral femoral cutaneous nerve, obturator nerve and femoral nerve (Figure 3).

The thickness of each lumbar root is shown in Table I. L4 is the thickest root of the lumbar plexus and L1 is the thinnest. The thickness of lumbar roots increase gradually from the upper part of the lumbar spine to the lower segments. The mean diameter of L1 was 4.1 mm (range: 3.9-4.2 mm), while the mean diameter of the L4 root was 5.5 mm (range: 5.1-5.9 mm).

The iliohypogastric nerve was the longest lumbar plexus nerve in the posterior abdominal region according to selected landmarks shown in Table II. The mean length of the iliohypogastric nerve was 210 mm (range: 207-213 mm), while the shortest lumbar nerve in our study was the femoral nerve at 154 mm (range: 152-156 mm). The size of each nerve is documented in Table III.

The ilioinguinal nerve was the thinnest nerve with a mean diameter of 1,2 mm (range: 1.0-1.3 mm), and the femoral nerve was the thickest nerve at 2.6 mm (range: 2.3-2.8 mm).

DISCUSSION

Lumbar plexopathies are less common peripheral nerve lesions affecting the lower extremities. The

Table I: The mean thickness of lumbar roots at the point they leave the dural sheath.

Root	Mean thickness (Range)
L1	4.1 mm (3.9-4.2 mm)
L2	4.8 mm (4.5-5.1 mm)
L3	5.2 mm (5.0-5.5 mm)
L4	5.5 mm (5.1-5.9 mm)

Table II: The measurement landmarks of the lumbar nerves in the posterior abdominal region after complete exposure of the lumbar plexus.

	Length landmarks		Thickness landmarks
Nerve	From	To	Level
Iliohypogastric nerve	Origin	Dividing point to the anterior and lateral cutaneous branches	L4
Ilioinguinal nerve	Origin	The entrance point to the inguinal canal	L4
Genitofemoral nerve	Origin	Dividing point to the genital and femoral branches	L4
Lateral femoral cutaneous nerve	Origin	The point where it passes below the inguinal ligament	L4
Obturator nerve	Origin	The entrance point to the obturator foramen	L4
Femoral nerve	Origin	The point where it passes below the inguinal ligament	L4

well-protected structure and safer location give the plexus more security. The lumbar plexus, which is the upper component of lumbosacral plexus, is composed of the anterior rami of the L1, L2, and L3 spinal nerves and part of the L4 anterior ramus. In its usual form, the first three lumbar nerves are entirely distributed to the lumbar plexus. The fourth lumbar nerve is divided between the lumbar and sacral plexuses and it is therefore called the furcal nerve (meaning forked) (2). The furcal nerve is usually formed by the fourth lumbar root. 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" (2, 3, 25). It is situated anterior to the lumbar transverse processes in the posterior part of the substance of the psoas major muscle in which the nerves of the plexus emerge at various levels (1, 6, 9, 15, 24, 28, 29). The lumbar plexus is therefore protected by layers of muscle and solid bony structures. The lumbar nerves forming the plexus lie greater distances from each other than the nerves of the brachial plexus. Thus, injury to the lumbar plexus produces a more discrete lesion.

Lumbar injuries (penetrating or non-penetrating), neoplasms on the posterior abdominal wall, vascular pathologies (aneurysm, bleeding, hematoma), abdominal and pelvic operations and infarct of the psoas muscle (especially in diabetics) are the most prominent causes of lumbar plexopathies (10, 13, 17, 19, 21, 22, 23, 26). Hope et al (12) have reported a case of neonatal lumbar plexus injury with lower-extremity weakness during the birth process. They stated that rapid breech extraction can cause severe

Table III: The measurement data of lumbar nerves forming the plexus.

Nerve	**Mean thickness (Range)**	**Mean length (Range)**
Iliohypogastric nerve	2.2 mm (2.0-2.5 mm)	210 mm (207-213 mm)
Ilioinguinal nerve	1.2 mm (1.0-1.3 mm)	188 mm (185-190 mm)
Genitofemoral nerve	1.4 mm (1.2-1.7 mm)	164 mm (162-167 mm)
Lateral femoral cutaneous nerve	1.8 mm (1.6-1.9 mm)	186 mm (184-189 mm)
Obturator nerve	1.6 mm (1.5-1.7 mm)	158 mm (156-161 mm)
Femoral nerve	2.6 mm (2.3-2.8 mm)	154 mm (152-156 mm)

lumbar plexus injury. Lumbar root avulsions are another cause of lumbar plexopathies and were first described by Nosik in 1955 (18). High velocity road traffic accidents are the most common causes of lumbar root avulsion and patients usually present with multiple injuries. Chin and Chew (4) have reported three cases of lumbosacral nerve root avulsion and emphasized the importance of myelography as a diagnostic tool. The formation of pseudomeningocele is characteristic for lumbar nerve root avulsion in myelography. In the Department of Neurosurgery at our institution, we treated 2 cases of lumbar plexus injury due to penetrating gunshot wounds. The diagnosis was made by electromyography (EMG) and computed tomography (CT). Conservative treatment was provided.

From this plexus issue the lumbar nerves such as the iliohypogastric nerve, the ilioinguinal nerve, the genitofemoral nerve, the lateral femoral cutaneous nerve, the obturator nerve and the femoral nerve. These lumbar spinal nerves arise from the lumbar roots which originate from the lumbar part of the spine. There are many reports on the size and the shape of the lumbar roots in the literature but none are definitive. Gillot and Singer (9) reported their results of dissection on 17 cadavers and emphasized the variations of the caliber of the lumbar roots and their connections with the sympathetic nervous system. According to their measurements, the L4 is the thickest root of the lumbar plexus while the obturator nerve is the thinnest nerve of the plexus. We recorded data similar to that of Gillot and Singer on the measurement of lumbar roots, but not for lumbar nerves. We found that the ilioinguinal nerve was the thinnest nerve of the lumbar plexus, followed by the genitofemoral nerve and the obturator nerve. The femoral nerve is the largest nerve of the lumbar plexus according to our measurements.

Many anatomical studies have been conducted on the anatomy of the lumbosacral plexus since it was first described in detail by Eisler (6) in 1892. Bardeen and Elting (1) have reported the results of their statistical study on the variations in the formation and position of the lumbosacral plexus in 1901. Rigaud et al (20) also reported their experiences on the asymmetry of the lumbar plexus. Webber (27) demonstrated some variations of the lumbar plexus. Urbanowicz (24, 25) studied the formation and connection of lumbar and sacral plexuses. He reported the largest study on the morphological features of such plexuses. He examined the variations of connections between the lumbar and sacral plexuses in detail and described four types of connections according to the formation of the furcal nerve. Bergman et al (2) examined these connections in 122 subjects and described 12 different types. They stated that the two plexuses were joined by a single furcal nerve in 91.8% of the subjects and no connection could be found in 7.4% of cases. Erbil et al (14) reported a complex bilateral variation in the formation of the lumbar plexus. The left plexus was postfixed in their case while the right one was prefixed. This variation is very rare and different from the other reports in the literature. In our dissections, we found one furcal nerve in all specimens and did not observe any variation of connection between the lumbar and sacral plexuses.

The lumbar plexus plays an important role in regional anaesthesia, especially in sacroiliac and pelvic region surgery. Lumbar plexus blockade is a useful technique, especially in the management of chronic pain and in the provision of surgical analgesia for adults and children. Farny et al (7) described the posterior approach to the lumbar plexus in fresh cadavers and concluded that the position of lumbar plexus is within the substance of the psoas major muscle. Hanna et al (11) performed an anatomical study concerning lumbar plexus block on six intact cadavers and described a simple technique with the posterior approach. However, their study consisted of only the L3 and L4 levels, not the entire lumbar plexus. We exposed the entire plexus via the posterior approach to obtain the precise sizes of the nerves.

Dietemann et al (5) performed an anatomical study on the lumbosacral plexus and emphasized that the plexus may be directly visualised on CT examinations if the radiologist knows the exact location of the nervous structures. Gebarski et al (8) also performed an anatomic-radiologic study using CT on the lumbosacral plexus and suggested that the CT is an effective method for the evaluation of the structural lesions of the lumbosacral plexus. We did not perform any radiological studies on the cadavers as it is impossible to make morphometric measurements of the lumbar plexus with CT examination. Radiological studies are however useful to reveal any plexopathology in the lumbar plexus.

Recently, Moro et al (16) conducted an anatomical study of the lumbar plexus to clarify the safety zone to prevent nerve injuries with respect to retroperitoneal endoscopic surgery. The lumbar spine of cadavers were cut parallel to the lumbar disc space. They concluded that the safety zone for retroperitoneal surgery, excluding the genitofemoral nerve, is at the L4-L5 level and above.

In conclusion; the lumbar plexus is located in the substance of the psoas major muscle on the posterior abdominal wall. The posterior approach is the best way to access the entire lumbar plexus and meticulous dissection is required for the best exposure.

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