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REVIEW ARTICLE

Morphological variability of lateral femoral cutaneous nerve and its potential clinical significance

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ABSTRACT

Background: The lateral femoral cutaneous nerve is derived from the dorsal branches of the L2 and L3 spinal nerves. It travels across the pelvis and heads towards the anterior superior iliac spine. It passes under the lateral part of the inguinal ligament and then divides into two branches, which are responsible for sensory innervation of the anterolateral and lateral skin of the thigh. However, the course of this nerve can vary morphologically. Numerous differences

have been observed in its exit from the pelvis and in the number of its main trunks and branches. Additionally, its angle with the inguinal ligament and its placement in relation to other structures (such as the femoral artery, femoral nerve, and the sartorius and iliacus muscles) also vary. All of these variants have potential clinical implications. Therefore, the aim of this review is to present the morphological variability of the lateral cutaneous nerve and to explore how these anatomical differences can introduce clinical concerns.

Materials and methods: Presented review of the literature was written based on over 30 studies. Comprehensive literature search was done using PubMed in order to study the morphological variability of lateral femoral cutaneous nerve (LFCN). To be included in this review studies needed to be meet certain criteria: been published before December 2023, present information valuable to this paper (variability of lateral femoral cutaneous nerve/clinical significance). The search included how LFCN vary either among fetuses and adults in the aim of providing more complex information about the variability of this nerve. During the search key words as following were used. No particular references were excluded from the analysis. All relevant studies were included, and citation tracking was used to identify publications.

Results: This review presents the description of variability of LFCN and its potential clinical impact. In the review differences in adult and fetuses were considered, morphological variability were divided into 4 groups: the origin of the nerve, the way it leaves the pelvis, the branching pattern, the angle between LFCN and surrounding structures and then, clinical significance were considered basing on available literature.

Keywords: lateral femoral cutaneous nerve, inguinal ligament, femoral region, meralgia paresthetica, lumbar plexus, thigh innervation, systematic review, nerve variability, morphological variation

INTRODUCTION

The lateral femoral cutaneous nerve (LFCN) originates from the lumbar plexus. It consists mainly of dorsal branches of either the L2 or L3 ventral rami. It passes under the lateral edge of the psoas major muscle. As it approaches the quadratus lumborum muscle it travels obliquely downwards towards the anterior superior iliac spine (ASIS), creating its lumbar part. The iliac part of the LFCN begins as the nerve emerges on the iliacus muscle. It passes

through the muscular lacuna or under the lateral part of the inguinal ligament (IL), where it forms the inguinal part. The femoral part is created as the LFCN reaches the thigh. Typically, the nerve divides into two divisions at this point: anterior (to the anterolateral part of the thigh) and posterior (to the lateral part of the thigh). The LFCN is responsible for sensory innervation of the lateral part of thigh and the gluteal area around the greater trochanter [1, 2, 4, 6–10].

Meralgia paresthetica (Bernhardt-Roth syndrome) is a pathological condition related to the LFCN injury [4]. Its etiology can include iatrogenic injuries caused by surgical procedures, inflammatory disease, diabetes, obesity, various toxicities or even tight clothing and results in sensory deprivation in either the anterolateral or the lateral part of the thigh [30].

The course of the LFCN can vary morphologically, as indicated in the literature, which has described the most common variations in its route from the lumbar plexus to the thigh. These include differences associated with crossing the anterior superior iliac crest, distances from the ASIS at the level of the IL, the distance to crossing the sartorius muscle, and the angle it creates with the IL. Morphological variability has been observed among both adult cadavers and fetuses [16].

The aim of this review is to present the morphological variability of the lateral cutaneous nerve as revealed in the available literature. A second purpose is to portray how the anatomical differences can lead to clinical concerns.

VARIABILITY OF LFCN AMONG FETUSES

Hryhorieva et al. [16] investigated the characteristics of sensory innervation of the anterior femoral region and the fascia lata in fetuses. Sixty-four preparations of lower extremities of fetuses were examined. Macromicroscopic preparations using a binocular magnifier were used to provide detailed results. During the preparation, branches derived from the lumbar plexus were dissected first without violation of the psoas major muscle; the muscle was then removed. In each case, the inguinal ligament remained intact. In order to prevent mutilation of the nerves, they were prepared following the sequence in which they arise from the lumbar plexus: iliohypogastric, ilio-inguinal, branches of either ilio-inguinal or genitofemoral, and finally the lateral femoral cutaneous, femoral and obturator nerves. This particular sequence

allowed the variability in innervation, overlapping zones and anastomoses between nerves to be demonstrated [16].

The preparation of the lumbar plexus revealed that the level at which the nerves originated from it was related to innervation of the skin. A higher level of origin was associated with more superficially located branches, and a lower level of origin was associated with deeper branches. This observation enabled three different sets of cutaneous nerves that innervate the anterior femoral region to be distinguished. One set includes the LFCN, anterior cutaneous branches of either the femoral or the iliohypogastric nerve, and the ilio-inguinal and genitofemoral nerves [16].

The LFCN tends to give rise to 2–5 branches after reaching the IL. It then travels to the lateral surface of the femur up to the knee. Branches providing sensory innervation to the antero-lateral surface primarily leave the femur region posterior to the medial and lateral thirds of the IL [16]. The LFCN forms anastomoses with the femoral nerve (FN), and more specifically its anterior cutaneous branches. This was noticeable across the whole femoral surface of the thigh in fetuses. As the anastomoses could be detected, this could suggest an overlap between the innervation areas of these two nerves, as also stated by Hryhorieva et al. [16]. Terminal branches of the FN overlapped not only with branches of LFCN but also with branches of the obturator, ilio-inguinal and posterior cutaneous nerves.

Fazliogullari et al. [10] studied the course of the LFCN and introduced a detailed classification of its branching, relating its branches to either the FN or the femoral artery (FA). Fifty lower extremities from 25 spontaneously miscarried fetuses were examined, and no malformations were found among them. There were 12 male and 13 female fetuses aged from the 15th to the 35th week (17 cases in the 2nd trimester and eight in the 3rd). The number of trunks that gave particular numbers of branches formed four main patterns, labeled I-IV. In Type I the LFCN passed behind the IL and then descended as a single trunk — it presented on a Fig. 1a–c. In Type II there was division into two trunks — presented on Fig. 1d–f. In Types III and IV there were respectively three and four trunks — Fig. 1g–h. Significantly, Types II and III were distinguished after the LFCN passed the IL, while Type IV divided before it reached the IL. However, some trunks were further divided to give various numbers of branches; these were described as subtypes ‘a’, ‘b’ or ‘c’, as even up to four branches of the LFCN were observed [5]. The quantitative data of occurrence of particular branching patterns

among male and female fetuses is presented in Table 1 according to Fazliogullari et al. [10] research.

Table 1. Sex differences in the incidence of different types of branching of the lateral femoral cutaneous nerve basing on Fazliogullari et al. [10] research

SEX	Type I			Type II			Type III	Type IV
	a	b	c	a	b	c		
Male	3	13	3	2	–	1	1	1
Female	4	14	4	2	1	–	1	–
Total	41 (82%)			6 (12%)			2 (4%)	1 (2%)

According to these data, Type Ib (two branches derived from the single trunk) was the most frequent variant, occurring in 54% of cases. Types III and IV were the least common and appeared in only 4% and 2%, respectively. However, a Mann-Whitney U test revealed no significant sex difference among the fetuses. To investigate age differences among the subtypes of fetal LFCN branching (whether it was the second or the third trimester) a chi square test was used; again, there were no significant differences [10].

Fazliogullari et al. [10] also examined the relationship between the LFCN and FN and compared the courses of the LFCN and FA. Distances from the FN in the second trimester ranged from 0.00 to 6.22 mm in males (mean 3.05 mm) and 0.00 to 7.97 mm in females (mean 3.80 mm), while in the third trimester it ranged from 0.00 to 7.74 mm in males (mean 5.66 mm) and 2.47 to 9.19 mm in females (mean 6.59 mm). Distances from the FA in the second trimester were 2.83–7.47 mm in males (mean 5.37 mm) and 2.12–10.35 mm in females (mean 9.36 mm), while in the third trimester they were 5.75–11.16 mm in males (mean 8.86 mm) and 5.82–11.17 mm in females (mean 9.36 mm) [10]. The calculated averages distances of the presented data are presented in Table 2.

Table 2. Average distances between lateral femoral cutaneous nerve and either femoral nerve or femoral artery according to the Fazliogullari et al. [10] research

	Average distance from lateral femoral cutaneous nerve [mm]
Femoral nerve	4.30 ± 2.62

Femoral artery	7.25 ± 2.49

Moreover, Fazliogullari et al. [10] stated that in 11 sides the courses of the LFCN and FN were in the close proximity in the pelvic cavity up to the IL.

Both the foregoing studies provided information about the LFCN in human fetuses. Hryhorieva et al. [16] investigated how it collaborates with other nerves from the lumbar plexus in innervating the anterior femoral region and fascia lata, creating ‘overlapping zones’. They found that the LFCN tended to divide into 2–5 branches as it passed the IL. These outcomes seem consistent with Fazliogullari et al. [10]. The second study focused on details of the branching pattern, creating a classification into four types corresponding to the presence of up to four main trunks. As these trunks often divided further, subtypes were identified. The distances from the FN and FA to the LFCN were also measured. Both studies revealed that the LFCN varies among fetuses.

VARIABILITY OF LFCN AMONG ADULTS

The LFCN varies not only among fetuses but also among adults. Numerous authors have studied different facets of its morphological variability. These include its different ways of exiting the pelvis [6–8] and differences in the numbers of its main trunks and branches [30]. Variations in the angle between LFCN and the IL have also been measured [12]. The placement of the LFCN in relation to other structures (such as the femoral artery, femoral nerve, and the sartorius and iliacus muscles) has also been investigated [15, 19].

Origin of the LFCN

The first variability of the LFCN is associated with its origin from the lumbar plexus. Haładaj et al. [13] studied 80 specimens from 40 cadavers (22 males and 18 females) to investigate these variations. In the most common pattern, the LFCN arose from L2 and L3 (47 cases, 58.75% of LFCNs); in 38 of those cases (47.5%) the L2 root dominated, while L3 dominated in the remaining nine. Origins from either L1 or L2 were observed in 12 cases (15% of nerves). Interestingly, when the LFCN arose from L1 and L2, the L2 root dominated. In nine cases (11.25%) the LFCN arose from L2 alone. In six cases (7.5%) it originated from the FN

[13]. However, the LFCN was absent in six cases (7.5%); in two cases (either female or male) on the left side and on both sides in one male.

Variability in the LFCN leaving the pelvis

Another variability in the course of LFCN concerns the location at which it exits the pelvis. Murata et al. [6] studied 108 cadavers from Japan. LFCNs from both sides of the lumbar plexus were prepared. Sixty-four male and 44 female bodies ranging in age from 60 to 97 were examined. After excluding nerves had been affected by cancerous changes, 205 remained [22].

One variation of the LFCN among adults occurs in the area of the ASIS. Murata et al. [22] provided information about the position of the LFCN and how it is related to the ASIS. Moreover, the point at which the nerve decussates over the iliac crest, or whether it travels under the IL without crossing the iliac crest, was considered. Four types labeled A-D were distinguished. In the first type (A) the LFCN crossed the iliac crest more than 2 cm back to the ASIS — Fig. 2a. Type B involved decussating over the iliac crest within 2 cm from the ASIS — Fig. 2b.; in type C it crossed over directly at the level of ASIS – Fig. 2c.; in type D it crossed the iliac crest under the IL, anterior to the ASIS — Fig. 2d. Table 3 presents the occurrence of these types.

Table 3. Comparison between percentage occurrences of particular types of lateral femoral cutaneous nerve on the basis of its relationship to the anterior superior iliac crest, suggested by Murata et al. [22]

Type	Relationship to the anterior superior iliac crest	Incidence
A	More than 2 cm back to the ASIS	2.0%
B	Within 2 cm from the ASIS	10.8%
C	At the level of the ASIS	28.7%
D	Under the IL, anterior to the ASIS	58.5%

ASIS — anterior superior iliac spine; IL — inguinal ligament

Type D was most frequent (58.5%), while Type A was least common (2.0%). Type B and Type C occurred in 10.8% and 28.8% of cases respectively [22].

A second classification presented by Murata et al. [22] concerned the level at which the LFCN crossed the iliacus muscle. Two types were distinguished. In type 1, it crossed the iliacus muscle 5 cm posterior to the ASIS. Type 2 included decussating the iliac crest within 3 cm (8.9%); in Type 2' the distance from the iliac crest exceeded 3 cm (91.1%) [22].

Similarly, Aszmann et al. [2] investigated the course of the LFCN in relation to soft tissues and bony landmarks as it left the pelvis. They studied 104 lower extremities of American cadavers. Five types of exit from the pelvis were distinguished [2], A–E, as presented in Table 4.

Table 4. Types of exit of the lateral femoral cutaneous nerve from the pelvis and their incidence [2]

Type	The point of exit from the pelvis	Incidence
A	Posterior to the ASIS, across the iliac crest	4%
B	Anterior to the ASIS, superficial to the origin of the sartorius muscle and within the substance of the IL	27%
C	Medial to the ASIS, ensheathed in the tendinous emergence of the sartorius muscle	23%
D	Medial to the emergence of the sartorius muscle, in the interval between the sartorius muscle and the fascia of the iliopsoas muscle, deep to the IL	26%
E	The most medial, embedded in the loose connective tissue deep to the IL, overlying the thin fascia of the iliopsoas muscle, assisting the femoral branch of the genitofemoral nerve	20%

ASIS — anterior superior iliac spine; IL — inguinal ligament

Type B was the most common (27% of cases). Similar results were obtained for type D, which was identified in 26% of lower extremities. The least prevalent was the type A, which appeared in only 4% of cases. Futhermore, Aszmann et al. [2] suggested that types A, B and C are the most susceptible to mechanical injury. As the type B LFCN is located within the

substance of the IL, procedures that involve interruption of the IL can lead to nerve injury. Similarly, type C is prone to injuries because it is sheathed in the tendinous emergence of the sartorius muscle. Without knowledge of this possible variability, the course of nerve can be interrupted during medical procedures.

The distance between the LFCN and the ASIS was also measured by Kosiyatrakul et al. [17]. Their research, conducted on 96 embalmed cadaveric specimens, revealed that 56 nerves (58.3%) passed medial to the ASIS, 22 (22.9%) passed at the level of the ASIS, and 18 (18.8%) passed lateral to the ASIS. Furthermore, the LFCN was mainly situated 2.1–3.9 cm beneath the crest and 2–5 cm lateral to the ASIS. In view of this variability, Kosiyatrakul et al. [17] recommend special consideration while harvesting graft of the ASIS bone in order to decrease the risk of nerve injury [17].

Surucu et al. [27] investigated the LFCN in 22 Turkish cadavers. Among the 44 lower extremities, seven nerves displayed differences. The nerve was located 1.52 cm medially to the ASIS.

Similar results were obtained by Mischkowski et al. [21]. They extracted 34 nerves from German cadavers to investigate the relationship beween the course of the LFCN and the ASIS. One nerve (2.9%) crossed the ASIS less than 5 mm superolaterally, while the others traveled below the IL at a mean distance of 14.6 mm inferomedial to the spine [21].

Hospodar et al. [15] obtained slightly different outcomes. Sixty-seven nerves were dissected from American cadavers and the distance from the LFCN to the ASIS was measured. No nerves passed laterally to the ASIS. They passed 21–25 mm medial to it in seven of the dissected cadavers, 26–30 mm in 10, and more than 30 mm in 14. The distances ranged from three to 46 mm (mean 20.4 mm). Moreover, the nerves passed anterior to the iliopsoas muscle in all samples.

More quantitative data about distances from the ASIS, the lateral margin of the FA and the lateral tip of the pubic tubercle were provided by Lee et al. [19]. They investigated 33 Korean cadavers, 22 males and 11 females, 56–94 years old (mean 74 years). The lower extremities were dissected yielding in 29 right and 31 left sides, samples with lesions and malformations of the LFCN being excluded. Digital calipers were used for measurements. Most (90.3%) LFCNs passed under the IL medially to the tip of the ASIS and laterally to the FA. The distance from the LFCN to the medial tip of the ASIS ranged from 4.3 to 40.2 mm (mean 8.8

mm). Subsequent measurements revealed that the medial tip of the ASIS was 55.4 mm from the lateral margin of the FA, while the lateral tip of the pubic tubercle was 57.5 mm away from it. Most (80.6%) LFCNs were found within 2 cm from the medial tip of the ASIS, two-thirds of them within 1 cm, and 2–4 cm away in only 10%. In 10% of cases the LFCN was lateral to the ASIS [19].

Tomaszewski et al. [30] investigated the correlation between geographical background and the distance between the exit of the LFCN and the ASIS. Europeans and North Americans tended to have longer distance than other groups, 2.32 cm, while samples from South America had the shortest, 0.99 cm. Comparison of distances between the sides revealed that the left LFCN was slightly further from the ASIS (mean 1.99 cm; mean 1.91 cm on the right) [30].

The aforementioned studies showed that the exit of the LFCN from the pelvis is variable, and so is the distance from the ASIS and its relative location. The LFCN usually lies medial to the ASIS, but there were incidences of lateral localization. There were more exceptions from the regular course. Dissection of sixty LFCTNs revealed that two (3.3%) did not pass under the IL but crossed the iliac crest instead [18]. Murata et al. [22] found that four nerves passed in the posterior direction towards the ASIS.

Variability in the branching pattern

The LFCN varies not only in its exit from the pelvis but also in the number of its branches. It tends to travel to the femoral region as a single branch until it splits into its terminal divisions. However, some studies have shown that the nerve can bifurcate, trifurcate or even quadrificate [30].

Several authors have investigated the branching pattern in adult cadavers [9, 26, 27, 31]. They focused first on then numbers of branches and then the percentage incidences. The results from the available literature are presented in Table 5.

Table 5. Percentage occurrences of numbers of branches documented in the literature

Studies	**Number of specimens examined**	**Range of number of branches**	**Incidence of occurrence**			
			One	**Two**	**Three**	**Four**
Surucu et al. (1997)	44	1–4	11.4%	84%	2.3%	2.3%

[27]						
Dias Filho et al. (2003) [6]	52	2–3	–	66%	34%	–
Doklamyai et al. (2008) [9]	85	1–4	75.3%	21.2%	2.3%	1.2%
Ropars et al. (2009) [26]	34	2–3	–	94.1%	5.9%	–
Zhang et al. (2010) [31]	20	2	–	100%	–	–

The most common number of branches was 1-4, but Zhang et al. found only two branches. Most of these studies suggest that the most common pattern is two branches: 84% [27], 66% [6], 94.1% [26], or 100% [31]. Interestingly, Doklamyai et al. [9] found that the most frequent type of branching (75.3% of cases) was single branch; only 21.2% of adult cadavers had two branches. According to Grothaus et al. [12] there was more than one branch in 26% even before the LFCN crossed the IL.

These outcomes seem consistent with the findings by Fazliogullari et al. [10] on human fetuses, where Type Ib — two branches derived from the single trunk — was the most frequent variant (54% of cases) [10].

Further information about the branches of the LFCN was provided by da Rocha et al. [5]. As the nerve passed the ASIS medially it branched into three rami (labeled by the authors as ‘wide-caliber’) in 70% of cases. In 30% there were only two rami. As the nerve approached the thigh region it tended to distribute into a network of plentiful small rami covered by adipose tissue. On the other hand, no nerve rami were observed in the lower third of the thigh [5].

As stated in the previously mentioned studies, the LFCN tends to show different branching patterns. This is very significant because many branches mean more possible ways by which the nerve can reach its destination, and therefore more opportunities for nerve injury.

Variability in the angle between the LFCN and the IL

The angle between the LFCN and the inguinal ligament is also variable. This is important as differences in it influence the course of the nerve. Grothaus et al. [12] investigated this particular angle — Figure 3. As the nerve branched into up to three rami, all their angles were measured. The range of angles and their mean values are presented in the Table 6.

Table 6. Angles between particular branches of the LFCN and the IL according to Grothaus et al. [12]

Branches	**Angle between particular branch of the LFCN and the IL**	
	Range [degrees]	**Mean [degrees]**
The first	20–90	63
The second	30–90	61
The third	60–90	70

The average value oscillated around 61–70 degrees for all of the branches; 61 degrees was observed for the second branch, while the highest mean angle (70 degrees) was noted for the third rami. The first branch had the widest range of angles (20 to 90 degrees), while the angle between the IL and the third branch ranged from 60 to 90 degrees [12].

Lee et al. [19] also studied the angle between the IL and the LFCN as the nerve enters the femoral region of the thigh. The value ranged from 68.08 to 111.08 degrees (mean 83.38 degrees) [19].

Relationships to other structures along the course of the LFCN

Another variability associated with the LFCN involves its relationship to other structures. Grothaus et al. [12] compared the course of LFCN with the sartorius muscle. Their aim was to measure the distance from the ASIS to the point where the LFCN crosses the sartorius muscle measured along the IL.

Table 7. Distance between particular branches of the LFCN and the sartorius muscle measured along the IL according to Grothaus et al. [12]

Branches	Distance between the asis and the point of crossing the sartorius muscle along the IL	
	Range [mm]	**Mean [mm]**
The first	1–36	12
The second	5–26	13
The third	6–21	13

The mean distance from the ASIS to the point where the nerve crossed the lateral border of sartorius muscle was 12 mm (range 1–36 mm). The distance where the branches crossed the lateral border of the sartorius muscle ranged from 2.2 to 11.3 cm inferior to the ASIS. The mean distances for the 1st, 2nd, and 3rd branches were 54, 60, 63 mm respectively inferior to the ASIS [12].

Lee et al. [19] investigated the structures to be found beneath the LFCN as it passed through the IL. It crossed the lateral border of the sartorius muscle in four cases (5.5%) and the medial border in 16 (22.5%). However, 30 nerves passed through the IL just above the medial region of the sartorius muscle (41.7%). There were also 12 (16.6%) cases where the structure beneath the LFCN was the femoral triangle.

Clinical significance of lfcn variability

The LFCN is morphologically variable in both human fetuses and adult cadavers in respect of the way it exits the pelvis, its branching pattern, its angle with the IL, and its relationships with other structures. These morphological variabilities could imply clinical significance as various medical procedures involve working on regions where the LFCN courses; because of the variability, additional awareness should be maintained to preclude iatrogenic injuries.

First, as described, the LFCN can exit the pelvis in many ways. The ASIS has been used as a bony landmark to measure its different possible placements. Although it is much more common for the nerve to travel medially to the ASIS, there are instances of lateral localization. According to Tomaszewski et al. [30], 2.6% of cases showed lateral placement. This particular variability increases the risk for iatrogenic injury during bone graft harvesting. This procedure is frequent in reconstructive orthopedic surgery in which use of a bone

enhances fracture healing and creates support [7]. Even though different bones are used for harvesting (for example tibia, radius or ribs), the iliac crest remains most popular. However, variants of the course of the LFCN should be considered while preparing for this procedure in order to prevent iatrogenic injury which could evenly cause meralgia paraesthetica [7].

According to Aszmann et al. [2], the LFCN was covered in 59% of samples by an aponeurotic expansion of the sartorius muscle, which was attached to the inferior border of the ASIS. However, some authors suggest that the nerve has its own canal, which isolates it not only from the skin and other superficial layers but also from the muscles that are found beneath it (sartorius muscle and tensor fasciae latae) [14]. The canal of the LFCN was described recently; special awareness should be maintained, because not only can the nerve have a different course or branching pattern, but it can also be even harder to estimate its placement and avoid injuring it. Aszmann et al. [2] observed that types A, B and C are the most prone to mechanical injury. As the type B LFCN is located within the substance of the IL, procedures that involve interruption of the IL can lead to nerve injury. Similarly, type C is prone to injuries because it is sheathed in the tendinous emergence of the sartorius musle. This is important as injury to the tissues surrounding the LFCN can lead to scar formation [14]. Moreover, any procedures on the area of sartorius muscle (such as operation on sarcoma) could result in potential injury of LCFN.

A variability in which there is a short distance from the ASIS to the LFCN could introduce a potential risk of trauma when the body is in prone position, or even when tight and heavy belts are worn [14].

Another concern is associated with variability in the branching pattern (1–4 branches: [9, 26, 27, 31]). This is especially significant during inguinal hernia repairs. The nerve tends to pass through the ASIS, the IL, or even through the muscle, simultaneously branching into various numbers of rami (in particular at the level of the IL). This is why variations of the LFCN should be considered in order to prevent traumas. Laparoscopic inguinal hernia repair has been shown to entail a lower risk ratio for postoperative neuralgia than open inguinal hernia repair [11, 23, 25]. To avoid potential injury to the LFCN owing to its variability in inguinal region, this method should be considered.

The variability of the LFCN affects the approach to hip arthroplasty. According to the literature, 81% of patients were admitted with the beginning of neuropraxia in the region innervated by the LFCN after hip arthroplasty using an anterior approach [3, 11]. The anterior

approach is used because it decreases the chances of dislocation; the lateral approach introduces more concerns about adduction function [24]. However, the anterior approach often leads to iatrogenic injury of the LFCN, causing a loss of sensation in the femoral region of the thigh. In order to preclude such injury, the exact location of the nerve should be recognized.

Periacetabular osteotomy (PAO) is one of the possible cause of iatrogenic injury to LFCN when anterior approach is used. This is the main treatment for either adolescents and young adults who suffer from hip dysplasia. The procedure is done in order to decrease hip pain and allow daily activities. Furthermore, it protects the hip joint and allow to decrease potential risk of arthritis. However, during the procedure, the series of cuts which are needed to perform are able to injure the LFCN as well. In the study conducted by Doi et al. [8] 42 patients after PAO were examined in terms of LFCN injury. It was observed that 31 of 42 (74%) patients suffered from LFCN injury. Moreover, the researchers observed that there was a significant difference in mental score using the Short-Form 36 Health Survey (SF-36). The possibility of injury and furthermore, the negative influence on patients' mental health could be limited with higher awareness of possible variations of LFCN [8].

Another procedure that may cause iatrogenic injury of LFCN is a primary and revision total hip arthroplasty (THA) using the direct anterior approach (DAA). DAA is used not only in THA but also in femoroacetabular impingement. However, different types of incisions that are used in this procedure could possibly result in nerve palsy. If LFCN is damaged during the surgery, it may result not only in feeling of numbness but also in burning sensation in anterolateral region of the thigh which in result may cause a severe pain. Thaler et al. [28] conducted a study in which the course of LFCN were compared with the respect to the skin crease bikini incision, the standard longitudinal approach for primary THA, the longitudinal extension of the DAA and the lazy S extension of DDA [28].

For the purpose of the study first of all these four incisions were done with the consultation of an arthroplasty surgeon and then, skin of the cadavers was removed with regard to localize the branches of LFCN. An 8-cm skin crease bikini incision was made starting 2-cm lateral and 2-cm distal to the ASIS as the one which is used for primary DAA. Then, either longitudinal extension and so-called lazy S extension were prepared – the first one at the level of the primary DAA approach and the second one in order to reach the entire femoral diaphysis without providing any risk to the nerve supply. The lazy S incision was directed to posterior at

the end of the primary incision at the level of the greater trochanter and then, extended distally [28].

According to the results, either skin crease bikini incision and the longitudinal extension of the DAA crossed the main branch of LFCN in 100% of researched cadavers. This observation supports the idea of previous study that extending the DAA results in cutting 1 or even more branches of LFCN [29]. Furthermore, it was concluded that the higher number of branches of LFCN, the higher risk for potential nerve injury. In that situation patients will feel some degree of numbness on the lateral part of operated area.

Lack of awareness of possible variations of the course of the LFCN can lead to iatrogenic injuries resulting in meralgia paresthetica. This disorder is characterized by a tingling, stinging or a burning sensation in the anterolateral part of the thigh [24]. However, this could be easily prevented using 18 MHz ultrasound transducer [20]. It is recommended to use the intermuscular space between the tensor fasciae latae muscle and the sartorius muscle as an initial sonographic landmark to scan the course of the LFCN. This particular ultrasound transducer should be used for easier imaging as it has higher frequency. A study revealed that the mean time required to identify the LFCN in all subjects was equal to 7s. Then, the course of the LFCN can be traced proximally and distally [32].

The study has its limitations as there is no data to compare the outcome and the chosen method could not provide more information about branches of LFCN with much smaller diameter. However, this study is an interesting starting point for further investigation. As the proposed method of tracing LFCN does not require much time, it could be a worthwhile option to use before planning a surgical approach to the LFCN as well as in regional anaesthesia when blocking the LFCN for the treatment of MP.

Preventing the LFCN injury is profitable for patients not only in regard to impact on previously mentioned mental score because of burdensome feeling of numbness but also it may reduce the number of possible neuromas of LFCN which are result in mechanical microtraumas or chronic irritation.

CONCLUSIONS

The LFCN is variable not only among fetuses but also among adults. Different authors have studied its various ways of exiting the pelvis, variations in the numbers of its main trunks and branches, variations in its angle with the IL, and its placement in relation to other structures (including the femoral artery, femoral nerve, and the sartorius and iliacus muscles). All of these differences should be considered when medical procedures are performed in the inguinal and femoral region because they can injure the LFCN leading to meralgia paresthetica, which is characterized by the loss of sensation, in the lateral part of the thigh. Meralgia paresthetica can result not only from external injury (either mechanical or iatrogenic) but also because of neuropathy or neuroma of the LFCN.

Article information and declarations

Author contributions

Kinga Władyka – project development, data collection and management, data analysis, and manuscript writing.

Nicol Zielinska — data collection and analysis and manuscript editing.

Richard Shane Tubbs — data collection and analysis and manuscript editing.

Krystian Maślanka. — data collection, analysis, and manuscript writing.

Andrzej Borowski — data analysis and manuscript writing.

Marek Drobniewski — data analysis and manuscript writing.

Łukasz Olewnik — numerous consultations, observations, and suggestions related to the paper. Data analysis and manuscript editing.

All authors have read and approved the manuscript

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FIGURE LEGENDS

Figure 1a. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine —subtype Ia — LFCN is passing behind the IL and then descending as a single trunk.

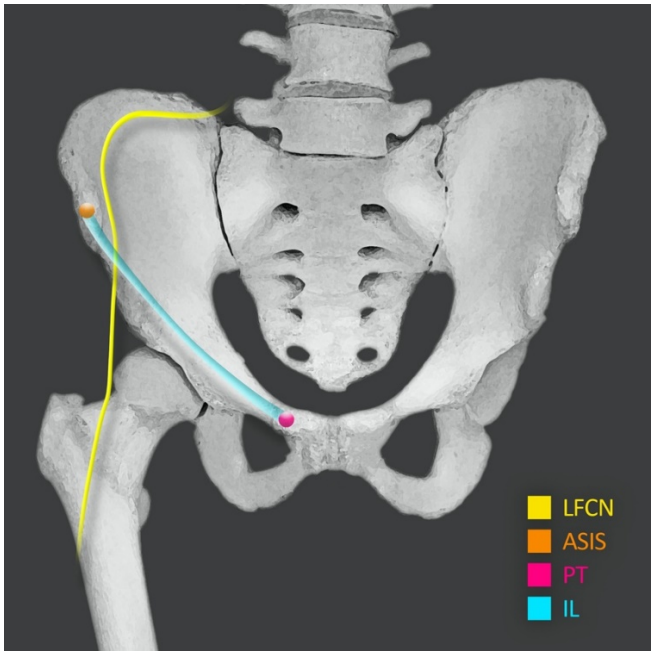


Figure 1b. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — subtype Ib — LFCN is passing behind the IL as a single trunk and then is divided into 2 branches

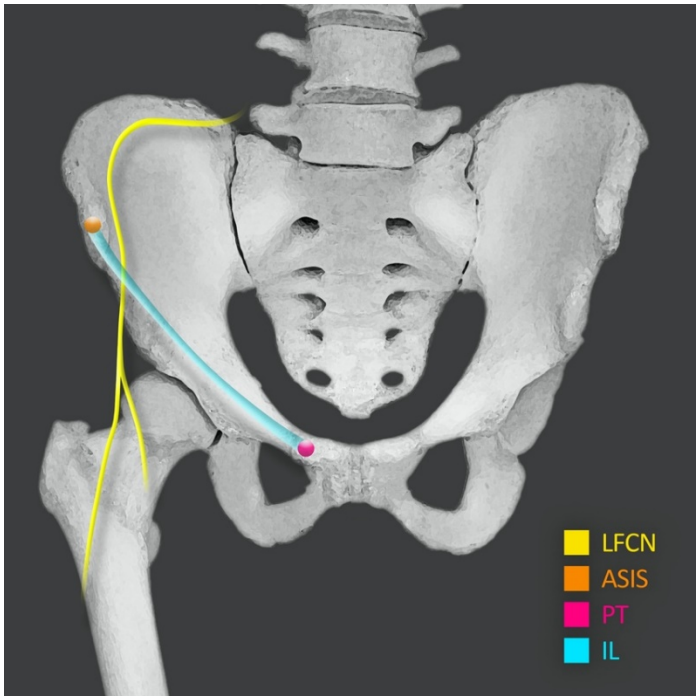


Figure 1c. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — subtype Ic — LFCN is passing behind the IL as a single trunk and then is divided into 3 branches

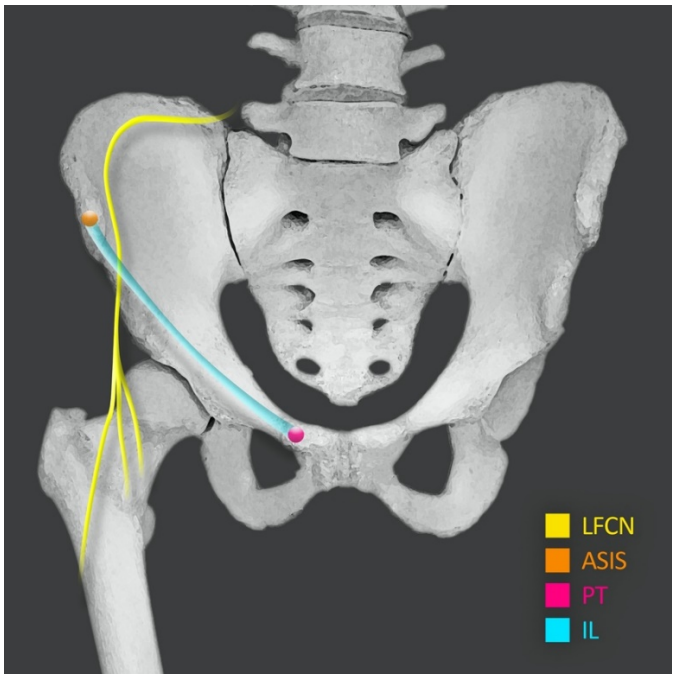


Figure 1d. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine – subtype IIa - 2 trunks of LFCN are passing behind the IL

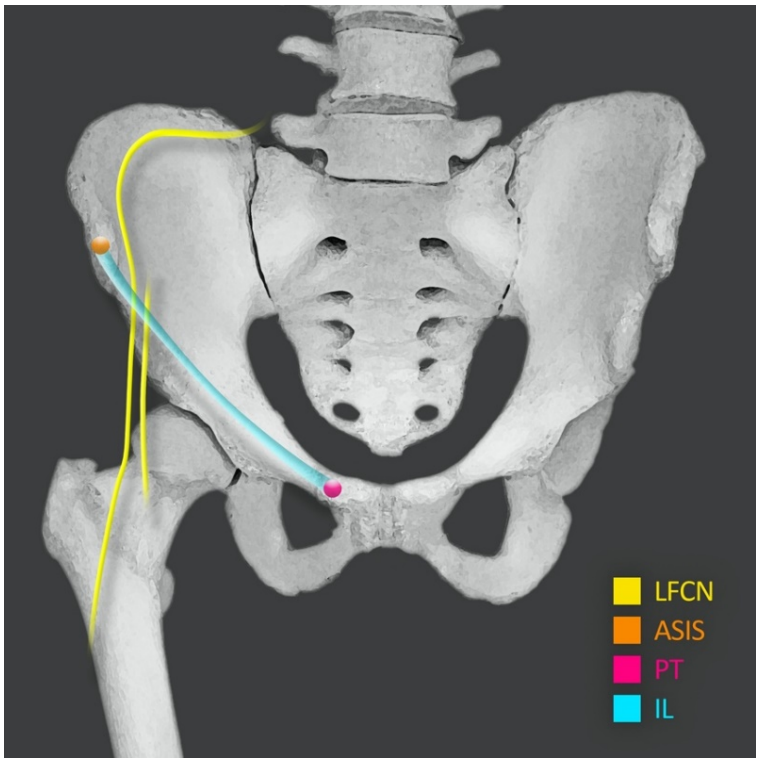


Figure 1e. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine – subtype IIb - 2 trunks of LFCN are passing behind the IL, one of them is further divided into 2 branches

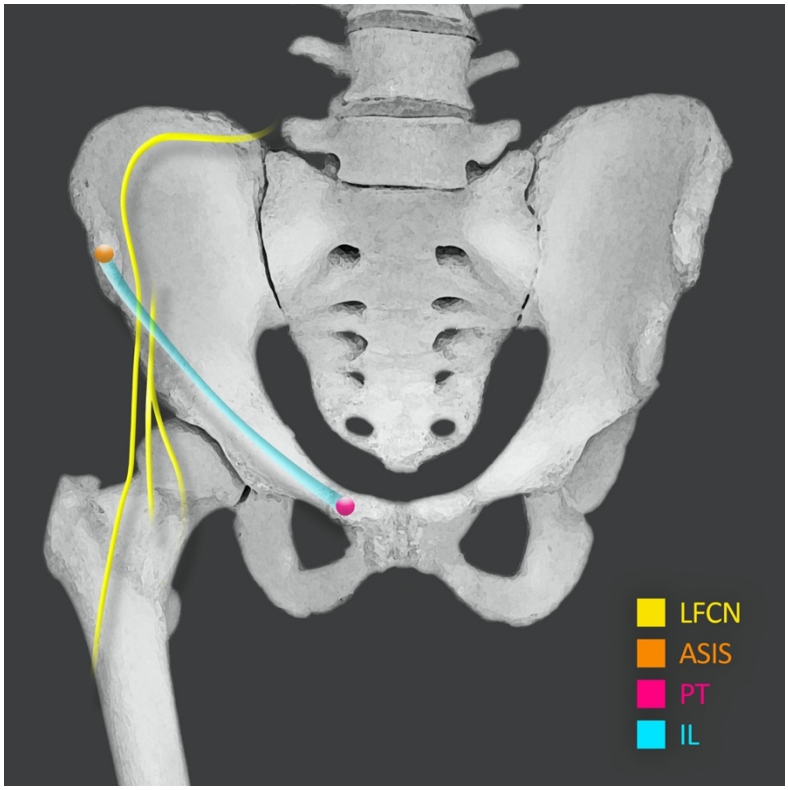


Figure 1f. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — subtype IIc — 2 trunks of LFCN are passing behind the IL, one of them is further divided into 2 branches

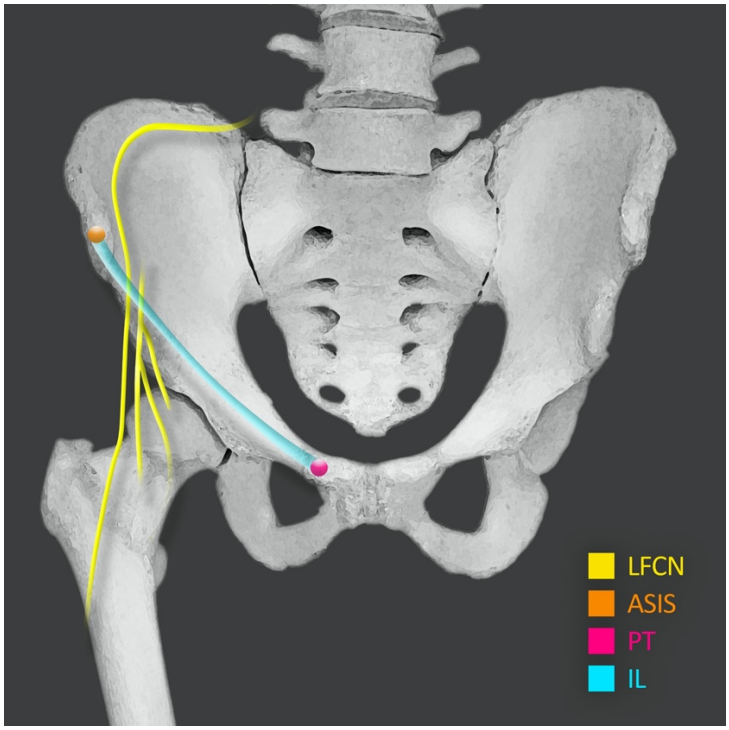


Figure 1g. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — subtype III — 2 trunks of LFCN are passing behind the IL, one of them is further divided into 2 branches

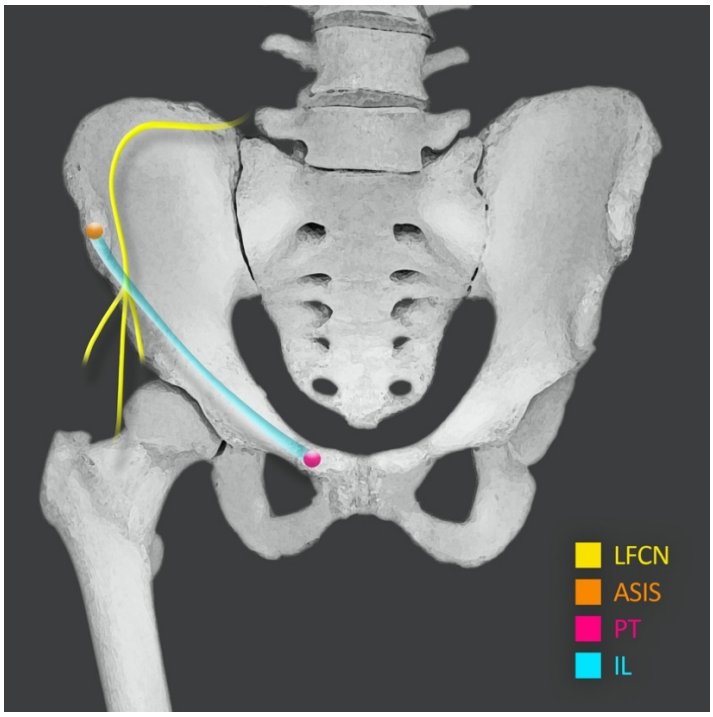


Figure 1h. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — subtype IV — 3 trunks of LFCN are passing behind the IL

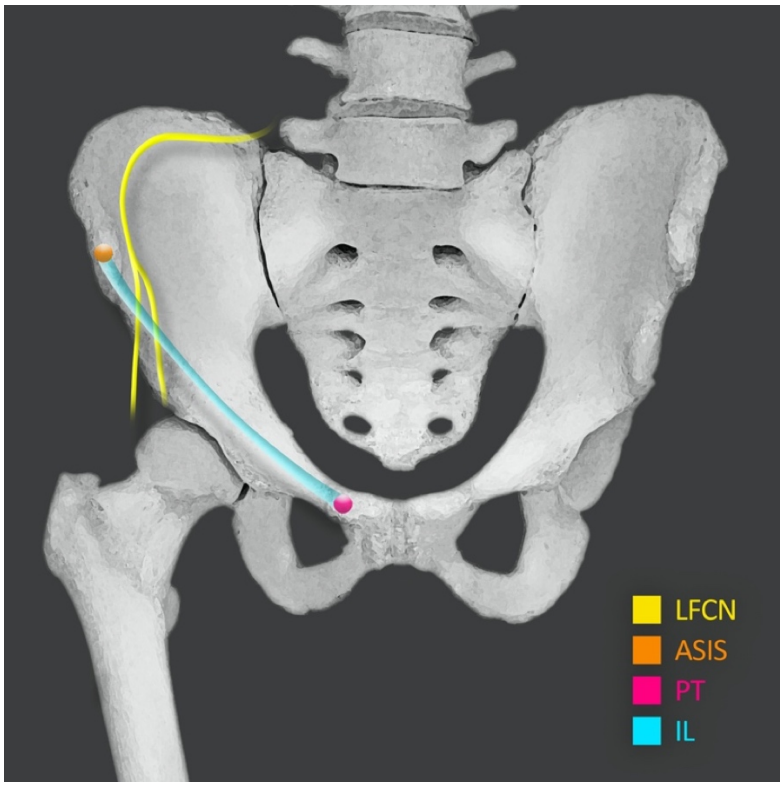


Figure 2a. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — type A — the LFCN is crossing the iliac crest more than 2 cm back to the ASIS

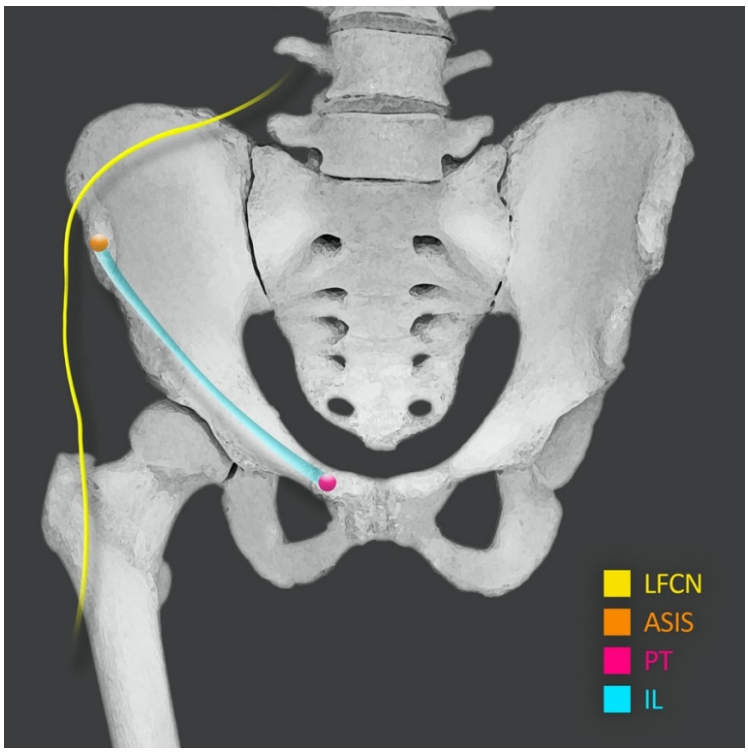


Figure 2b. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — type B — LFCN is decussating over the iliac crest within 2 cm from the ASIS

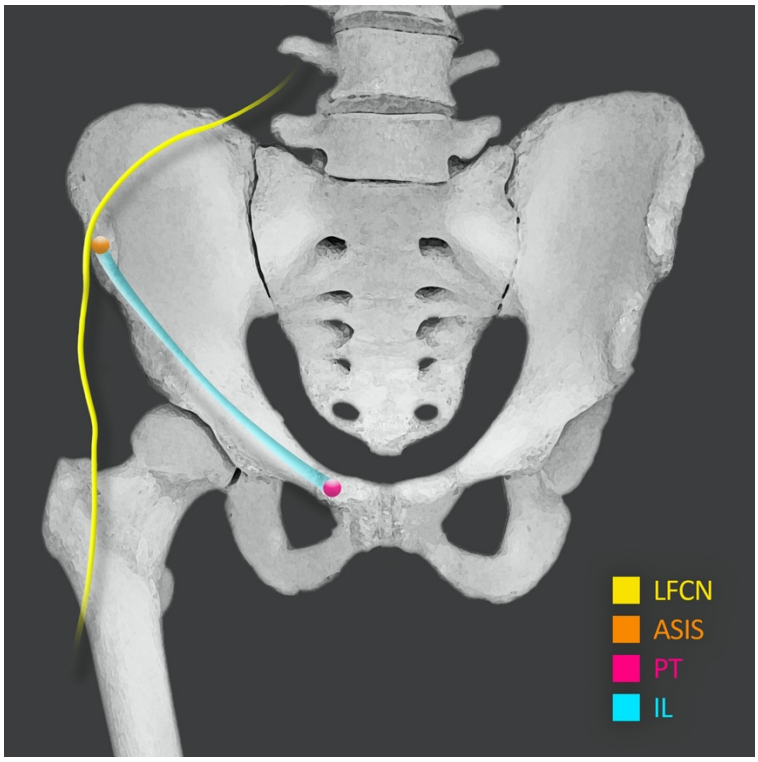


Figure 2c. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine – type C – LFCN is crossing over directly at the level of ASIS

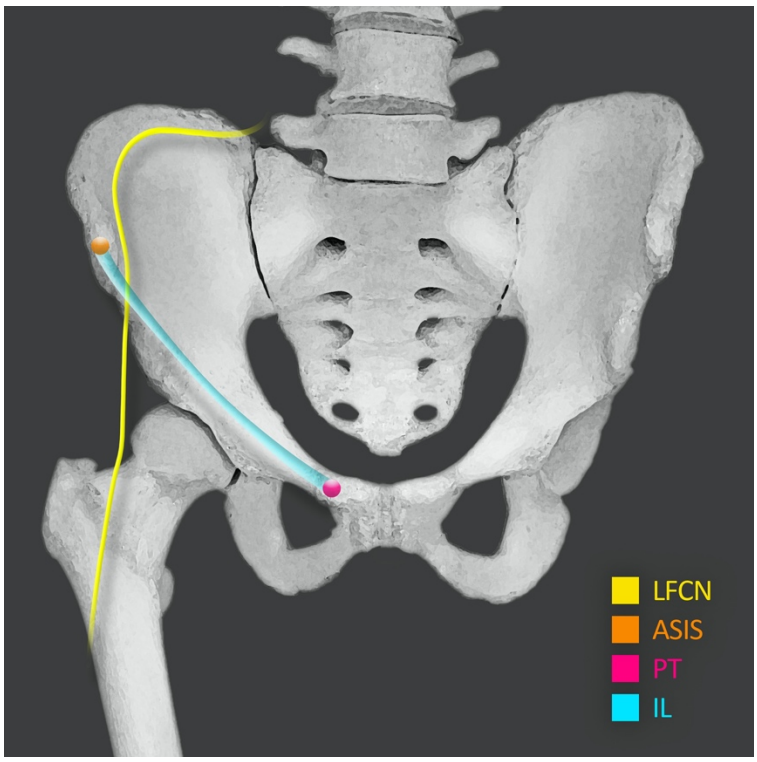


Figure 2d. Relation of the lateral femoral cutaneous nerve to the anterior superior iliac spine — type D — LFCN is crossing the iliac crest under the IL, anterior to the ASIS

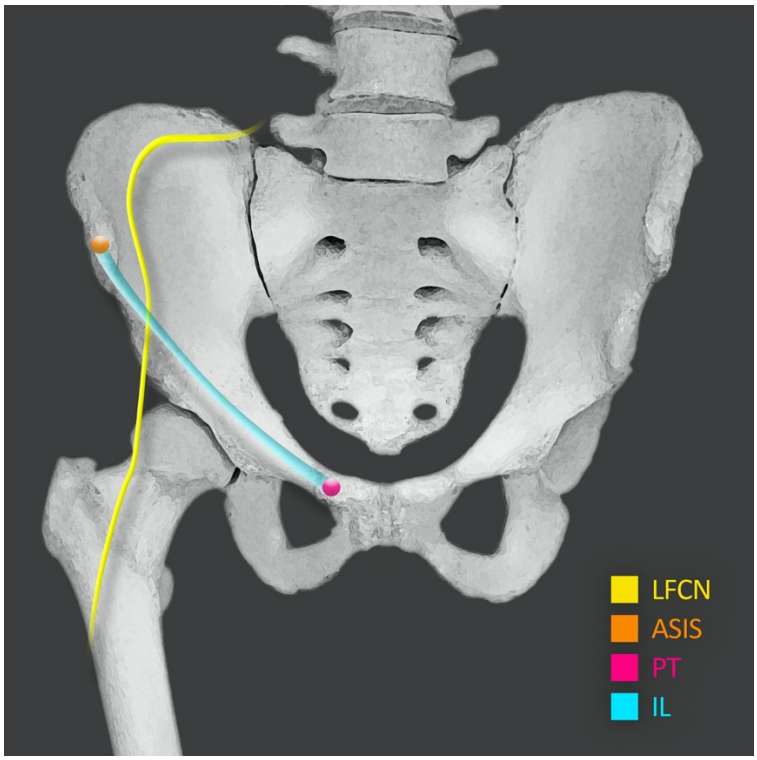
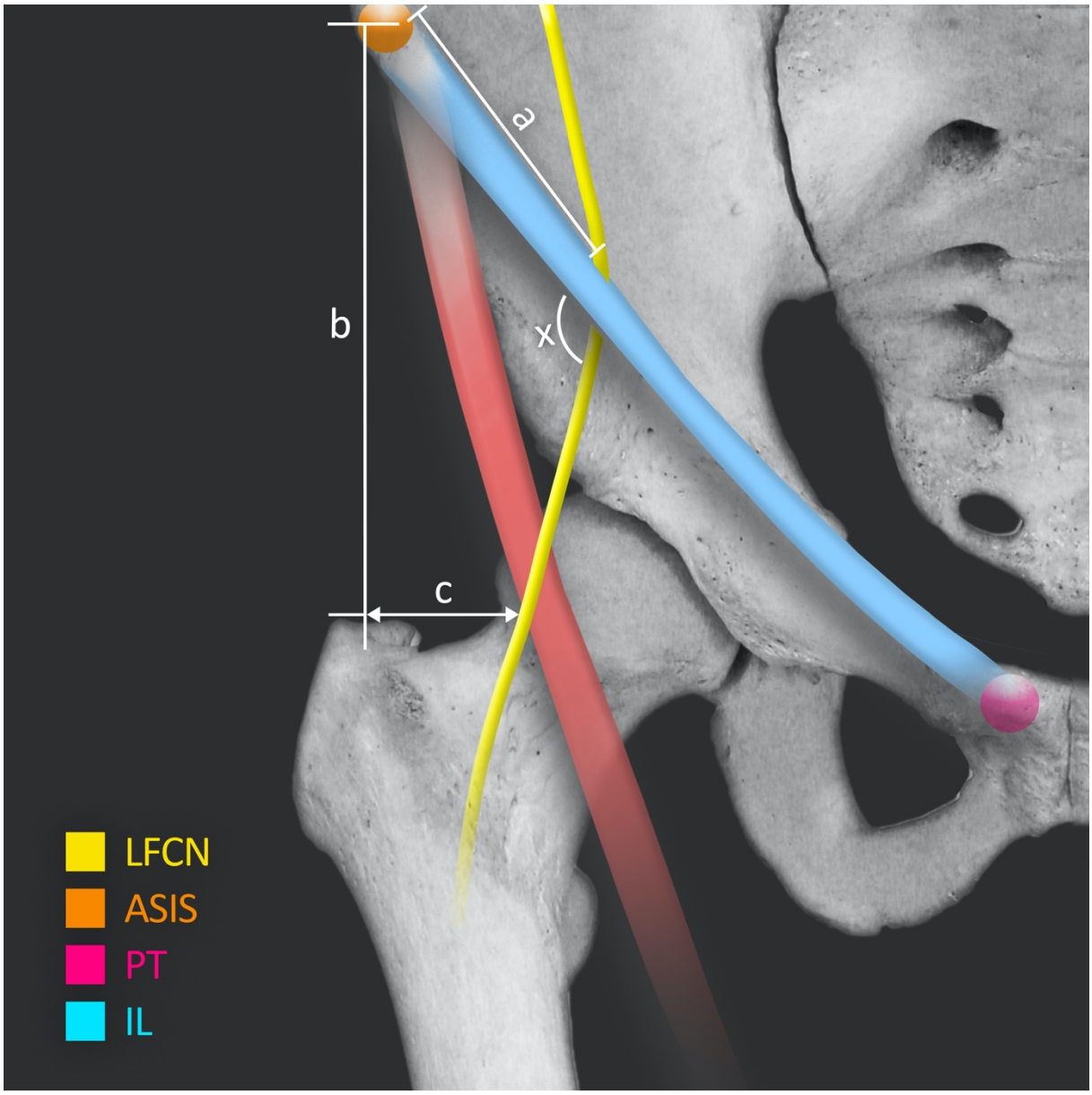


Figure 3. Relationship to other structures along the course of lateral femoral cutaneous nerve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