What is the Risk Posed to the Lateral Femoral Cutaneous Nerve During the Use of the Anterior Portal of Supine Hip Arthroscopy and the Minimally Invasive Anterior Approach for Total Hip Arthroplasty?

Abstract

Purpose

The purpose of the study was to determine 1) What is the proximity of the lateral femoral cutaneous nerve (LFCN) to the anterior portal (AP) used in supine hip arthroscopy (SHA)? 2) What is the proximity of the LCFN to the incision in the minimally invasive anterior approach (MIAA) for total hip arthroplasty? 3) What effect does lateralizing the AP have on the likelihood of nerve injury? 4) What branching patterns are observable in the LFCN?

Methods

Forty-five hemipelves were dissected. The LFCN was identified and its path dissected. The positions of the nerve in relation to the AP and the MIAA incision were measured.

Results

The AP intersected with 38% of nerves. In the remainder, the LFCN was located 5.7 ± 4.5mm from the portal's edge. Additionally, 44% of nerves crossed the incision of the MIAA. Of those that did not, the average minimum distance from the incision was 14.4 ± 7.0mm. We found a significant reduction in risk if the AP is moved medially by 5mm or laterally by 15mm (P = .0054 & P = 0.0002). The LFCN showed considerable variation with four branching variants.

Conclusions

These results show the LFCN is at high risk during SHA and the MIAA, emphasizing the need for meticulous dissection. We suggest that relocation of the AP 5mm medially or 15mm laterally will reduce the risk to the LFCN.

Clinical Relevance

- These results provide insight into the location of the LFCN in relation to the AP and the incision of the MIAA.
- Relocation of the AP 5mm medially or 15mm laterally may significantly reduce the risk of LFCN injury.

Introduction

The growing use of minimally invasive surgical techniques combined with the widespread implementation of enhanced recovery programs has led to dramatic reductions in the length of stay for patients undergoing elective hip procedures [1–4]. These advances are exemplified by two techniques: arthroscopic hip surgery and the minimally invasive anterior approach to the hip (MIAA). Improvements in technical skills and instrumentation have advanced our ability to accurately diagnose and arthroscopically treat an increasing number of hip pathologies, with patients experiencing greatly reduced recovery time compared to traditional open procedures [2,5–8]. Hip arthroscopy can be performed with the patient in the lateral or supine positions, with the surgeon utilizing a variety of portals in order to gain access to the joint. For example, when operating with the patient in the supine position, the anterior portal (AP) penetrates the muscle bellies of Sartorius and Rectus Femoris before entering the joint capsule [9,10]. This portal is one of the three main arthroscopy portals, and is placed at the intersection of a sagittal line drawn inferiorly from the ASIS and a line drawn medially along the superior margin of the greater trochanter [11].

The MIAA involves significantly shortening and lateralizing the Smith-Petersen incision whilst continuing to utilize the intermuscular plane between Sartorius and Tensor Fascia Lata to access the hip joint [12]. The skin incision used in the MIAA begins proximally at a point 20mm lateral and 20mm distal to the Anterior-Superior Iliac Spine (ASIS), and runs distally for 100mm towards a point 20mm lateral to the head of the fibula [12]. Although similar to the Hueter approach's incision, this approach utilizes a slightly more distal incision, and the angle of incision is less oblique. This technique's small incision and soft tissue preservation means it is now considered highly effective for minimally invasive total hip arthroplasty, and its lateral position is thought to reduce the risk of nerve injury [1,12,13].

During both supine hip arthroscopy (SHA) using the AP and the MIAA, the structure often quoted as being most at risk is the lateral femoral cutaneous nerve (LFCN), with a reported incidence of injury ranging from 0.1-16.5% for SHA, and 0.2-25% for the MIAA[14–20]. Such injury can have serious consequences for a patient's recovery and quality of life, with symptoms ranging from transient neurapraxia to long term sensorineural dysfunction [20,21]. Although previous cadaveric studies into the risk during AP placement have emphasized the close proximity of the LFCN to the AP, these studies are few in number and small in size [19,22–24]. Previous cadaveric studies into this risk during the MIAA have focused on the path of this nerve in relation to bony landmarks, not the nerve's proximity to the incision at its lateralized site [25,26]. Furthermore, despite repeated documentation into the variability of the LFCN anatomy, only one study has attempted to categorize the anatomical variants and assess the impact these variants have on surgical procedures [27].

The purpose of this cadaveric study was to determine 1) What is the proximity of the LFCN to the AP used in SHA? 2) What is the proximity of the LCFN to the incision in the MIAA? 3) What effect does lateralizing the AP have on the likelihood of nerve injury? 4) What branching patterns are observable in the LFCN? We hypothesize that the LFCN will be in close proximity to the AP of SHA and will intersect with the incision line of the MIAA in the majority of cadavers, despite its more lateral site.

Methods

A total of 45 hemipelves from 39 formalin preserved cadavers (20 males and 19 females, with no lower limb or spinal abnormalities and no history of spinal or hip surgery) with a mean age of 83.9 years (range 62-100) were dissected in this study. 45 cadavers were used as this was the maximum number available for use. Though an apriori power calculation was not performed, a post-hoc power calculation showed our study to have a power of 93% (with alpha = 0.05). Use of cadavers in this study was approved by the Human Tissue Authority and all specimens were assessed prior to their inclusion in the study by JL, with no specimens excluded from this study. Midline abdominal and bilateral subcostal incisions were made and the abdominal viscera removed, allowing visualization of the psoas muscle. The LFCN was identified in the abdomen based on its position lateral to the psoas muscle and traced distally to the inguinal ligament (IL). The nerve was dissected out of the thigh to an inferior limit at the level of the patella.

To locate the site of AP placement, one length of thread was traced inferiorly from the ASIS and a second was traced medially along the line of the superior margin of the greater trochanter. A pin was placed at the intersection of these two lines to indicate the position of the AP. Two observers (JB and JL) were used for all measurements. The distance between all the LFCN's branches and the pin were measured in the transverse plane using Vernier Callipers. Additionally, the closest point the nerve travelled to the pin was marked and its distance from the pin measured. This point's distance from the pin in the sagittal (y) and transverse (x) planes was also noted, thus giving an x,y coordinate of the nerve's location relative to the portal's center. For all measurements greater than 2.5mm from the pin, 2.5mm was subtracted, thus allowing calculation of the nerve's distance from a 5mm arthroscopy portal's edge.

In order to measure the LFCN in relation to the MIAA, a length of thread was used to mark a line from a point 20mm lateral and 20mm distal to the ASIS to a point 20mm lateral to the head of the fibula (lateralized Smith-Petersen Line). A pin was placed 100mm distal to the proximal end of the thread, thus demarcating the incision used in the Minimally Invasive Anterior Approach. The following were measured using Vernier Callipers:

- If the LFCN crossed the incision line, the distance from the proximal end of the incision at which it crossed.
- If the LFCN did not cross the incision line, the minimum distance between the nerve and the incision line, and the distance along the incision at which this occurred.
- If the LFCN crossed the lateralized Smith-Petersen (LSP) line distal to the incision, the distance from the distal end of the incision line to the LFCN along the LSP line (this is the distance the incision could safely be extend without risk of nerve injury).
- The length of the inguinal ligament (IL) and the distance from the ASIS to the point at which the LFCN crosses it.
- The distance proximal or distal to the IL that the nerve first divides.

Statistical Analysis

All analyses were conducted using R version 3.2.1 (Vienna, Austria) (25). Using the position of all LFCN branches in the transverse plane, the number of nerve-AP intersections and misses were calculated for the current AP location and for AP location following lateralization and medialization by 5mm, 10mm, 15mm, 20mm, 25mm or 30mm. 2 x 2 tables were produced comparing the frequency of AP intersection and misses for the portal's current location with each of the new locations. These tables were then analyzed using Pearson's Chi-square test to assess significant differences between the current location and the new location's AP intersection frequency. The relative risk reductions of nerve-portal intersections at the new locations were also calculated. All other data are presented as mean ± standard deviation.

Results

What is the proximity of the LFCN to the AP used in SHA?

Out of the 45 nerves dissected, 17 (38%) were found to be within a 2.5mm radius of the pin placed at the site of AP, with the remaining 28 (62%) nerves passing 5.7 ± 4.5mm from the portal's edge (**figure 1**). If the nerve passed laterally to the portal, the average closest distance to the nerve in the transverse plane was found to be 5.4 ± 4.3mm. If the nerve passed medially, it was found to do so at a distance of 6.6 ± 5.1mm.

What is the proximity of the LCFN to the incision used in the MIAA?

Of the 45 nerves dissected in this study, 20 (44%) crossed the incision line used in the MIAA at a mean distance of 47.0 ± 28.0mm distal along the incision (**figure 2a**). Of the 25 nerves that did not cross the incision line, the mean minimum distance between the nerve and incision was 14.4 ± 7.0mm. This point occurred, on average, 74. ± 37.3mm along and medial to the incision. For 15 of these 25 nerves, this closest point occurred at the distal limit of the incision (100mm). 20 of these 25 nerves went on to cross the LSP line at a point distal to the incision. In these instances, the incision could have been safely extended a mean distance of 56.7 ± 46.1mm along the LSP line before coming into contact with the LFCN (**figure 2b**).

What effect does lateralizing the AP have on the likelihood of nerve injury?

Based on all LFCN branches, we found a significant reduction in risk if the portal is moved to a point 5mm medial or 15mm lateral to its current location, as only 5 and 2 nerves respectively would have been immediately below the 2.5mm radius of the insertion point (P = .0054 & P = 0.0002, relative risk reduction: 0.71 & 0.88) (**figure 3**).

What branching patterns are observable in the LFCN?

In our specimens, we observed four distinct branching patterns. Of the 45 nerves dissected, 29 (15 male and 14 female) displayed the classical branching pattern of the LFCN, giving rise to distinct femoral and gluteal branches around the level of the IL (**figure 4**). In the remaining 16 cadavers, three novel branching patterns were seen: late, primary femoral and trifurcate. In the 8 nerves (5 male and 3 female) that were described as ‘late branching’, the nerve was seen to offer two branches after passing beyond the upper thigh (**figure 5**). 6 nerves (2 male and 4 female) offered no evident gluteal branch of the LFCN and instead continued down the antero-lateral thigh. This was described as primary femoral branching (**figure 6**). In two instances (one male and one female), the LFCN gave rise to three equally sized trunks that travelled across the thigh. This was described as trifurcate branching (**figure 7**). In all the dissected hips, the LFCN was observed to be located medial to the ASIS. In 5 cases (11%) the LFCN divided before passing under the inguinal ligament (IL), in 28 (62%) cases the LFCN divided after passing below the IL and in the remaining 12 cases (27%), at the level of the IL. The average distance beyond the IL the nerve travelled before branching was 15.1 ± 23.7mm (**table 1**). When it was observed that the nerve divided before the IL, the branches travelled together under the IL in all except two cases where the nerves passed under the IL 9mm and 19mm apart respectively. In one of these instances, the LFCN appeared to be composed of two completely separate nerve trunks that originated in the abdomen and travelled separately under the IL (**figure 8**).

Discussion

We found that in over a third of cases the LFCN intersected the AP, and that the LFCN passed across the incision used in the MIAA in nearly half of cases, even with its 2cm of lateralization, thus confirming our hypotheses. Additionally, we were able to show a reduction in risk to the LFCN during SHA if the AP were moved 5mm medially or 15mm laterally, and that there were four main LFCN branching patterns identifiable in our study population.

Due to its close proximity to the AP's insertion point, the LFCN is considered to be the structure most at risk during SHA [19]. Previous smaller cadaveric studies have found the nerve to lie 3-15mm from the AP insertion point on average, with considerable variation in the path of the nerve relative to the AP [22–24]. Similarly, a study by Wastson et al examined the path of the LFCN in one hundred MRI scans and found the mean distance of the LFCN from the AP insertion point to be 6.37mm (though this study did not account for portal diameter in its measurements) [28]. These results are similar to those from our study, which found that in one third of cases the nerve was directly deep to the AP's insertion point, and, when not deep to the insertion point, was 5.7 ± 4.5mm from the portal edge. This further highlights the considerable risk to the LFCN during AP insertion and the need for meticulous dissection before portal placement. In order to aid identification of the LFCN before portal insertion, we assessed the proximity of the nerve's closest branch in the transverse plane, finding it to be on average 5.4 ± 4.3 mm lateral or 6.6 ± 5.1mm medial to the portal.

In our study, we found that the LFCN would lie in the path of the MIAA incision in nearly half of patients, even with its 2cm of lateralization. This is important as the lateralized incision site has been suggested to reduce the risk of LFCN injury [12]. Though higher than Rudin et al's suggestion that in 33% of instances injury to the LFCN is unavoidable, this difference is explained by differing definitions used in our studies [27]. In Rudin et al's work, branching pattern classification was used an indicator of 'definite' injury and not each branch's proximity to the incision used. Thus, branching patterns defined as not at definite risk may still have offered branches that intersected the MIAA's incision line [27]. Additionally, though Ropars and colleagues were able to suggest a region 27mm to 92mm distal to the ASIS where the nerve was most at risk, we found considerable variance in the distance along the incision at which the nerve crossed, meaning that a 'probable' location for intraoperative use cannot be determined [26]. Furthermore, this study did not thoroughly assess the nerve's location lateral to the ASIS. However, in cases where the nerve and incision line do not cross, the closest point between the two most commonly occurred at the distal end of the incision. The distal end of the incision therefore represents the primary area were the LFCN is at risk of blind injury through soft tissue handling and muscle retraction. Additionally, this study characterized the risk posed to the LFCN by extending the MIAA incision. Twenty of the twenty-five nerves that did not cross the incision line went on to cross the LSP line distally. However, there was large variation in the point at which the nerve crossed the LSP line and therefore a recommendation of a safe extension distance for the incision cannot be made.

Owing to the high number of AP-nerve intersects, we found a significant reduction in risk to the LFCN if the portal were moved 5mm medial or 15mm lateral to its current location. At these new locations only 5 and 2 nerves respectively were found below the portal, compared with 17 at its current position ($P = .0054$ & $P = 0.0002$; relative risk reduction: 0.71 & 0.88). These new locations offer preferable sites for portal placement as there is both a reduction in the risk to the LFCN during the initial incision, and reduced need to dissect out the LFCN trunk. These new locations are distinct from the mid-anterior portal, a portal devised to reduce the risk of LFCN injury, with the mid-anterior portal placed approximately 7cm distal and lateral to the AP. As a capsulotomy is performed immediately following insertion of the AP, these alterations to the portal location are unlikely to significantly impact the arthroscopic field of view. However, the effect this alteration may have on the work space is unclear and may result in hand-to-hand abutting.

In this study, we have found the anatomy of LFCN to be highly variable, exhibiting four distinct branching patterns - classical, late, primary femoral and trifurcate. As the late branch variants give rise to the gluteal branch distal to the level of the greater trochanter, it is highly likely to be at risk of injury during the MIAA, as the gluteal branch traverses the thigh perpendicular to the incision line. Conversely, classical branch variants are more likely to give rise to their gluteal branches proximal to the level of the incision and are thus at lower risk of damage from the incision. Trifurcate branch variants are also at high risk of injury owing to the close proximity of their 'middle' branch to the incision as it traverses the thigh. Primary femoral branch variants lack a gluteal branch and thus carry a lower risk of injury, with the nerve travelling down the anterolateral thigh, medial to the incision (**figure 7**). These branch variants are similar to those described by Rudin et al, however we found a lower frequency of 'fan-type' branching pattern, described here as trifurcate [27]. Additionally, the trifurcate branching pattern we noted consisted of fewer branches and travelled more medially than Rudin et al's 'fan-type'. They also describe the classical and late branching patterns as a 'posterior-type' of branching and do not distinguish between the distance travelled before the gluteal branch arises, meaning it is unclear how many of these branches would have been at risk. However, the 'sartorial-type' of branching pattern they describe follows the same definition as our primary femoral branching type.

Limitations

Although this study gives detailed information about the location of the LFCN and its risk of injury, the primary limitation of this study is that our data gives no indicator of injury severity, nor the impact on patients' quality of life. Though we were able to accurately quantify the risk of LFCN injury, the size of the nerve trunk intersecting with the AP, or crossing the incision line, varied greatly. Thus, some of the nerves we deemed to have been at risk may have only provided a minor contribution to the sensory innervation of the thigh and therefore injury would not lead to significant sensory impairment. Redundancy within the sensory innervation of the thigh could also reduce the impact LFCN injury has on a patient's quality of life. These facts are likely to explain the discrepancy between the high nerve-portal intersection and nerve-incision rate found in this study, and the prevalence of LFCN injuries in the literature. Additionally, during our study, the cadaver's hips were not in traction as they may be during SHA, nor were they extended as in the MIAA.

Furthermore, several factors may have altered the proximity of the LFCN to the AP and MIAA when compared to real-life. The formalin used in the embalming process may have altered the position of the LFCN by affecting the dimensions of the tissues surrounding it, thus influencing its proximity to the MIAA incision site and the AP. The age of the specimen's dissected in this study may have had an impact on the anatomy. Age-related quadriceps muscle atrophy may also have influenced the structures surrounding the LFCN, particularly when compared to the younger population undergoing THA and SHA.

Measurements taken were also undertaken following removal of the soft-tissues overlying the LFCN and may therefore have altered the relative position of the portal and incision to the nerve.

Additionally, this study only offers insight into the risk posed to the LFCN when using the AP. Another commonly used portal, the mid-anterior portal (MAP), though more distal and lateral to the AP, may also place the LFCN at risk. In this study, we chose not to assess the proximity of the LFCN to this portal as its location is based relative to the AP and the anterolateral portals, not bony landmarks, thus limiting its reproducibility.

Conclusions

These results show the LFCN is at high risk during SHA and the MIAA, emphasizing the need for meticulous dissection. We suggest that relocation of the AP 5mm medially or 15mm laterally will reduce the risk to the LFCN.

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Tables

Table 1 – The Lateral Femoral Cutaneous Nerve's Branching and Location with Regards to the Inguinal Ligament

Distance between the anterior superior iliac spine and nerve along the inguinal ligament in mm n = 47	**Nerve location medial to the anterior superior iliac spine as % distance along inguinal ligament n = 47**	**Distance beyond inguinal ligament nerve travels before branching in mm n = 44**
19.5 ± 15.07	15.1 ± 11.91	15.1 ± 23.7

Figure Legends

Figure 1. Position of LFCN's closest point in relation to an anterior portal on the right hip and diagram of AP position on a hip for orientation. A: The x-axis represents the transverse plane, negative values indicate distances laterally and positive values medially. The y-axis represents the sagittal place, positive values indicate distances superiorly and negative values inferiorly. The x,y intercept represents the center of the anterior portal and the red ring indicates the portal's position. Blue dots indicate the position of the LFCN at its closest point. It should also be noted that 15 data points are at the origin. B: The anterior portal location depicted as the intersection of two lines – a sagittal line drawn inferiorly from the anterior superior iliac spine and a transverse line drawn medially from the greater trochanter.

Figure 2. Position of LFCN in relation to incision line of the MIAA on a right hip with extension and diagram of the MIAA on a hip for orientation. A: X-axis represents the incision line. Red dots indicate points where the nerve crossed the incision line, green dots indicate position of the nerve at its closest point if it did not cross the incision line and orange dots represent points where the nerve crossed upon extension of the incision. B: The MIAA incision beginning 2cm inferior and 2cm lateral to the anterior superior iliac spine, and continue along the lateralized Smith-Petersen line for 10cm.

Figure 3. Position of all LFCN branches in the transverse plane and effect of moving portal. Red bar indicates nerve branches beneath current portal location. Blue bars indicate nerve branches beneath portal location following medial and lateral relocation. Differences between original portal location and relocalised position are all significant ($p<0.05$) unless otherwise indicated in the graph (n/s).

Figure 4. Classical LFCN Branching Pattern on left thigh. The A flag indicates the position of the ASIS. The B flag indicates the position of the nerve at the level of the inguinal ligament. The C and D flags indicate the femoral and gluteal branches of the LFCN respectively. The path of the incision used in the MIAA is represented by the red string between the E and F flags.

Figure 5. LFCN Late Branching Pattern on right thigh. The A flag indicates the position of the ASIS. The B flag indicates the position of the nerve at the level of the inguinal ligament. The C and D flags indicate the femoral and gluteal branches of the LFCN respectively. The path of the incision used in the MIAA is represented by the red string between the E and F flags.

Figure 6. LFCN Primary Femoral Branching Pattern on left thigh. The A flag indicates the position of the ASIS. The B flag indicates the position of the nerve at the level of the inguinal ligament. The C flags indicate the various femoral branches of the LFCN. The path of the incision used in the MIAA is represented by the red string between the D and E flags.

Figure 7. LFCN Trifurcate Branching Pattern on right thigh. The A flag indicates the position of the ASIS. The B flag indicates the position of the nerve at the level of the inguinal ligament. The C flags indicate the three main nerve trunks of the LFCN. The path of the incision used in the MIAA is represented by the red string between the D and E flags.

Figure 8. Novel two-trunk LFCN anatomy on left side. The LFCN was composed of two completely separate nerve trunks that originated in the abdomen and travelled separately

under the inguinal ligament. A flag indicates the position of the ASIS. The B & C flags highlight the two separate trunks as they pass beneath the inguinal ligament.