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The Anatomical Course of the Lateral Femoral Cutaneous Nerve in Relation to Various Skin Incisions Used for Primary and Revision Total Hip Arthroplasty With the Direct Anterior Approach

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ABSTRACT

Background: Although the direct anterior approach (DAA) has become a standard for primary and revision total hip arthroplasty, it involves a high risk of injuring the lateral femoral cutaneous nerve (LFCN). The aim of this study is to examine the course of the LFCN in relation to various skin incisions and approach extensions used for the DAA.

Methods: We obtained 44 limbs and hemipelves from 22 formalin-preserved cadavers, in which LFCN was identified. All nerve branches of the LFCN were carefully traced. The branching pattern and the distribution in the thigh were described in relation to the standard approach for primary total hip arthroplasty, the skin crease bikini incision, the longitudinal extension, and the lazy S extension of the DAA.

Results: We found 31 (70.5%) Sartorius-type, 6 (13.6%) posterior-type, and 7 (15.9%) fan-type branching patterns of the LFCN. We observed 2.02 branches per hemipelvis. All fan-type LFCNs had 3 or more than 3 branches. We found that the main branch of the LFCN was medial to the primary DAA approach as well as to the lazy S extended DAA approach. The bikini incision and the incision for the longitudinal extension of the DAA crosses the main branch of the LFCN in 100% of cases.

Conclusion: The fan-type pattern of the LFCN might be harmed by all skin incisions. Chances are high that LFCN branches could be jeopardized with a bikini-type incision and the longitudinal extension of the DAA. The risk of jeopardizing the LFCN with a lazy S-type distal extension is reduced.

The Smith-Petersen interval or Hueter approach was originally described for the treatment of pediatric orthopedic surgery for developmental hip dysplasia or septic arthritis [1–4]. The direct anterior approach (DAA), an adaption of the Smith-Petersen approach, has become a standard approach in primary total hip arthroplasty (THA) during the last decade [5,6]. Moreover, the DAA interval has recently been used for revision THA [7] as well as for surgery for femoroacetabular impingement [8,9]. Some authors postulate that the DAA is also an internervous approach, as all muscles medial to the portal are supplied by the femoral nerve and all lateral muscles by the superior gluteal nerve [5,7].

Nerve palsy following THA is a devastating complication exerting a severe impact on the patient's life. In general, sciatic nerve palsy is reported to be the most common nerve injury after THA [10]. The lateral femoral cutaneous nerve (LFCN) is a purely sensory nerve arising from the second or third vertebral nerve roots and supplies the skin on the anterolateral aspect of the thigh [11]. The LFCN may be injured when using the DAA, with the reported incidence varying from 0.1% to 81% [11–14]. Moreover, the risk of any LFCN injury is even higher in revision cases than in primary

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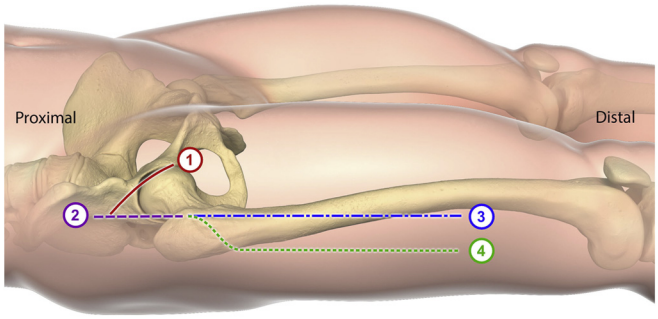

Fig. 1. Relationship between the 4 different skin incisions for DAA approaches and the hip joint and the femur: (1) skin crease bikini incision; (2) longitudinal skin incision; (3) longitudinal extension; and (4) lazy S extension (right limb). DAA, direct anterior approach.

cases, especially when a distal extension of the DAA interval is needed to approach the femoral diaphysis [15]. In such cases, nearly 100% of patients display some kind of numbness of the lateral thigh [8]. Besides this numbness, which is not a major neurological complication, patients with LFCN injury may also suffer from a burning sensation in the anterolateral region of the thigh, which can be a cause of severe pain.

Only one study has investigated the distribution and variation in the course of the LFCN in the proximal aspect of the thigh in relation to the primary DAA interval [16]. We investigated the LFCN course in relation to extended DAA intervals in case of revision surgery or difficult primary THAs. The aim of this study is to describe the course of the LFCN in the thigh with 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 the DAA (Fig. 1).

Materials

Our investigation included 44 hemipelves and thighs from 22 formalin-preserved full-body cadavers. All body donors gave informed consent. With regard to gender, 11 were females and 11 males. Mean age at death was 75.2 (range 44-92) years. Average body height was 170 cm (range 153-182) and mean body mass index was 24.8 (range 21.1-28). None of the cadavers showed clinical evidence or had any evidence of trauma or surgery in their medical reports within the area of interest. The following study and dissection protocol were applied. First, the skin incision of the primary longitudinal DAA, a bikini incision, as well as 2 possible skin incisions for distal extension of the longitudinal approach was marked on the skin with a pen by a consultant arthroplasty surgeon.

An 8-cm skin crease bikini incision was made at the patient's inguinal fold approximately two-thirds lateral and one-third medial to the anterior superior iliac spine (ASIS) [17]. We simulated an 8-cm skin incision starting 2-cm lateral and 2-cm distal to the ASIS, as the longitudinal skin incision is used for primary DAA. For the study, 2 distal extensions of the DAA were analyzed. The first extension was a longitudinal extension [18] at the level of the primary DAA approach [18]. The second extension was the so-called lazy S extension to access the entire femoral diaphysis without endangering the nerve supply [15]. For the lazy S skin incision, the incision was curved to posterior at the end of the primary incision at the level of the greater trochanter (GT) and then extended to distal. All simulated skin incisions are shown in Figure 1. The length of all simulated skin incisions was measured.

As a next step, the skin of the cadaver was removed in order to localize the branches of the LFCN. All nerve branches of the LFCN were carefully traced distally in the subcutaneous tissue of the thigh. The branching pattern and the distribution of the LFCN within the thigh were described and measured (cm) with respect to 5 landmarks: the ASIS, the medial border of the tensor fasciae latae (TFL), the GT, a reference point lateral (RPL), and a reference point anterior (RPA). The RPL is located between the GT and the lateral condyle (LC) (half distance between GT and LC). The RPA is located distal to the ASIS (parallel to the line from the GT to the LC) at the level of the RPL (perpendicular to the line between GT and LC at the level of the RPA) (Fig. 2).

We also classified the branching pattern of the LFCN according to Rudin et al [16] as Sartorius-type, posterior-type, or fan-type (Table 1). Moreover, we defined the thickest branch of the LFCN as the main branch and calculated the distance between the main branch in relation to the primary DAA approaches and the extended approaches used for revision THA.

As the data were not normally distributed (Shapiro-Wilk test), the median and interquartile range were calculated.

Results

A large number and variability of branches of the LFCN were found. In the proximal aspect of the thigh, distal to the ASIS, a weak

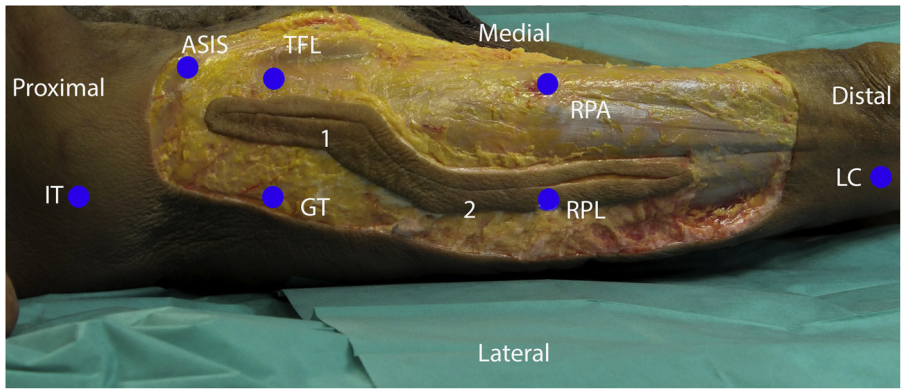

Fig. 2. Landmarks of the hemipelves and the thigh that served as reference markers for measuring distances to the LFCN: (1) longitudinal skin incision (primary DAA) and (2) lazy S extension (revision DAA). LFCN, lateral femoral cutaneous nerve; DAA, direct anterior approach; ASIS, anterior superior iliac spine; GT, greater trochanter; LC, lateral condyle; IT, iliac tubercle; RPA, reference point anterior; RPL, reference point lateral; TFL, tensor fasciae latae (right limb).

Table 1
LFCN Classification According to Rudin et al.

Classification	Type	Branch Pattern
I	Sartorius	Dominant anterior branch on the lateral border of the Sartorius muscle and further branches in the anterior aspect of the thigh
II	Posterior	Strong posterior branch equal in thickness to, or thicker than, the anterior branch. It runs laterally and crosses the medial border of the TFL muscle distal to the ASIS
III	Fan	Multiple nerve branches of equal thickness on the anterolateral region of the proximal aspect of the thigh, crossing over the TFL and the lateral border of the Sartorius

LFCN, lateral femoral cutaneous nerve; TFL, tensor fasciae latae; ASIS, anterior superior iliac spine.

fascia consistently divided the subcutaneous fat tissue into a superficial and a deep layer, and the branches of the LFCN regularly ran within the deep layer. According to the Rudin classification regarding branching pattern of the LFCN, we found 31 (70.5%) Sartorius-type (Fig. 3), 6 (13.6%) posterior-type (Fig. 4), and 7 (15.9%) fan-type (Fig. 5) branching patterns [16]. We found that the LFCN pattern was similar on both sides of the pelvis in 12 of 22 cadavers.

Moreover, we observed 89 branches in 44 hemipelves and limbs (2.02 branches per hemipelvis). In relation to the ASIS, 16 (36.3%) of the 44 LFCN branches entered the proximal aspect of the thigh medial to the ASIS, 19 (43.2%) entered distal to the ASIS, and 9 (20.5%) entered lateral to the ASIS. Of the 89 branches observed, we found in 15 limbs only 1 branch of the LFCN, in 18 specimens 2 branches per limb could be traced, in 6 specimens 3 branches per limb were detected, and in 5 cadavers 4 branches per limb of the LFCN were detected. All fan-type LFCNs had 3 or more branches per hemipelvis. We found that the median values of the main branch of the LFCN were medial to the primary DAA approach as well as to the extended DAA approach for revision (Fig. 6). The median distances to the LFCN branches are shown in Table 2. The vector of median values for the main branch of the LFCN in relation to the skin incisions is shown in Figure 6. The median values of the main branch of the LFCN were medial to the standard longitudinal approach for primary THA, and the lazy S extension of the DAA. The skin crease bikini incision and the longitudinal extension of the DAA crossed the main branch in 100% of our cases.

Discussion

The skin incision of the original Hueter or Smith-Petersen approach [19] starts proximal to or at the level of the ASIS, crosses the ASIS, and runs distal at the level of the ASIS. The proximal extension of this approach provides visualization of the entire ilium and hip joint. Although extending to distal it is limited by branches of the femoral nerve running into the vastus lateralis muscle. For iliac osteotomies, part of the muscle from the ilium as well as the TFL muscle can be released to enable a full view on the hip joint. This technique is a standard one for pelvic osteotomies for all age groups. The most frequent complication after a periacetabular osteotomy is dysesthesia of the LFCN with an incidence of 30% [20]. Dysesthesias of the LFCN were also observed frequently for the classic Smith-Petersen approach [2,21]. In pediatric orthopedic surgery, this complication is regarded as minor in the literature and given little attention as an outcome parameter despite its frequent occurrence.

The Hueter or Smith-Petersen approach to the hip has been used by Judet and Judet since 1947 for hip joint exposure for arthroplasty technique [22,23]. For the so-called modified Smith-Petersen approach used for primary THA, the skin incision was moved more to lateral and distal of the ASIS in order to avoid injuries to the LFCN. The start of the skin incision varies from 1 cm lateral and distal to the ASIS [24] to 3 cm lateral as well as distal to the ASIS [25]. Most authors concur on a skin incision 2 cm lateral to the ASIS [6]. These modifications were done in order to not jeopardize the LFCN for primary THA. Recently, in addition to the classic longitudinal incision for DAA, a modified oblique skin crease bikini incision was described for THA with the DAA [26]. The reported incidence of injury of the LFCN after the anterior approaches including the bikini incision ranges from 0.1% to 81% [11–14]. However, few anatomical data have been published regarding the exact course of the LFCN. The rare anatomical data include reports with 28 [16] to 34 [27] hemipelves, which were outnumbered by the hemipelves used in our study (n = 44). Another report demonstrated the branch pattern of the LFCN in relation to the primary DAA approach in 64 thighs from formalin-preserved cadavers of 45 Japanese individuals [28]. This report describes the relationship between the LFCN and an estimated longitudinal primary skin incision, which ran along the midline of TFL, 3 cm proximal to the tip of GT and 9 cm distal to the trochanter (12 cm in total) [28]. However, due to most published clinical data and our clinical experience, a skin incision for the DAA 3 cm proximal to the tip of GT and 9 cm distal to the trochanter is very uncommon for THA [5,6,9,12–14,25]. Surgical exposure of the acetabulum might be difficult proximally and the distal length of the incision is rather used for revision THA [7,8,15,18,29].

In recent years, the DAA interval has been used for all kinds of revision THA as well, including the treatment of periprosthetic fractures [8], septic 2-stage revisions [29], femoral revisions [29], and the implantation of acetabular reconstruction cages [7]. Two

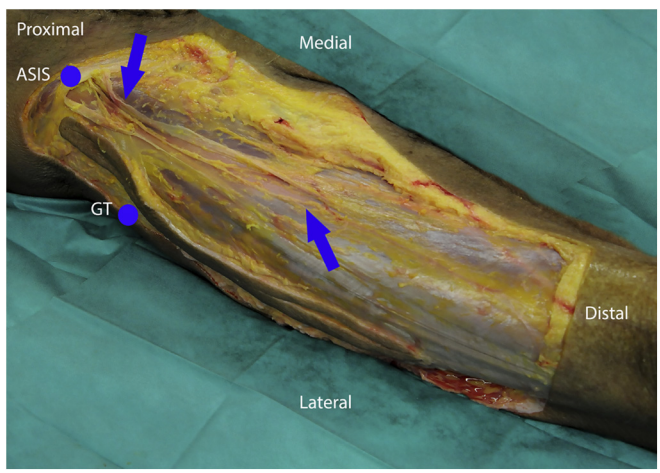

Fig. 3. Sartorius-type LFCN pattern. Blue arrows indicate the branches of the LFCN. LFCN, lateral femoral cutaneous nerve; ASIS, anterior superior iliac spine; GT, greater trochanter (right limb).

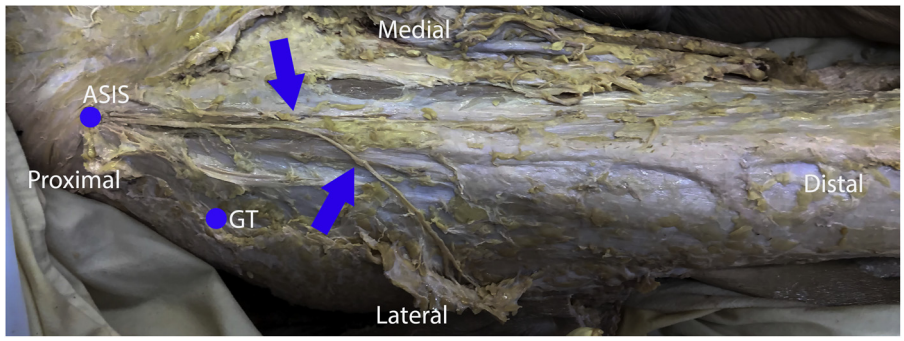

Fig. 4. Posterior-type LFCN pattern. Blue arrows indicate the branches of the LFCN. LFCN, lateral femoral cutaneous nerve; ASIS, anterior superior iliac spine; GT, greater trochanter (right limb).

possible extensions of the longitudinal DAA approach have been described: longitudinal extension at the level of the primary skin incision and the lazy S extension. The authors of the mentioned studies reported that if the DAA is extended to distal, 1 or 2 branches of the LFCN must be cut. They observed that all patients in their cohort felt some degree of numbness on the lateral aspect of the operated thigh. However, none of their patients experienced meralgia paresthetica following revision surgery [8] and their conclusion was not supported by objective data.

Therefore, the present study investigated the course and patterns of the LFCN in relation to 4 skin incisions used for primary as well as revision DAA. We found that the type of primary incision (longitudinal or bikini incision) and the extension of the approach for revision (longitudinal extension or lazy S) influence the potential risk for LFCN injury. In addition, the distribution pattern and the number of branches of the LFCN are a potential risk for nerve lesions.

In contrast to published reports with smaller cadaver numbers, we showed a Sartorius-type branch pattern (70.5%) of the LFCN in the majority of cases, while a posterior-type and a fan-type were detected in 13.6% and 15.9% of cases, respectively. Although the main branch of the LFCN ran medial to the approach (Fig. 6), limbs with a fan-type pattern of the LFCN (15.9%; Fig. 5) have a high chance of being jeopardized by either of the primary DAA approaches (longitudinal and bikini) as well as either of the extended DAA approaches (longitudinal extension and lazy S extension). We found that proximal extension of the DAA should be performed subcutaneously to the level of the ASIS in order not to injure LFCN branches in a posterior-type pattern of the LFCN (13.6%). As compared to data previously published by Rudin et al [16] (32%: fan-type pattern; 32%: posterior-type pattern), the incidence of the fan-type and the posterior-type of the LFCN branching pattern in our study was significantly smaller. Sugano et al [28] simplified Rudin's classification system. In Sugano's publication, unpublished preliminary study results were mentioned, showing difficulties to apply the classifications system published by Rudin et al. However, Sugano did not justify this statement with any data. Sugano combined the fan-type and the Sartorius-type into an anterior type, which was characterized by a thicker anterior branch of the LFCN, and a posterior type, which was characterized by posterior branches thicker than or equal to the thickness of the anterior branch of the LFCN. Sugano showed that none (0%) of the anterior branches of the LFCN crossed over the primary longitudinal skin incision, indicating that all anterior types were safe, and 68% of the posterior type LFCN crossed the skin incision. In total, Sugano concluded that 27 of 64 thighs (42%) were at risk for an injury of the LFCN during DAA in THA. In contrast to Sugano we had no difficulties applying Rudin's classification system

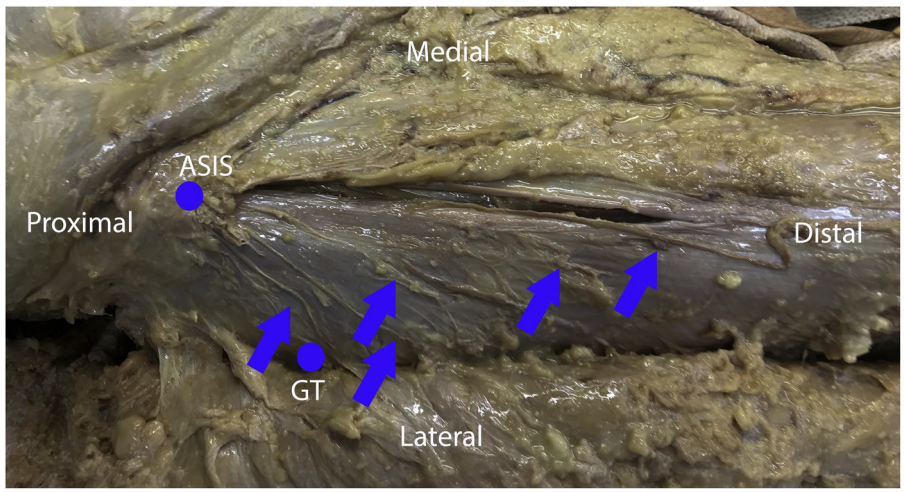

Fig. 5. Fan-type LFCN pattern. Blue arrows indicate the branches of the LFCN. LFCN, lateral femoral cutaneous nerve; ASIS, anterior superior iliac spine; GT, greater trochanter (right limb).

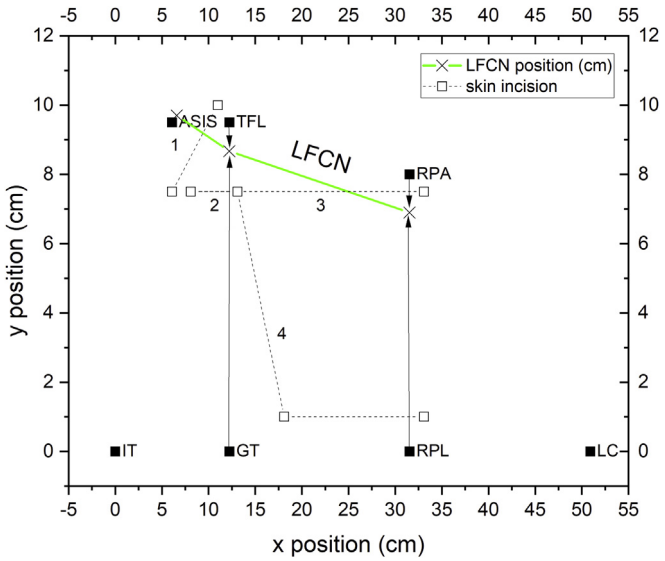

Fig. 6. Median course of the main branch of the LFCN in relation to ASIS. LFCN, lateral femoral cutaneous nerve; ASIS, anterior superior iliac spine; GT, greater trochanter; LC, lateral condyle; IT, iliac tubercle; RPA, reference point anterior; RPL, reference point lateral; TFL, tensor fasciae latae and the 4 skin incisions: (1) skin crease bikini incision; (2) longitudinal skin incision; (3) longitudinal extension; and (4) lazy S extension (right limb).

and were able to distinguish the fan-type from the Sartorius-type and we could also identify the fan-type. Therefore, we compared our results to Rudin's classification system. We observed that irrespective of the LFCN pattern, injury to some branches of the LFCN cannot be avoided with the bikini incision, even with the most careful preparation in the subcutaneous tissue. We also found that in majority of cadavers (n = 12), the LFCN pattern was similar on both sides of the pelvis.

Table 2
Median Distances to LFCN Branches.

Reference Point	Median Distance
RPL	6.5 cm (min: 2 cm; max: 12.5 cm)
RPA	−1 cm (min: −2 cm; max: +4 cm)
GT	8.75 cm (min: 0 cm; max:13 cm)
TFL	1 cm (min: 0 cm; max: 1.5 cm)

RPL, reference point lateral; RPA, reference point anterior; GT, greater trochanter; TFL, tensor fasciae latae; −, medial to RPA; +, lateral to RPA; min, minimum; max, maximum.

We found 2 or more than 2 branches of the LFCN in 65.9% of all specimens. Rudin et al [16] found 2 or more than 2 branches in only 50% of dissected limbs. However, she did not find more than 4 branches in her cadaver cohort. As in other studies [30,31], we observed 3 and 4 LFCN branches in 25% of our specimens. Hence, we concluded that there is a higher risk of harming branches of the LFCN in both primary as well as both extended DAA approaches if the LFCN has more than 4 branches.

Furthermore, we found that the most prominent branch of the LFCN runs medial to the longitudinal skin incision used for primary THA as well as for the lazy S distal extension of the approach (Fig. 5). However, the longitudinal extension crosses the main branch of the LFCN in 100% of cases and, therefore, injury to the LFCN cannot be avoided (Fig. 7).

Although injury to the LFCN does not pose a major neurological complication or cause functional limitations, patients may report numbness or a burning sensation in the anterolateral region of the thigh and, in the worst cases, dysesthesia or meralgia. The most commonly experienced clinical neuropathic symptom following direct anterior THA is "numbness," which occurs in 15%-37% [32,33] of cases. Neuropathic symptoms after DAA THA steadily improve over time without functional limitations, and by 8 years [32,33] the prevalence of symptoms is significantly reduced to nearly 10% [32,33].

Our study has several limitations. First, we did not investigate the divisions of the LFCN superior to the inguinal ligament. However, we focused on the lateral aspect of the thigh, where surgery for primary and revision THA is performed. Second, we conducted an anatomical study and attempted to transfer our results to a clinical setting. However, anatomy is the basic principle of surgical skills. DAA for primary as well as revision arthroplasty has become a standard approach for THA. Therefore, surgeons should be aware of the limitations of the approach and the potential risks associated with it. In addition, prior to surgery patients should be informed about the risk for LFCN injury. Third, Sugano et al concluded that the classification by Rudin et al could not be applied in their cadavers to classify the pattern of branching. Like any other classification system, the Rudin classification system has its limitations and further studies should evaluate the intraobserver and interobserver reliability of this classifications system. Hence, this might be one reason for the differences in distribution of pattern in published reports.

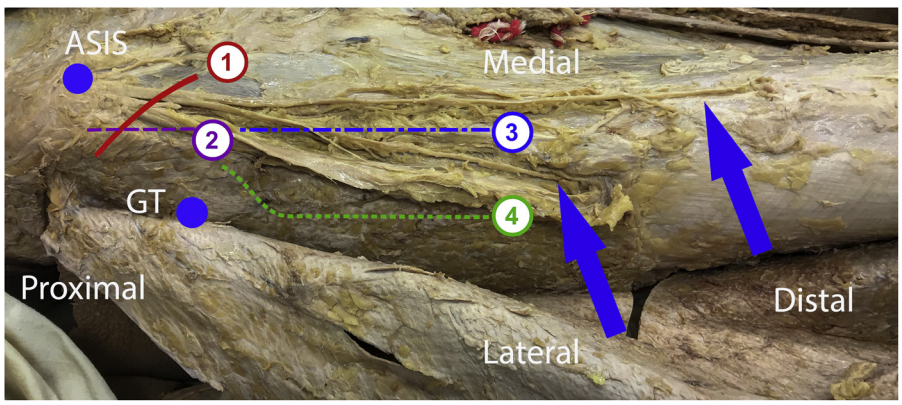

Fig. 7. Sartorius-type LFCN pattern that crosses the longitudinal extension of the LFCN. Skin incision for the DAA approaches: (1) skin crease bikini incision; (2) longitudinal skin incision; (3) longitudinal extension; and (4) lazy S extension. Blue arrows indicate the branches of the LFCN. LFCN, lateral femoral cutaneous nerve; DAA, direct anterior approach; ASIS, anterior superior iliac spine; GT, greater trochanter (right limb).

Conclusion

Fan-type LFCN patterns occurring in 15.9% of cases might be harmed by the 2 primary as well as the 2 extended approaches. There is a high chance of jeopardizing the LFCN with a bikini-type incision. Longitudinal extension of the DAA entails a high risk of harming the main branch of the LFCN. There is a reduced risk of jeopardizing the LFCN with a lazy S-type distal extension of the DAA. We are not suggesting that the bikini incision or the longitudinal extension for the DAA should be abandoned. However, surgeons should exercise caution when adopting surgical techniques without knowing the anatomical basics and the potential risks of different skin incisions for the DAA.

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