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Original Article

Cadaveric Study of Variations in the Course of Lateral Femoral Cutaneous Nerve: Insight to Prevent Injury

Lateral Femoral Kutanöz Sinir Seyrindeki Varyasyonların Kadavra Çalışması: Yaralanmayı Önlemeye Yönelik İçgörü

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ABSTRACT

Objective: A recent spurt in incidence of meralgia paresthetica to 0.1-81% due to minimally invasive anterior approach to hip joint has resulted in reinterest in anatomy of lateral femoral cutaneous nerve (LFCN). Familiarity with variations in the course of LFCN will reduce the morbidity associated with orthopedic procedures around the anterior superior iliac spine (ASIS) and inguinal ligament (IL).

Methods: Twenty five adult human formalin embalmed cadavers were dissected. Course and relations of nerve to ASIS, IL and sartorius muscle was noted, distance of nerve from ASIS at IL was measured and statistically analyzed.

Results: Mean distance of LFCN from ASIS at IL was 1.73±1.15 cm. Differences between two sides and sexes was statistically not significant (p=0.51 and p=0.96 respectively). Inferomedial to ASIS, 94% of LFCNs crossed IL with 92% of them present within 4 cm medial to ASIS. Majority of LFCNs (90%) exited pelvis and entered thigh posterior to IL. Out of these nerves 48% were single trunks on entry into thigh, then bifurcated into anterior and posterior branches. Remaining LFCNs bifurcated proximal to IL or at level of IL. Trifurcations were seen in 6% while a rare case of pentafication was observed. In 66% main trunk/branches were present in intermuscular cleft between sartorius muscle and tensor fascia lata.

Conclusions: Care should be exercised by surgeons while dissecting around IL as more than half of nerves are liable to be injured during operative procedures. This would help in better anticipation of problem, acceptance and reducing litigation.

Keywords: Lateral femoral cutaneous nerve, anterior superior iliac spine, inguinal ligament

ÖZ

Amaç: Kalça eklemine minimal invaziv anterior yaklaşıma bağlı olarak meraljia parestetika insidansının %0,1-81'e yükselmesi, lateral femoral kutanöz sinir (LFCN) anatomisine yeniden ilgi duyulmasına neden olmuştur. LFCN seyrindeki varyasyonların daha iyi anlaşılmasıyla, anterior superior iliak spine (ASIS) ve inguinal ligaman (IL) çevresinde uygulanan ortopedik prosedürlerle ilişkili morbidite azalacaktır.

Yöntemler: Formalinle mumyalanmış yirmi beş yetişkin insan kadavrası parçalara ayrıldı. Sinirin ASIS, IL ve sartorius kası ile seyri ve ilişkileri not edildi, IL'de sinirin ASIS'e olan mesafesi ölçüldü ve istatistiksel olarak analiz edildi.

Bulgular: IL'de LFCN'nin ASIS'e ortalama mesafesi 1,73±1,15 cm idi. İki taraf ve cinsiyetler arasındaki farklar istatistiksel olarak anlamlı değildi (sırasıyla p değeri =0,51 ve p değeri =0,96) ASIS'nin inferomedialinde, LFCN'lerin %94'ü IL'yi geçiyordu ve bunların %92'si ASIS'in 4 cm medialinde idi. LFCN'lerin çoğunluğu (%90) pelvisten çıkıyordu ve IL'nin arkasından uyluğa giriyordu. Bu sinirlerin %48'i uyluğa girişte tek gövde halindeydi ve daha sonra ön ve arka dallara ayrılıyordu. Geriye kalan LFCN'ler IL'ye yakın veya IL düzeyinde çatallanmıştı. %6 oranında trifürkasyon görülürken nadir görülen bir pentafikasyon olgusu da gözlendi. Sartorius kası ile tensör fasya lata arasındaki intermusküler yarıkta %66 ana gövde/dallar mevcuttu.

Sonuçlar: Ameliyat prosedürleri sırasında sinirlerin yarısından fazlasının yaralanması muhtemel olduğundan, IL çevresinde diseksiyon yaparken cerrahlar tarafından dikkatli olunmalıdır. Bu şekilde, sorunun daha iyi öngörülmesi, kabul edilmesi ve hukuksal davaların azaltılması sağlanabilir.

Anahtar kelimeler: Lateral femoral kutanöz sinir, anterior superior iliak spina, inguinal ligaman

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INTRODUCTION

Lateral femoral cutaneous nerve (LFCN), a sensory nerve of lumbar plexus, is formed by dorsal branches of second and third lumbar ventral rami within the substance of psoas major. It emerges from the lateral border of psoas major at or below level of iliac crest and courses obliquely across anterior surface of iliacus muscle under cover of iliac fascia. Textbooks describe it to pass beneath or through inguinal ligament (IL), a little below and about one cm medial to anterior superior iliac spine (ASIS) to emerge in the anterolateral thigh. It divides into branches -anterior branch pierces the fascia lata at about 10 cm from ASIS to supply skin of anterior and lateral thigh as far as knee while the posterior branch supplies skin on posterolateral surface from greater trochanter to about mid-thigh[1]. However, surgeons sometimes are unable to locate the nerve at the above-described textbook site. The nerve is vulnerable to damage during operative procedures leading to meralgia paraesthetica, pain, dysesthesia or hyperesthesia along its distribution resulting in mild to disabling pain[2].

The growing popularity of anterior approach to the hip joint for exposing the anterolateral aspect of acetabulum or femoral head and neck during fractures, total hip replacement or for taking biopsies, excisions and treatment of various congenital/development dysplasia in adult and pediatric population, has resulted in a spike in the incidence of meralgia paraesthetica which currently ranges from 0.1-81%[3-7]. This resulted in renewed interest in the course, branching pattern and relations of LFCN.

The aim of the study was to thus, delineate the course and branching pattern of LFCN in the thigh and especially define morphometric and descriptive relation of the nerve with reference to sartorius and ASIS.

MATERIALS and METHODS

The study was conducted on 25 adult formalin embalmed cadavers-19 male and 6 female. The anterior two-thirds and lateral aspect of the thigh was dissected. The course of the nerve/or its branches and their relation to sartorius muscle whether anterior or passing through its substance was noted and photographed. Distance of LFCN from ASIS at the level of IL (Figure 1) was measured with help of digital vernier calipers. The measurements were compared for side-to-side variation. Mean, standard deviation and range were calculated from the data.

Statistical Analysis

Distance of LFCN from ASIS at the level of IL were compared for any statistically significant difference between two sexes, as well as for variation among right and left sides in either sex, using independent sample t-test [SPSS version 29 (trial version)]. Value of $p<0.05$ was considered significant.

The cadavers used for the study were donated to Department of Anatomy, Maulana Azad Medical College, New Delhi. The study was exempt of IRB approval. All local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research were followed.

RESULTS

Distance of LFCN From the ASIS at Level of Inguinal Ligament

The mean distance of LFCN from ASIS at IL was 1.73±1.15 cm and it ranged from 6.31 cm medial to 3.71 cm lateral to ASIS. Table 1 shows the side to side and gender variations of the distance of LFCN to ASIS along the IL. In both sets, difference between the two sets was not statistically significant ($p=0.51$ and $p=0.96$ respectively).

In our cohort, 47 nerves passed infero-medial to ASIS at IL, 1 nerve was located at ASIS while 2 nerves emerged

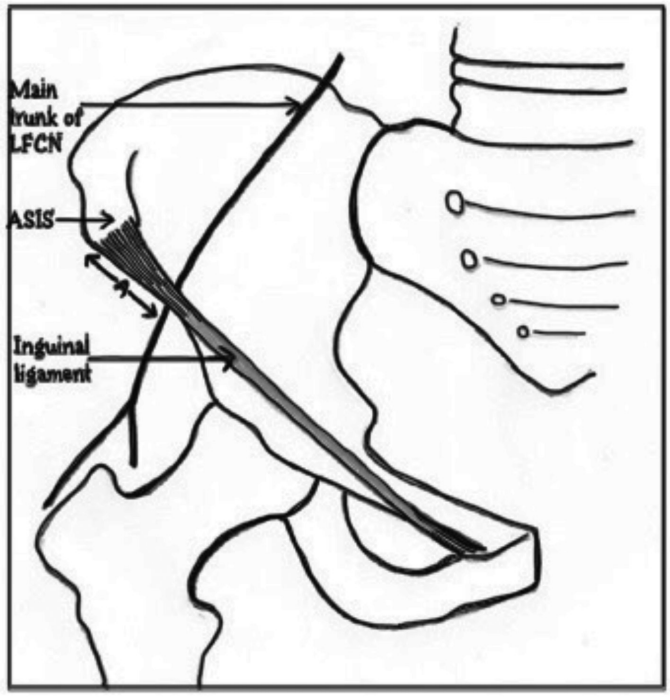

Figure 1. Schematic diagram showing the LFCN and its relationship with the adjacent structures. 'A' represents the distance of LFCN from ASIS at the inguinal ligament.

LFCN: Lateral femoral cutaneous nerve, ASIS: Anterior superior iliac spine

lateral to ASIS. Of the 47 nerves, 66% LFCNs were present within 2 cm of ASIS, 26% were located within a distance of 2-4 cm from ASIS and in 4% nerves were present beyond 4 cm from ASIS. The nerve passed beneath the IL in 45 cases (90%) while in 5 cases (10%) it passed through the IL to reach the thigh (Figure 2).

Site of Division of LFCN into Its Terminal Branches

A single trunk of LFCN terminating distal to IL in the thigh was the most common pattern observed (48%) (Figure 3A, B). In 30% the nerve was found to divide at the level of IL while 22% divided proximal to IL.

Branching Pattern of LFCN

The classical pattern of bifurcation of LFCN was observed in 46 limbs (92%). While the main site of bifurcation was distal to IL in only 48% (Figure 3A, B), in the remaining limbs there was in equal incidence of LFCNs bifurcating either proximal to IL (Figure 3C, D) and at the level of IL itself (Figure 3E, F) [11 limbs (22%) each]. However, in 3 limbs (6%) instead of bifurcating LFCN trifurcated (Figure 3G, H). Incidentally, all trifurcations were observed on left lower limbs of male cadavers. Rare pentafication, was observed at the level of IL (2%) in one female limb (Figure 3I, J).

Relation of the LFCN to Sartorius Muscle

In 66% of the limbs, LFCN entered the thigh superficial to sartorius in region of IL and then its branches coursed parallel to lateral border of sartorius. These nerves were located in intermuscular space between sartorius and tensor fascia lata muscle (TFL) (Figure 4A, B). The site of

Table 1. Showing mean distances of LFCN to ASIS along the inguinal ligament.

Gender	Side	Mean Distance (LFCN-ASIS) (in cm)	Standard deviation (in cm)	Range (in cm)
Male	Right	1.51	0.86	0-3.92
	Left	1.91	1.44	0.52-6.31
Female	Right	1.80	1.21	0.35-3.60
	Left	1.60	0.95	0.38-3.26

P-value (right and left): 0.51; p-value (male and female): 0.96. LFCN: Lateral femoral cutaneous nerve, ASIS: Anterior superior iliac spine

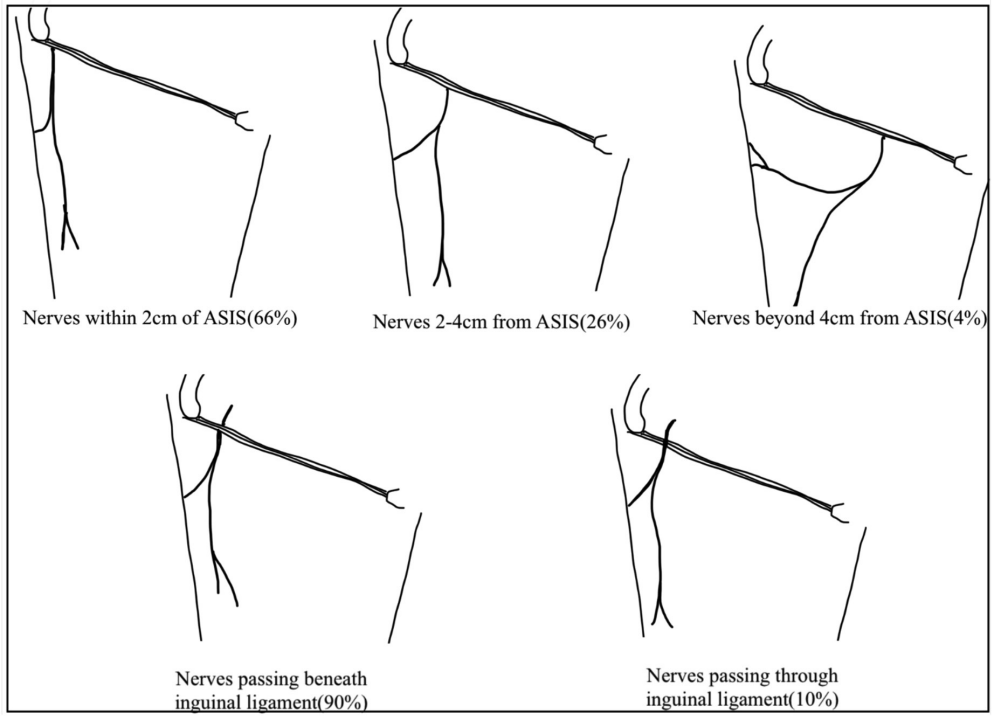

Figure 2. Schematic diagram showing LFCN and its various relations to ASIS and inguinal ligament.

LFCN: Lateral femoral cutaneous nerve, ASIS: Anterior superior iliac spine

division of the nerves into its branches varied. Meanwhile in 16 limbs the nerve and its branches were superficial to sartorius/TFL throughout its course (Figure 4C, D) and only one LFCN passed through the muscle to enter the thigh (Figure 4E, F).

DISCUSSION

The anatomy of the LFCN is especially important while performing various orthopaedic surgical procedures around the hip by the anterior approach as well as open, laparoscopic, robotic and minimally invasive procedures in the groin and upper part of the thigh. It is routinely encountered while performing inguinal lymph nodes dissection for surgical clearance of cancerous lymph nodes, hernia repairs, abdominoplasty, iliac bone harvesting, external fixation of pelvic fractures and accessing the hip joint in orthopedic procedures[8]. Although a sensory nerve, iatrogenic injury to leading to meralgia paresthetica, and in spite of good primary surgical outcome the patient may be left debilitated.

We found 94% of the LFCN crossed IL infero-medial to ASIS with 92% of them being present within 4 cm medial to ASIS. Majority of the LFCNs (90%) exited the pelvis and entered the thigh posterior to the IL.

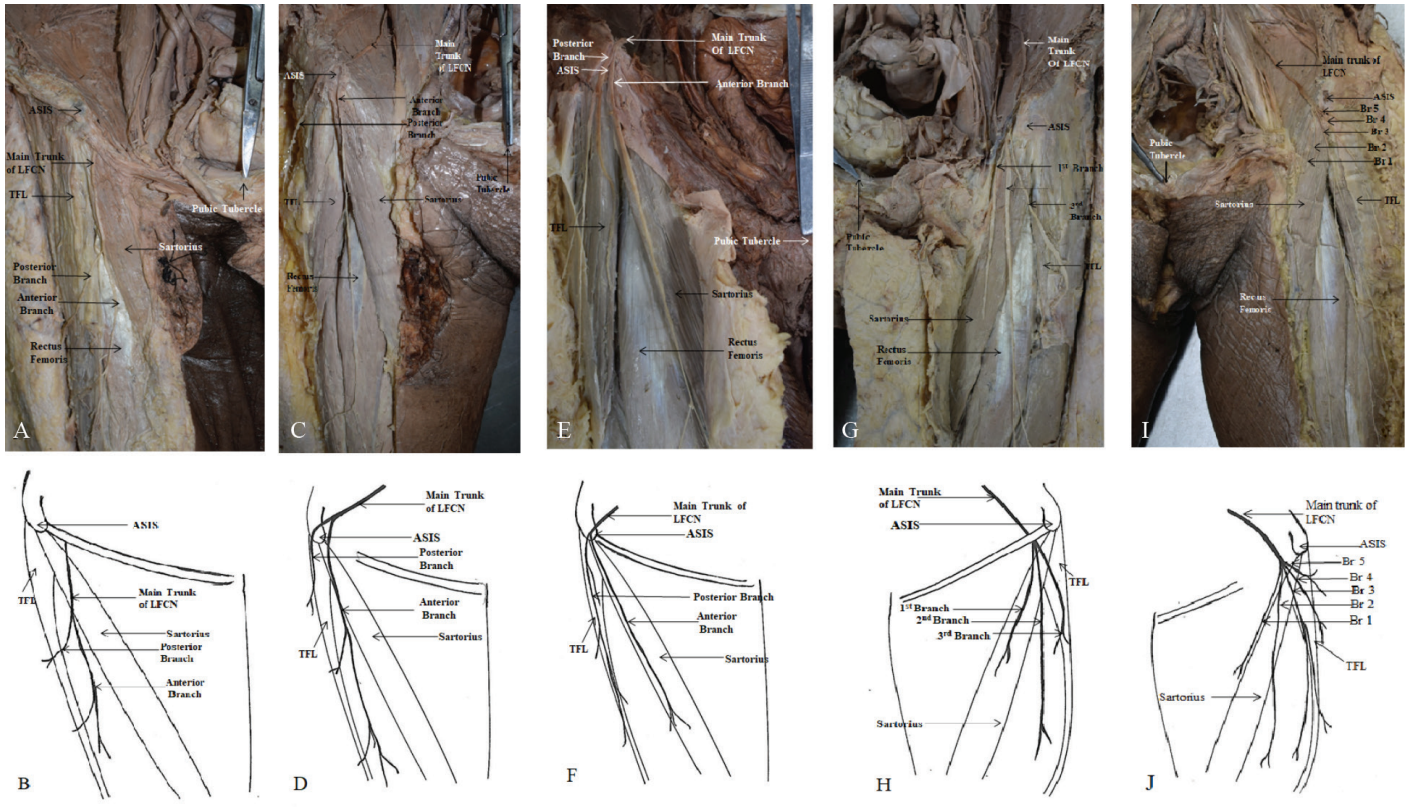

Figure 3. A. Dissected specimen of right thigh showing the main trunk of LFCN medial to ASIS, superficial to sartorius before dividing into anterior and posterior branches in the thigh (distal to inguinal ligament). **B.** Schematic diagram showing same as Figure 3A. **C.** Dissected specimen of right thigh showing the LFCN dividing proximal to the inguinal ligament, posterior branch is traversing lateral to ASIS and anterior branch is medial to ASIS, the branches then supply the usual area of distribution. **D.** Schematic diagram showing same as Figure 3C. **E.** Dissected specimen of right thigh showing the LFCN passing directly over ASIS and dividing into anterior and posterior branches. **F.** Schematic diagram showing same as Figure 3E. **G.** Dissected specimen of left thigh showing the LFCN trifurcating at the level of inguinal ligament. The 1st and 2nd branches course superficial to the sartorius to reach their usual area of distribution. The 3rd branch follows the course of the posterior branch of LFCN. **H.** Schematic diagram showing same as Figure 3G. **I.** Dissected specimen of left thigh showing the LFCN dividing into five branches at the level of inguinal ligament, the branches then fan out and course into the thigh. The 1st branch can be seen parallel to the medial border of sartorius, the 2nd branch is superficial to the muscle while the 3rd branch lies in the intermuscular space between the sartorius and TFL. The 4th and 5th branches move over the TFL and supply the area of distribution of the posterior branch. **J.** Schematic diagram showing same as Figure 3I.

LFCN: Lateral femoral cutaneous nerve, ASIS: Anterior superior iliac spine

Almost half of these nerves were a single trunk on entry into the thigh which then bifurcated into anterior and posterior branches. The remaining LFCNs either bifurcated proximal to IL or at the level of IL. In one rare instance the nerve divided into 5 branches and in 6% of the cases it trifurcated. In 66% of cases these branches were lateral to the sartorius in the intermuscular cleft between it and TFL. In one third of the limbs LFCN and its branches were present superficial to sartorius. And in one rare instance they pierced the sartorius. Only 10% of the nerves passed through the IL.

Out of every 66 patients undergoing laparoscopic inguinal hernia repair 1 patient presented with meralgia paraesthetica, which resulted in an additional surgery of either neuroma excision, neurectomy or staple removal[9]. Dibenedetto et al.[10] (1996) advocated that staples during hernia repair should not be placed within

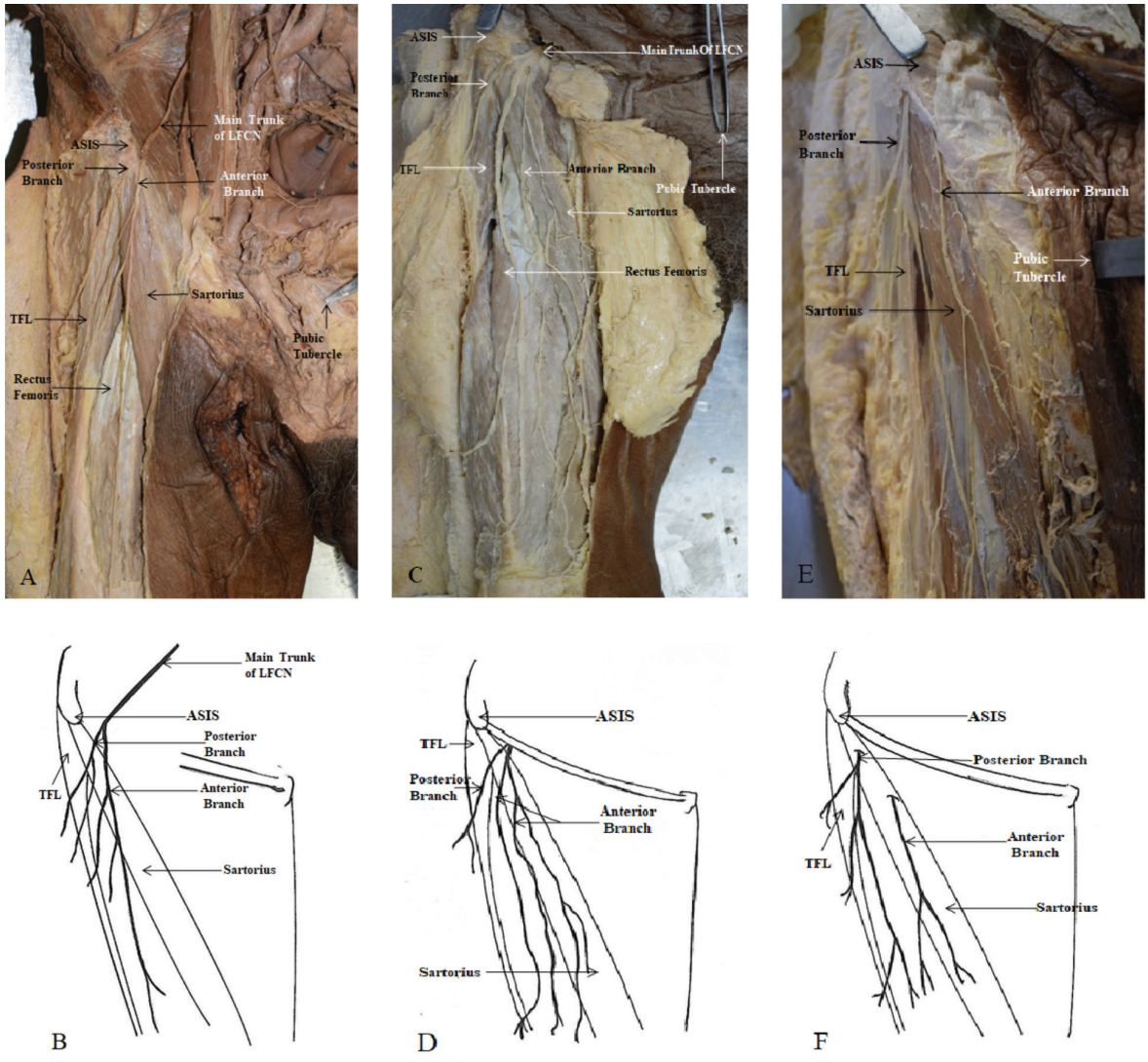

Figure 4. A. Dissected specimen of right thigh showing the LFCN bifurcating at the inguinal ligament into anterior and posterior branches, entering the thigh to supply their usual area of distribution. **B.** Schematic diagram showing same as Figure 4A. **C.** Dissected specimen of right thigh showing the LFCN bifurcating at the inguinal ligament into anterior branch and posterior branch. Anterior branch can been seen dividing into multiple branches coursing superficial to the sartorius muscle while the posterior branch turns laterally. **D.** Schematic diagram showing same as Figure 4C. **E.** Dissected specimen of right thigh showing the anterior and posterior branch of LFCN passing through the sartorius muscle, the nerves then supplied their usual area of distribution. **F.** Schematic diagram showing same as Figure 4E.

LFCN: Lateral femoral cutaneous nerve, ASIS: Anterior superior iliac spine

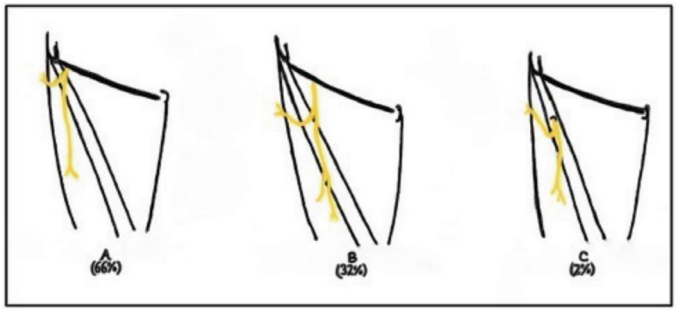

Figure 5. Schematic diagram showing the relation of the LFCN to the sartorius muscle, **A.** LFCN is superficial to the muscle near the inguinal ligament then courses parallel to its lateral border, (33/50). **B.** LFCN is superficial to the muscle (16/50), **C.** LFCN passes through the muscle (01/50).

1 cm of ASIS. We found that only 20% nerves are within 1 cm of ASIS. Roughly two - thirds of LFCNs were present beyond this safe zone distance in our cohort. The mean distance of LFCN from ASIS in our study was measured as 1.73±1.15 cm. This average distance of LFCN from ASIS was comparable to that reported by Ray et al.[11] (2010) of 1.87±0.48 cm. Tomaszewski et al.[12], (2016) keeping in mind the lack of homogeneity of the distance between ASIS and LFCN between various racial ethnic groups postulated that dangerous zone for the placement of staples be 1.9 cm. They suggested a distance of 3 cm from the ASIS should be considered as a danger zone for other surgical procedures such as abdominoplasties around ASIS irrespective of racial differences[12]. In our study 86% of LFCNs were located within 3 cm of ASIS, while 92% were located within a distance of 4 cm. Chances of injury to the nerve are greater during surgical intervention within 4 cm of ASIS as >90% of nerves were present within this distance. Chowdhry et al.[13], (2015) also proposed that minimal and careful dissection must be done 4 cm medial to ASIS during abdominoplasty to protect the proper LFCN structure and function. An ideal approach however would be to determine the precise location of LFCN using ultrasound. However, in case of lack of access to such modalities, a safe rule would be to exercise extreme care and caution while performing dissection 4 cm medial to ASIS.

While we found only one LFCN was entering the thigh at ASIS, Dias Filho et al.[14], (2003) and Rudin et al.[3], (2016) observed 44% and 11% LFCNs at ASIS respectively. When LFCN is located on surface of ASIS it may be present underneath attachment of IL leading to the nerve being sandwiched between IL anteriorly and ASIS posteriorly. Also 10% of the nerves passed through the IL predisposing them to nerve entrapment. Medially coursing LFCN however, may escape this fate due to large amount of loose connective tissue between the nerve and surrounding structures, which provides a gliding space for the nerve and decreases chances of compression considerably[15].

LFCNs exiting the pelvis at or lateral to ASIS are also at risk to compression against the underlying bone[16,17]. In our study 4% LFCNs were observed lateral to ASIS traversing iliac crest to enter the thigh certain studies, however, have not reported any such variant in their cohort[11,14,16,18-20]. Although rare, this lateral relation of the nerve to ASIS borne in mind especially during iliac crest bone graft harvesting. LFCN may be vulnerable to injury in bone graft harvesting during exposure of the crest, ligation, electrocautery or retraction through iliacus muscle or during external fixation of pelvic fracture[21]. The incidence of meralgia paraesthetica after anterior iliac bone graft harvesting has been reported as 19% with higher risk where grafts are of larger size[22].

Only 48% of LFCN, i.e., less than half, exhibited a typical textbook description of bifurcation distal to IL. This contrasts with the incidence of 54%, 62% and 86% respectively reported in literature[14,23,24]. 22% of LFCNs were found to have bifurcated proximal to IL while another 22% of LFCNs bifurcated at the level of IL. In present study, 6% of LFCNs were observed to have trifurcated at the level of IL. In South American population the incidence of trifurcations much higher (24.7%) as compared to bifurcations[12].

Patients with proximal bifurcations, including those within the pelvis and in the area of IL would be at higher risk of iatrogenic injury during surgery as there would be more branches to keep track of in the area compared to the normal anatomy[12]. Failure on part of the surgeon to identify and secure all the branches may lead to inadvertent injury[25].

Minimally invasive anterior approach to the hip joint utilizes intermuscular space between sartorius and TFL to access the joint and its components. In this soft tissue sparing approach, there is no detachment or division of any muscle and hence results in less post-operative pain, shorter hospital stay and faster functional recovery[23,26]. But this approach results in increase predisposition to injury to LFCN which may vary from 0.1-81%[5-7,27,28]. And the most probable cause of this being the variant course of LFCN and its relation to sartorius muscle[23]. In our study, we observed that most LFCNs (66%) initially passed superficially to the

sartorius muscle and after that coursed parallel to its lateral border in the intermuscular space between the sartorius and TFL. The very site where the anterior incision for the minimally invasive anterior approach surgeries is made. Even if the nerve escapes injury during incision, it is still at risk because the use of retractors in the intermuscular space can result in the stretching of the nerve as it is retracted medially towards sartorius[23]. More lateral the LFCN higher the traction force applied, greater the damage by the retractors[11]. Trifurcations, qualifications and the rare pontifications of LFCN provide more targets for accidental injury[12]. Aggressive dissection around the muscle would further predispose LFCN to entrapment in the resulting scar tissue[29]. Only 32% nerves, approximately one-third, nerves and its branches were superficial to the muscle during their entire course in the thigh as shown in (Figure 5). It is these which are relatively safe during surgery. Rudin et al.[3], (2016) classified the nerves into 3 subtypes based on the thickness and position of its branches as sartorius type with an incidence of 36%, posterior type (32%) and fan type (32%). They described the optimum site of the incision based on these nerves. Although 62% of the nerves are present in the intermuscular cleft, the authors suggest that 32% of fan like structures are definitely at risk during minimally invasive procedures. Careful retraction, a more lateral and distally placed incision, and blunt dissection are key to protect the main trunk or branches of the LFCN[3].

CONCLUSION

Our detailed anatomical study of the course of LFCN and its relation to crucial surrounding structures suggests that 66-68% of the patients undergoing surgery using anterior approach to hip are likely to experience varying degree of meralgia paraesthetica. This should serve as a guide to the surgeon in preventing injuries to the nerve at various anatomical sites, especially the groin and thigh and as a preoperative counselling point to the patient. This would help in better anticipation of the problem, acceptance and reducing litigation.

Ethics

Ethics Committee Approval: The study was exempt of IRB approval. All local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research were followed.

Informed Consent: Cadaveric study.

Peer-review: Externally and internally peer-reviewed.

Author Contributions

Surgical and Medical Practices: N.M., Concept: S.W., S.M., S.S., N.V., Design: S.W., S.M., S.S., N.V., Data Collection and/or Processing: N.M., Analysis and/or Interpretation: S.W., S.M., S.S., N.V., Literature Search: N.M., S.W., Writing: N.M., S.W., S.M., S.S., N.V.

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