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A nerve-to-implant distance as a novel predictor for lateral femoral cutaneous nerve injuries after anterior subcutaneous pelvic internal fixation

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ABSTRACT

Although anterior subcutaneous pelvic internal fixation is a valuable tool for the reduction and fixation of unstable pelvic ring injuries, lateral femoral cutaneous nerve irritation by the implant is the most common complication. This study aimed to investigate the association between the nerve-to-implant distance and the postoperative lateral femoral cutaneous nerve symptom. Patients who underwent anterior subcutaneous pelvic internal fixation between 2016 and 2019 were retrospectively analyzed. Lateral femoral cutaneous nerve status was defined as follows: not identified, nerve-to-implant distance <13 mm, and ≥13 mm. The proportion of patients who experienced postoperative nerve disorders was compared using the nerve status. Nerve-to-implant distances were compared using the presence or absence of postoperative lateral femoral cutaneous nerve disorders. The predictive value of a nerve-to-implant distance of 13 mm for postoperative nerve disorders was assessed. Overall, 26 lateral femoral cutaneous nerves were included. Ten patients had postoperative nerve disorders, of which seven had an nerve-to-implant distance <13 mm, while the other three occurred in patients whose nerves were not identified. A nerve-to-implant distance ≥13 mm was significantly associated with a decreased risk of postoperative nerve disorder compared to a nerve -to-implant distance <13 mm ($p = 0.017$). A nerve-to-implant distance ≥13 mm had a perfect sensitivity (100%) and modest specificity (58.3%). Nerve-to-implant distance was ≥13 mm. Nerve disorders were frequently observed when the nerve-to-implant distance was <13 mm or the nerve was not identified intraoperatively. Efforts to identify the lateral femoral cutaneous nerve may be useful to avoid internal fixation-related nerve disorders.

Keywords: lateral femoral cutaneous nerve, anterior subcutaneous pelvic internal fixation, irritation, pelvic fracture

Abbreviations:
ASPIF: anterior subcutaneous pelvic internal fixation
BMI: body mass index
LFCN: lateral femoral cutaneous nerve

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INTRODUCTION

Anterior external fixation is commonly used for initial stabilization and definitive treatment of pelvic fractures. Complications such as pin tract infections, osteomyelitis, loosening, loss of reduction, and difficulty in mobilizing or sitting upright have been reported.[1-3] To avoid these complications associated with external fixators of the anterior pelvis, anterior subcutaneous pelvic internal fixation (ASPIF) was developed.[3,4] The indications for anterior fixation with ASPIF include AO Foundation/Orthopaedic Trauma Association (AO/OTA) classification 61-B and 61-C fractures in conjunction with posterior fixation. ASPIF is superior to anterior external fixation in terms of strength, incidence of infection, patient comfort, and the risk of failure of treatment, despite the secondary operation (removal of implants) for ASPIF.[4]

While ASPIF is a valuable tool for reduction and fixation in patients with unstable pelvic ring injuries, irritation of the lateral femoral cutaneous nerve (LFCN) is one of the most common complications following ASPIF.[4,5] Vaidya et al reported that 30% of patients experienced irritation of the LFCN after ASPIF.[3] The edge of the pedicular screw or rod may irritate or compress the LFCN during the manipulation and/or insertion of the rod.[6] The LFCN is a pure sensory nerve that is responsible for cutaneous sensation over the anterolateral thigh. LFCN disorders can result in hypesthesia, pain, or dysesthesia on the anterolateral aspect of the thigh, reportedly causing a reduction in patients' quality of life (QOL).[7]

Although the LFCN-to-implant distance can be a marker that is associated with postoperative LFCN injuries, there were few reports regarding the LFCN-to-implant distance. Apivatthakakul et al reported that the average LFCN-to-implant distance was 13.5 ± 1.7 mm (95% confidence interval [CI] 12.871–14.103) from the lateral end of the rod.[6] Reichel et al also reported that the average LFCN-to-implant distance was 2 cm (95% CI 0.0–0.4). The nerve was adjacent to the screws in most of the cases (10 of 11 cases).[8] However, their measurement of the LFCN-to-implant distance may be underestimated due to the absence of tissue turgor and deflation of blood vessels in their cadaver specimens. Additionally, their cadaver studies did not answer the question regarding the association between the LFCN-to-implant distance and postoperative symptoms related to LFCN injury.

Therefore, this study aimed to investigate the utility of an LFCN-to-implant distance of 13 mm, predict postoperative LFCN disorders, and examine the best cut-off point for the LFCN-to-implant distance using our cohort.

MATERIALS AND METHODS

Patient characteristics

This study was conducted at a tertiary medical center for trauma that covers a population of approximately 374,000 individuals in Japan after obtaining institutional review board approval. Informed consent was obtained from all individual participants included in the study. We retrospectively reviewed the data on 14 patients who underwent ASPIF between April 2016 and November 2019 after a pelvic ring fracture. The inclusion criterion consisted of an unstable pelvic fracture that required stabilization by means of ASPIF, with a follow-up period of at least 6 months postoperatively. We excluded patients based on the following criteria: hemodynamically unstable patients, patients with soft tissue defects that prevented the coverage of the ASPIF,

and patients with fractures through the insertion points of the supraacetabular screws. We also excluded patients with missing baseline characteristics and those with an insufficient follow-up period (<6 months). All data were obtained from the medical records of the municipal hospital. The baseline patient characteristics of this study included age, sex, height (meter), weight (kilogram), and body mass index (BMI). BMI was calculated as follows: a person's weight in kilograms divided by the square of their height in meters. Obesity in this study was defined[9,10] as a BMI of >25 kg/m^2.

Ethical statement

All procedures performed in this study, involving human participants, were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The patients were informed that data from the research would be submitted for publication and gave their consent.

Assessment of pelvic fractures

All patients underwent a preoperative assessment of the anteroposterior pelvis using inlet and outlet radiographs and pelvic computed tomography (CT) scans. Radiographs and CT scans were assessed by at least two experienced orthopedic surgeons. They were classified according to the Young and Burgess classification and the AO/OTA classification of pelvic fractures.[11,12]

Surgical techniques

ASPIF consisted of custom polyaxial pedicle screws used in spinal operations and a connecting rod. The ASPIF operative technique was almost identical to the one previously described.[13,14] Briefly, we inserted the device through two supraacetabular incisions that were approximately 5 cm long. The screws were 7.5–8.5 mm in diameter and 70–100 mm in length depending on the size of the patient, and they were placed bilaterally into the supraacetabular osseous canal at the level of the anterior inferior iliac spine. The two screws were connected by a rod that was inserted subcutaneously anterior to the symphysis. The rod was pre-bent before being placed through the screw heads and was fixed with its curvature in the plane of the screw shafts (Fig. 1). We inserted the pedicular screw carefully and left some space between the pedicular screw

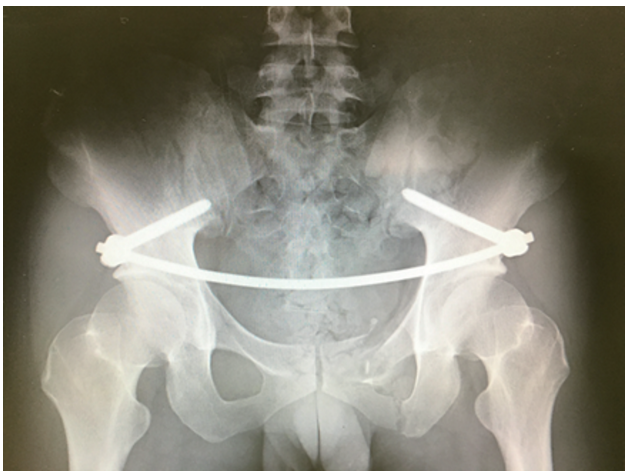

Fig. 1 X-ray of the anterior subcutaneous pelvic internal fixation (ASPIF)

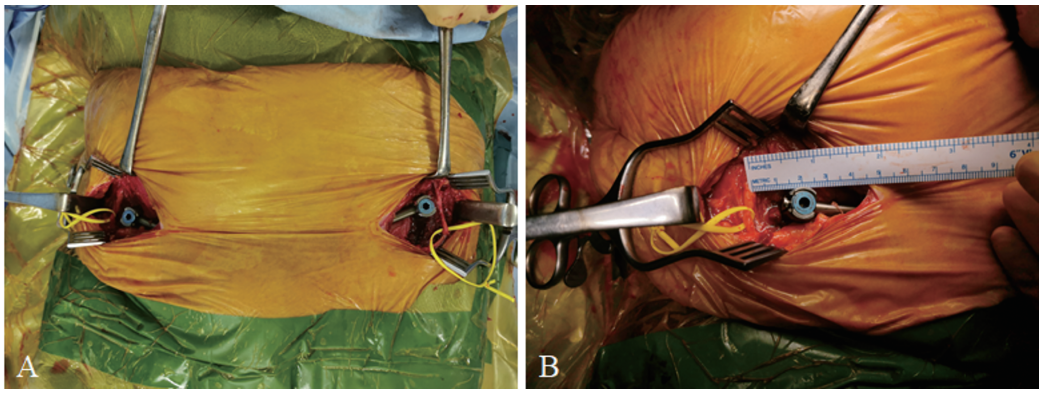

Fig. 2 Lateral femoral cutaneous nerve (LFCN) neurolysis and LFCN-to-implant distance
Fig. 2A: We performed neurolysis of the LFCN and investigated its position.
Fig. 2B: Investigation of the LFCN-to-rod end distance. The distance, in this case, is 13 mm.

and the rectus fascia to avoid both compression of the femoral nerve and skin complications. We also trimmed the rod as short as possible to allow more space for the LFCN, thereby reducing the incidence of LFCN irritation. We used the SYNTHES Expedium SAI (Sacral-Alar-Iliac Fixation) φ8 mm implant in seven cases, the SYNTHES Expedium Verse® spinal system φ8 mm implant in three cases, the Stryker ES2® spinal system φ7.5 mm implant in two cases, and the Stryker ES2® spinal system φ8.5 mm implant in one case.

We performed neurolysis of the LFCN at 0 degrees of hip flexion in the supine position. We investigated its position (Fig. 2A) intraoperatively in all cases. We explored the LFCN below 5 cm (50 mm) medial and lateral to the screw. We investigated the LFCN-to-implant distance (Fig. 2B) and the postoperative symptoms of LFCN disorder. Both the neurolysis of the LFCN and the measurement of the distances in all cases were performed by the fourth author, the senior doctor of our unit, who has more than 15 years of experience as a trauma surgeon and a microsurgeon.

Measurement of the LFCN-to-implant distance

The LFCN-to-implant distance, expressed in millimeters (mm), was measured using the shortest distance between the LFCN and the implant (medial edge of screw head or end of the rod). Based on the positional relationship between the LFCN and the implant, the distance measurement method was modified as follows: 1) In cases in which the LFCN was medial to the screw, the medial edge of the screw head was used, and 2) in cases in which the LFCN position was lateral to the screw, the end of the rod was used.

According to a previous cadaver study, the distance between the end of the rod and the LFCN was 13.5 ± 1.7 mm.[6] Thus, LFCN status was defined as follows: not identified, LFCN-to-implant distance <13 mm, and LFCN-to-implant distance ≥13 mm.

Outcome measures

The outcome of this study was defined as self-reported neurological symptoms, such as numbness, tingling, jolt-like sensation, or a strange feeling over the lateral aspect of the thigh before/after ASPIF and before/after the removal of implants. During postoperative interviews, we confirmed the absence of these symptoms both before the injury and before undergoing ASPIF for those who had had these neurologic symptoms. The symptoms were followed at our outpatient clinic at least every 2 to 3 months for 6 months.

Statistical analyses

Continuous variables were presented as medians (interquartile range: IQR), and categorical variables were presented as numbers (%). Statistical significance was evaluated using the Wilcoxon rank-sum test for continuous variables and Fisher's exact test for categorical variables. A two-sided p-value <0.05 was considered statistically significant.

The patients' baseline characteristics and LFCN-to-implant distances were compared to the presence or absence of postoperative LFCN disorders. The proportion of patients who experienced a postoperative LFCN disorder was compared, based on the LFCN status (not identified and LFCN-to-implant distance <13 mm and ≥13 mm). The predictive value of an LFCN-to-implant distance of 13 mm for postoperative LFCN disorder was assessed based on the following indices: sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. Finally, receiver operating characteristic (ROC) curve analyses were utilized to estimate the ability of the LFCN-to-implant distance to discriminate postoperative LFCN disorders in this study. The area under the curve (AUC) was calculated to assess the predictive ability of the LFCN-to-implant distance. All statistical analyses were performed using statistical software (StataCorp. 2019. Stata Statistical Software: Release 16.1 College Station, TX: StataCorp LLC).

RESULTS

Between April 2016 and November 2019, 14 patients were eligible for this study. After excluding one patient because of insufficient follow-up duration (<6 months), we finally analyzed 13 patients [median age, 55 years (IQR: 43–70 years); male, 9 (69.2%); median BMI, 22.8 kg/m^2 (IQR: 21.7–26.3)]. The minimum follow-up duration was 8 months (median: 12 months; range: 8–33 months).

Table 1 provides details on the baseline characteristics of all cases included in this study. Five of the 13 patients underwent ASPIF only, and the remaining underwent both ASPIF and posterior fixation with percutaneous screws or open reduction internal fixation with plates. Overall, 26 LFCNs (two per patient) were treated independently and analyzed. There were no significant differences between patients with and without postoperative LFCN disorders, respectively, in terms of age [median 54.5 (IQR: 28–66) vs 55.0 (IQR: 46–73), p = 0.37], sex (70.0% vs 68.8%, p = 1.00), height [median 1.6 (IQR: 1.5–1.7) vs 1.6 (IQR: 1.5–1.7), p = 0.71], weight [median 65 (IQR: 50–69) vs 57 (IQR: 50–73), p = 0.83], and BMI [median 22.4 (IQR: 21.7–26.8) vs 22.9 (IQR: 21.6–24.9), p = 0.83]. There was no significant association between obesity (BMI>25) and the occurrence of a postoperative LFCN disorder (p=0.665).

The median LFCN-to-implant distance in 19 LFCNs was 10.0 mm (IQR: 0–17.0) in cases where the LFCNs were identified, whereas the nerve could not be identified in seven out of 26 cases within the range of 50 mm from the screw both medially and laterally. Postoperative LFCN disorders were observed in 10 out of 26 LFCNs before the removal of the implant. Of these 10 cases, the LFCNs in seven cases were located within <13 mm from the implant. The rest of the three LFCNs could not be identified within the range of 50 mm from the screw medially or laterally. An LFCN-to-implant distance of ≥13 mm was significantly associated with a decreased risk for postoperative LFCN disorder compared to an LFCN-to-implant distance of <13 mm (0% vs 58.3%, p = 0.017, Fig. 3), but the difference was not significant compared to the case where LFCN could not be identified (p = 0.192, Fig. 3). In five of 10 affected LFCNs, the LFCN disorder resolved within a month after the removal of the implant. Conversely, in the other five cases of LFCN disorder, the symptoms persisted even up to 6 months after removal.

Table 1 Patient demographics, LFCN-to-implant distance, LFCN position for end of rod, postoperative symptoms of LFCN disorder, and timing of device removal

Case	Age (yrs)	Sex	Height (cm)	Weight (kg)	BMI	AO/OTA classification	Young-Burgess classification	Time to surgery (days)	Concomitant injuries	LFCN-to-implant distance and LFCN position from the end of the rod		Symptom of LFCN disorder		Removal of device (months)
										Right	Left	Right	Left	
1	28	M	169	62	21.7	61B2.2(c)	LC-3	11	Right olecranon fracture Orbital blowout fracture	5 mm lateral	0 mm lateral	+ → −	+ → −	6
2	66	M	158	67	26.8	61B3.3(d)	APC-3	17	−	No nerve below 50 mm	No nerve below 50 mm	+ → +	+ → +	12
3	43	M	167	75	26.9	61B2.1(b) 62C3(f)	LC-3	11	Pneumothorax, Left wrist fracture	10 mm lateral	10 mm medial	+ → −	+ → −	6
4	20	M	174	69	22.8	61B2.1(b)	LC-1	7	Urethral injury	No nerve below 50 mm	No nerve below 50 mm	−	+ → −	6
5	70	F	151	50	21.9	61B2.1(a)	LC-1	6	Right proximal humerus fracture	12 mm lateral	0 mm lateral	+ → +	+ → +	7
6	46	M	171	77	26.3	61B2.1(b)	LC-3	7	−	0 mm lateral	0 mm lateral	−	−	5
7	55	M	156	57	23.4	61B2.1(b)	LC-3	12	−	20 mm lateral	8 mm medial	−	−	4
8	71	F	146	49	23.0	61B3.3(b)	APC-1	9	Left scapula fracture	No nerve below 50 mm	10 mm medial	−	−	−
9	17	M	180	107	33.0	61B2.3(b)	APC-2	8	Lumbar fracture Kidney injury	15 mm lateral	15 mm lateral	−	−	8
10	49	M	169	64	22.4	61B2.1(a)	LC-1	12	Left wrist fracture	No nerve below 50 mm	No nerve below 50 mm	−	−	8
11	66	F	152	44	19.0	61C1.2(b,j)	VS	11	Right femoral trochanteric fracture	10 mm lateral	0 mm lateral	+ → +	−	10
12	75	M	159	53	21.0	61B2.1(a)	LC-1	11	Liver injury Pneumothorax	20 mm lateral	17 mm lateral	−	−	8
13	79	F	152	50	21.6	61B3.2(b)	LC-3	17	Right clavicle fracture	20 mm lateral	25 mm lateral	−	−	−

BMI: body mass index

AO/OTA: AO Foundation/Orthopaedic Trauma Association

LFCN: lateral femoral cutaneous nerve

In cases where the LFCN was medial to the screw, the medial edge of the screw head was used to measure the LFCN-to-implant distance. In cases where the LFCN position was lateral to the screw, the end of the rod was used.

Symptom of LFCN disorder: (postoperative symptom) → (symptom after implant removal). +: symptom, −: no symptom

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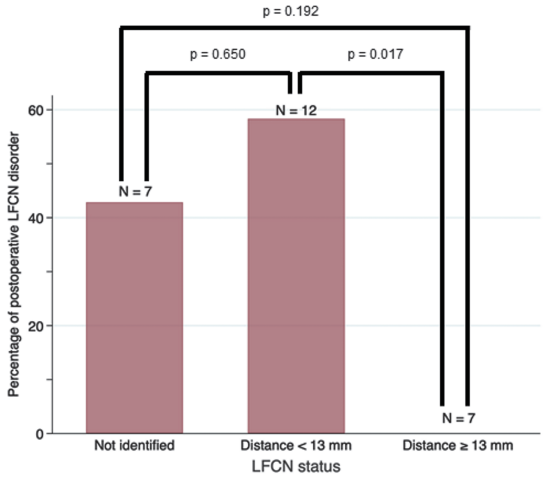

Fig. 3 Difference in the percentage of postoperative LFCN disorder by LFCN status
LFCN: lateral femoral cutaneous nerve

The distribution of the LFCN-to-implant distance according to the occurrence of postoperative LFCN disorders is demonstrated in Fig. 4. There was no significant difference between the two groups in terms of the LFCN-to-implant distance ($p = 0.142$). However, in the LFCN disorder (+) group, the LFCN-to-implant distance did not exceed the cut-off value of 13 mm. As a result, an LFCN-to-implant distance of ≥13 mm had a perfect sensitivity (100%) and negative predictive value (100%) for postoperative LFCN disorders, whereas it had modest specificity (58.3%) and positive predictive value (58.3%). The accuracy of an LFCN-to-implant distance of ≥13 mm was moderate (73.7%).

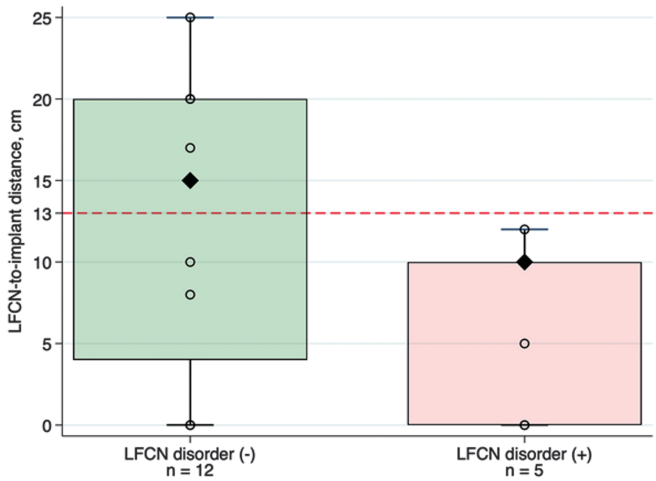

Fig. 4 Distribution of the LFCN-to-implant distance according to the presence of a postoperative LFCN disorder
The red dash line indicates the cut-off value of 13 mm based on the previous cadaver study. The black diamond indicates the median of the LFCN-to-implant distance.
LFCN: lateral femoral cutaneous nerve

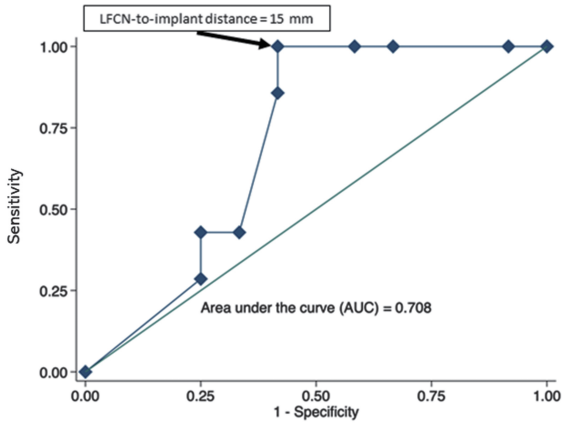

Fig. 5 Receiver operating characteristic curve of the LFCN-to-implant distance for a postoperative LFCN disorder
LFCN: lateral femoral cutaneous nerve

Finally, the ROC curve is illustrated in Fig. 5. Given an LFCN-to-implant distance of ≥15 mm, the sensitivity reached 100% with modest specificity. The AUC was 0.708 in this study.

DISCUSSION

We found that patients did not have any postoperative LFCN disorder provided the LFCN-to-implant distance was ≥13 mm. In addition, an LFCN-to-implant distance of ≥13 mm had a significantly lower risk of postoperative LFCN disorder. Moreover, 42.8% of the patients experienced LFCN disorders in cases where LFCN was not identified intraoperatively. Finally, postoperative LFCN disorders resolved in 50% of cases. To our knowledge, this is the first study to investigate the association between direct identification and evaluation of LFCN during ASPIF and postoperative LFCN disorders.

Given that LFCN can be identified, an LFCN-to-implant distance of ≥13 mm allows surgeons to exclude the possibility of postoperative LFCN disorders (sensitivity 100%, negative predictive value 100%), suggesting that the LFCN-to-implant distance can be useful in ruling out a diagnosis of postoperative LFCN disorder. Conversely, an LFCN-to-implant distance of <13 mm was significantly associated with increased risks for postoperative LFCN disorders. Since the cut-off value of 13 mm was obtained from a previous cadaver study, not a clinical study, we first assumed that the LFCN-to-implant distance was underestimated and not clinically relevant. However, our data showed that the cut-off point of 13 mm from the implant may be a sufficient distance (or margin) to prevent postoperative LFCN disorders.[6] Additionally, the ROC curve analysis suggested that the cut-off value of 15 mm in the LFCN-to-implant distance had a perfect sensitivity and modest specificity, which also supported the utility of the cut-off value of 13 mm.

In cases where the LFCN cannot be identified, a failure to identify the LFCN itself is considered a risk for postoperative LFCN disorders in this study. Our results showed that 42.8% of the patients whose LFCN was not identified experienced postoperative LFCN disorders, and this percentage was not significantly different from that in patients with an LFCN-to-implant distance of <13 mm. Therefore, in cases where the LFCN is not identified during ASPIF, it may be important to explain to the patients or their relatives that they have a higher risk of

postoperative LFCN disorders. In cases where the LFCN was not identified intraoperatively and the patients had symptoms, the postoperative LFCN disorders persisted in three out of four cases after the removal of the implant, suggesting that the LFCN was damaged despite our careful observation or due to compression by a hematoma or postoperative nerve adhesions.

In this study, postoperative LFCN disorders resolved in 50% of cases. This could be due to nerve compression by a hematoma, inflammation, or postoperative nerve adhesions. In addition, the LFCN may have been missed or damaged during the operation despite our careful observation. To avoid these complications, ultrasonography may be useful in identifying the LFCN preoperatively or intraoperatively.[15] Although it was not used in the present study, in the future we will identify LFCN using ultrasonography preoperatively.

Due to the small sample size, we could not validate our results using inner and/or outer validation cohorts. However, to the best of our knowledge, our viewpoint is unique, and no study has investigated the association between LFCN distances and postoperative LFCN disorders. Thus, our study is considered important since it elucidated the significance of the LFCN-to-implant distance measurements in daily clinical practice to be used in identifying postoperative LFCN disorders in patients who underwent ASPIF (sensitivity 100%). The strengths of this study include attempts to identify the LFCN in all patients who underwent ASPIF. Additionally, all patients were regularly followed up at the outpatient clinic, and the presence or absence of LFCN disorders was repeatedly confirmed. Finally, although it was a single-center study, our study was conducted in a tertiary trauma center that covers a population of approximately 374,000 individuals. Therefore, the results from this study may be generalized to the other large medical centers in Japan. Further, our data may be meaningful because there are no studies examining the utility of intraoperative LFCN assessment besides fresh frozen cadaver studies.[6,8] However, this study has several limitations. First, the small sample size did not allow us to implement a detailed statistical analysis, and the statistical power was considered small. However, this study did clearly show that an LFCN-to-implant distance of ≥13 mm perfectly distinguished the risk of postoperative LFCN disorders even in a small number of patients. Second, identification of LFCN is not considered a standard clinical practice in ASPIF in Japan, and some training may be needed before LFCN identification becomes feasible. Third, there was no consideration of whether LFCN was on the medial or lateral side of the screw nor of the details of the symptoms depending on the limb position at the hip. Fourth, a self-reported outcome was utilized in this study, and quantification and validation of the outcome were not performed. Thus, further studies are warranted to evaluate the outcome in a more standardized manner. Nevertheless, this study indicated the utility of LFCN identification during ASPIF and is considered to play a vital role as a hypothesis-generating study.

Since there were no similar previous studies, other than those using cadavers, an evaluation of external validity was not possible. In addition, due to the small number of cases, it was also impossible to evaluate the internal validity. Nevertheless, this study is a novel exploratory study focusing on the postoperative quality of life (QOL) of patients, which is an area that has not received attention in the past, and is considered important because it has the potential to improve postoperative QOL.

In conclusion, this study demonstrated that postoperative LFCN disorders were not observed in cases where the LFCN-to-implant distance was ≥13 mm. In contrast, LFCN disorders were frequently observed in cases where the LFCN-to-implant distance was <13 mm or in cases where the LFCN was not identified intraoperatively. Therefore, the attempt to identify the LFCN during the operation may be useful for postoperative risk assessment of LFCN disorders in patients who undergo ASPIF.

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DISCLOSURE STATEMENT

None.

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