

**Femoral nerve status during the anterolateral approach for total hip arthroplasty:
motor-evoked potential analysis and an influencing factor**

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Abstract

Background: Femoral nerve palsy is an uncommon but serious complication during the anterolateral approach for total hip arthroplasty. One of the reported reasons for femoral nerve palsy is retractor-induced intraoperative damage after retractor placement on the anterior wall of the acetabulum. The present study aimed to clarify the femoral nerve status during anterolateral approach total hip arthroplasty using motor-evoked potential analysis and to identify risk factors influencing the nerve status.

Methods: From June 2019 to September 2020, 32 hips in 31 patients underwent primary total hip arthroplasty via the anterolateral approach. The integrity of the femoral nerve was tested by the motor-evoked potential at three time points: preoperatively as a control (first period), immediately after retractor placement on the anterior wall of the

acetabulum (second period), and after the procedure (third period). In the second period, the hips were divided into the following two groups: a <50% femoral nerve amplitude group and a \geq 50% group. The iliopsoas muscle volume was evaluated by measuring the muscle cross-sectional area on preoperative computed tomography images, and compared between the two groups.

Results: The mean amplitude of the femoral nerve was significantly reduced from 100% in the first period to 35% in the second period ($p < 0.01$), but then significantly recovered to 54% in the third period ($p < 0.01$). In 26 (81%) hips, the femoral nerve amplitude was <50% in the second period. The muscle cross-sectional area of the iliopsoas muscle in the <50% group was significantly smaller than that in the \geq 50% group ($p < 0.05$).

Conclusions: The mean amplitude of the femoral nerve was significantly reduced to 35% in the second period, and the iliopsoas muscle volume was considered to influence this femoral nerve status.

Introduction

The anterolateral approach, a modification of the Watson-Jones approach, is used as a minimally invasive approach for total hip arthroplasty (THA) [1], and has been proposed to lead to early functional recovery and good clinical results through reduced blood loss and less soft-tissue damage. A reduction in postoperative pain and early mobilization can also be accomplished by the minimal muscle insertions [2-5].

However, intraoperative complications such as femoral fracture, abductor muscle and tendon damage, and femoral nerve palsy (FNP) have been reported [6-9].

FNP is an uncommon but serious complication during anterolateral approach THA, occurring in 0.6% to 5% of cases [8,9]. Several causative factors have been proposed, including hematoma formation, traction, ischemia, laceration, and retractor-induced damage [10-15]. Placement of the retractor on the anterior wall of the acetabulum has been considered to damage the femoral nerve directly or indirectly by compression through the iliopsoas muscle bulk [14,15].

To our knowledge, no previous reports have investigated the effects of the anterior retractor on the femoral nerve status during anterolateral approach THA. The present study aimed to (1) clarify the effects of the anterior retractor on the femoral nerve status using motor-evoked potential (MEP) analysis and (2) identify risk factors influencing

the femoral nerve status.

Materials and Methods

This study was approved by our institutional review board, and informed consent was obtained in conformance with the laws and regulations of our country. Prior to the present study, a single hip surgeon had performed anterolateral approach primary THA in the supine position on nearly 100 hips.

We performed a prospective analysis of femoral nerve function on the basis of MEP monitoring for 37 hips in 36 patients who underwent anterolateral approach primary THA by the same surgeon from June 2019 to September 2020. Five hips were subsequently excluded because they had incomplete nerve monitoring reports. Thus, 32 hips in 31 patients (6 male, 25 female) comprised the final study population.

At the time of the procedure, the patients had a mean age of 62.3 ± 11.5 years (range, 38–83 years), a mean height of 157.5 ± 9.1 cm (range, 138.6–177.5 cm), a mean weight of 62.9 ± 11.7 kg (range, 41.9–88.0 kg), and a mean body mass index (BMI) of 25.3 ± 3.8 kg/m² (range, 18.6–35.2 kg/m²). Thirty hips were diagnosed with osteoarthritis, and two hips were diagnosed with osteonecrosis. According to the Crowe classification [16], all patients had grade I developmental dysplasia of the hip. The Harris hip score (HHS)

and the Japanese Orthopaedic Association (JOA) hip score were used as preoperative disease-specific health outcomes [17,18]. The flexion range of motion was measured preoperatively. The right side was affected in 14 hips and the left side in 18 hips (Table 1).

MEP monitoring and analysis were performed based on a previously reported method [15]. The femoral nerve and median nerve integrities were tested by recording the MEP at three time points: after a train-of-four monitor showed recovery at 100% preoperatively as a control (first period), immediately after the retractor was placed at the 3-o'clock position on the osseous wall of the anterior acetabulum (second period), and after reduction with the prosthesis attached (third period). In the second period, the retractor was gently pulled to gain an adequate view of the anterior capsule using a Magic Tower (Zimmer Biomet, Warsaw, IN, USA) as a self-retaining retractor (Fig. 1).

After closing the skin and subcutaneous tissue with the prosthesis attached, the MEP was recorded in the third period. The amplitude in the first period was defined as 100%. The nerve monitoring data were displayed for comparison with the first period response. The operative time was recorded, and the possible association between operative time and femoral nerve amplitude in the third period was examined.

The thickness of the iliopsoas muscle was evaluated by measuring the muscle cross-

sectional area (M-CSA) based on preoperative axial computed tomography (CT) images (Aquilion TSX-101/HA; Toshiba Medical Systems Co., Tokyo, Japan).

The reliability of CT imaging for muscle evaluation was reported to be high [19]. The evaluated CT slice was located at the level of 15 mm proximal to the anterior horn tip of the acetabulum [20], because this level is close to the osseous wall of the anterior acetabulum at the 3-o'clock position and the mean vertical distance at the level of 15 mm proximal to the teardrop line corresponds to the center of the femoral head in normal Japanese women [21]. The M-CSA was automatically calculated based on the circumferential outline after manual tracing (Fig. 2). The test-retest reliability was analyzed to evaluate the validity of the M-CSA measurement. Intraobserver and interobserver reliabilities for the measurement of M-CSA were analyzed using the intraclass correlation coefficient; the measurements were reviewed three times on different days by each observer, and mean values were calculated. The intraclass correlation coefficient was 0.98 and the interclass correlation coefficient was 0.94.

Nerve dysfunction was defined as MEP amplitude of <50% based on a previous report [22]. The hips were divided into the following two groups by the amplitude of the femoral nerve in the second period: <50% and \geq 50%. The M-CSA of the iliopsoas muscle was compared between the <50% group and the \geq 50% group.

Causalgia of the femoral nerve and a manual muscle test (MMT) for the strength of knee extension were evaluated 1 week after THA.

Statistical analyses were performed using SPSS version 20.0 for Windows (IBM Japan, Tokyo, Japan). The Wilcoxon rank-sum test was used to compare the corresponding amplitudes of the rectus femoris muscle and the thenar muscle between the first and second periods as well as between the second and third periods. The two-sample *t*-test, Mann–Whitney U test, and chi-square test were used to compare sex, age, height, weight, BMI, and M-CSA of the iliopsoas muscle between the <50% group and the ≥50% group on the operative side. The Spearman correlation coefficient was used to compare the M-CSA of the iliopsoas muscle with the corresponding age, height, weight, BMI, HHS, JOA hip score, and range of motion. Significance was assumed for *p*-values of < 0.05.

Results

The mean amplitude of the femoral nerve was significantly reduced from 100% in the first period to $35.1\% \pm 26.3\%$ (range, 4.6%–100%) in the second period, but then significantly improved to $53.7\% \pm 29.5\%$ (range, 12.4%–100%) in the third period (*p* < 0.01) (Table 2). In the second period, 29 (93%) of the 32 hips had a reduced amplitude

of the femoral nerve, while only 3 hips showed no reduction. The mean amplitude of the median nerve was 100% in the first period, $99.1\% \pm 3.5\%$ (range, 81.6%–100%) in the second period, and $98.3\% \pm 5.1\%$ (range, 81.3%–100%) in the third period, with no significant differences between first period versus second period and second period versus third period ($p = 0.18$ and 0.35).

The mean operative time was 94 minutes (range, 73 to 121 minutes). No significant correlation was observed between operative time and femoral nerve amplitude in the third period ($p = 0.54$ and $r = -0.08$).

The mean M-CSA of the iliopsoas muscle in the 32 hips was $6.41 \pm 1.72 \text{ cm}^2$ (range, 3.79–11.21 cm^2). A significant correlation was observed between the M-CSA of the iliopsoas muscle and height ($p < 0.01$ and $r = 0.59$). However, no significant correlations were observed between the M-CSA of the iliopsoas muscle and age ($p = 0.34$ and $r = -0.17$), weight ($p = 0.06$ and $r = 0.34$), JOA hip score ($p = 0.67$ and $r = 0.07$), HHS ($p = 0.60$ and $r = 0.10$), or flexion range of motion ($p = 0.67$ and $r = 0.09$).

In the second period, 26 (81%) of the 32 hips had $<50\%$ amplitude of the femoral nerve, while only 6 hips had $\geq 50\%$. There were no significant differences in age ($p = 0.09$), sex ($p = 1.00$), height ($p = 0.17$), weight ($p = 0.38$), or BMI ($p = 0.94$) between the $<50\%$ group and the $\geq 50\%$ group (Table 3). The M-CSA of the iliopsoas muscle was

significantly smaller in the <50% femoral nerve amplitude group compared with the
≥50% group between the first and second periods ($p < 0.05$) (Table 4). No patients
developed postoperative MMT deterioration in knee extension strength or causalgia of
the femoral nerve.

Discussion

In anterior approach THA, the anterior retractor tip has been considered to directly
traumatize the femoral nerve [14] or indirectly compress the femoral nerve through the
iliopsoas muscle bulk [15]. In a previous study, a self-retractor used to minimize direct
trauma to the femoral nerve caused a significant decrease in the femoral nerve
amplitude in 77% of patients after retractor placement on the anterior wall of the
acetabulum, suggesting that the femoral nerve may have been indirectly damaged by the
retractor compressing the femoral nerve through the iliopsoas muscle bulk [15]. The
present study found similar results, indicating that the femoral nerve may be damaged
not only directly by the tip of the retractor, but also indirectly by compression through
the iliopsoas muscle bulk even when the anterolateral approach is used.

The correlation between the decrease in the femoral nerve amplitude and the thickness
of the iliopsoas muscle may be related to the muscle stiffness, as a mechanical response

to the deformation applied by the retractor. Stiffness is the extent to which an object resists deformation in response to an applied force [23]. A small M-CSA has higher stiffness than a large M-CSA when a constant compressive force is applied to the muscle [24], and high stiffness of the muscle may reduce cushioning compared with low stiffness. Therefore, it is possible that the compression force from the retractor transmitted to the femoral nerve through the iliopsoas muscle was greater when the M-CSA of the iliopsoas muscle was smaller.

In this study, the second MEP measurements were performed immediately after the retractor placement on the anterior wall of the acetabulum based on the previous report [15]. In addition, it has been reported that the nerve damage can be detected just after the nerve depression by the retractor based on the nerve monitoring study [25]. On the other hand, it may be better to measure the second MEP before the retractor is removed to maximize the compression effects by the retractor. But this timing measurement may be influenced by the period of the retractor placement and the retractor position is often changed to obtain the appropriate view. The second timing of the MEP measurement may need further consideration.

The present findings suggested that a reduced iliopsoas muscle volume influenced the femoral nerve status at the time of anterolateral THA. In patients with a small iliopsoas

muscle, it would be helpful to relieve muscle tension by intermittent release of the anterior retractor, and slight flexion of the hip joint may be useful to decrease the tension of the femoral nerve [26,27]. In addition, 16 weeks of preoperative physiotherapy with leg-cycling and arm-cranking ergometers was reported to increase the muscle volume [28].

This study had several limitations. First, the anterior retractor was manually pulled to obtain an adequate view of the anterior margin of the acetabulum, and thus the amount of tension could not be evaluated. Second, most of the patients in this study were female with a short stature and low BMI. These factors may affect the variation in the iliopsoas muscle volume. Third, the M-CSA measurement was based on only one CT slice located at 15 mm proximal to the anterior horn tip of the acetabulum.

In conclusion, the mean amplitude of the femoral nerve was significantly reduced from 100% in the first period to 35% in the second period. The iliopsoas muscle volume was considered to influence the femoral nerve status.

Conflict of interest

The authors have no conflicts of interest directly relevant to the content of this manuscript.

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Table 1. Characteristics of the 32 hips in 31 patients who underwent primary total hip arthroplasty with the anterolateral approach in the supine position in whom motor-evoked potential analysis was available

Characteristic	All hips (n = 32)
Sex, male : female (no. of hips)	6 : 26
Age ^a (yr)	62.3 ± 11.5 (38–83)
Height ^a (cm)	157.5 ± 9.1 (138.6–177.5)
Weight ^a (kg)	62.9 ± 11.7 (41.9–88.0)
BMI ^a (kg/m ²)	25.3 ± 3.8 (18.6–35.2)
HHS ^a	61.5 ± 12.1 (25–88)
JOA hip score ^a	60.4 ± 9.7 (33–83)
Flexion ^a (°)	95.6 ± 12.4 (70–120)
Diagnosis	
Osteoarthritis	30
Osteonecrosis	2

^a Data are shown as mean ± standard deviation (range).

BMI, body mass index; HHS, Harris hip score; JOA, Japanese Orthopaedic Association.

Table 2. Mean amplitudes of the femoral nerve and median nerve based on motor-evoked potentials in 32 hips that underwent primary total hip arthroplasty with the anterolateral approach

		Amplitude					
		Femoral nerve			Median nerve		
		First	Second	Third	First	Second	Third
		period	period	period	period	period	period
32	hips ^a	100	35.1 ± 26.3	53.7 ± 29.5	100	99.1 ± 3.5	98.3 ± 5.1
	(%)		(4.6–100)	(12.4–100)		(81.6–100)	(81.3–100)
	p-value		<0.01 ^b	<0.01 ^c		0.18	0.35

^aData are shown as mean ± standard deviation (range).

^bSignificant difference ($p < 0.01$) between the first and second periods.

^cSignificant difference ($p < 0.01$) between the second and third periods.

Table 3. Comparisons of preoperative clinical data between the <50% and ≥50%

femoral nerve amplitude groups in the second period

Characteristic	<50% group (n = 26 hips)	≥50% group (n = 6 hips)	p-value
Age ^a (yr)	63.9 ± 10.7 (46–83)	55.2 ± 12.9 (38–75)	0.09
Sex, male : female (no. of hips)	6 : 20	2 : 4	1.00
Height ^a (cm)	156.5 ± 9.3 (138.6–177.5)	162.1 ± 7.2 (154.2–172.2)	0.17
Weight ^a (kg)	62.0 ± 11.3 (41.9–84.5)	66.8 ± 13.7 (50.6–88)	0.38
BMI ^a (kg/m ²)	25.3 ± 3.9 (20.1–35.2)	25.2 ± 3.5 (21.3–29.7)	0.94

^aData are shown as mean ± standard deviation (range).

BMI, body mass index.

Table 4. Comparison of mean muscle cross-sectional areas measured on preoperative computed tomography images between the <50% and ≥50% femoral nerve amplitude groups in the second period

	Mean muscle cross-sectional area		
	<50% group	≥50% group	p-value
	(n = 26 hips)	(n = 6 hips)	
Iliopsoas muscle ^a (cm ²)	6.06 ± 1.56	7.92 ± 1.73	<0.05 ^b
	(3.8–6.6)	(6.2–11.2)	

^aData are shown as mean ± standard deviation (range).

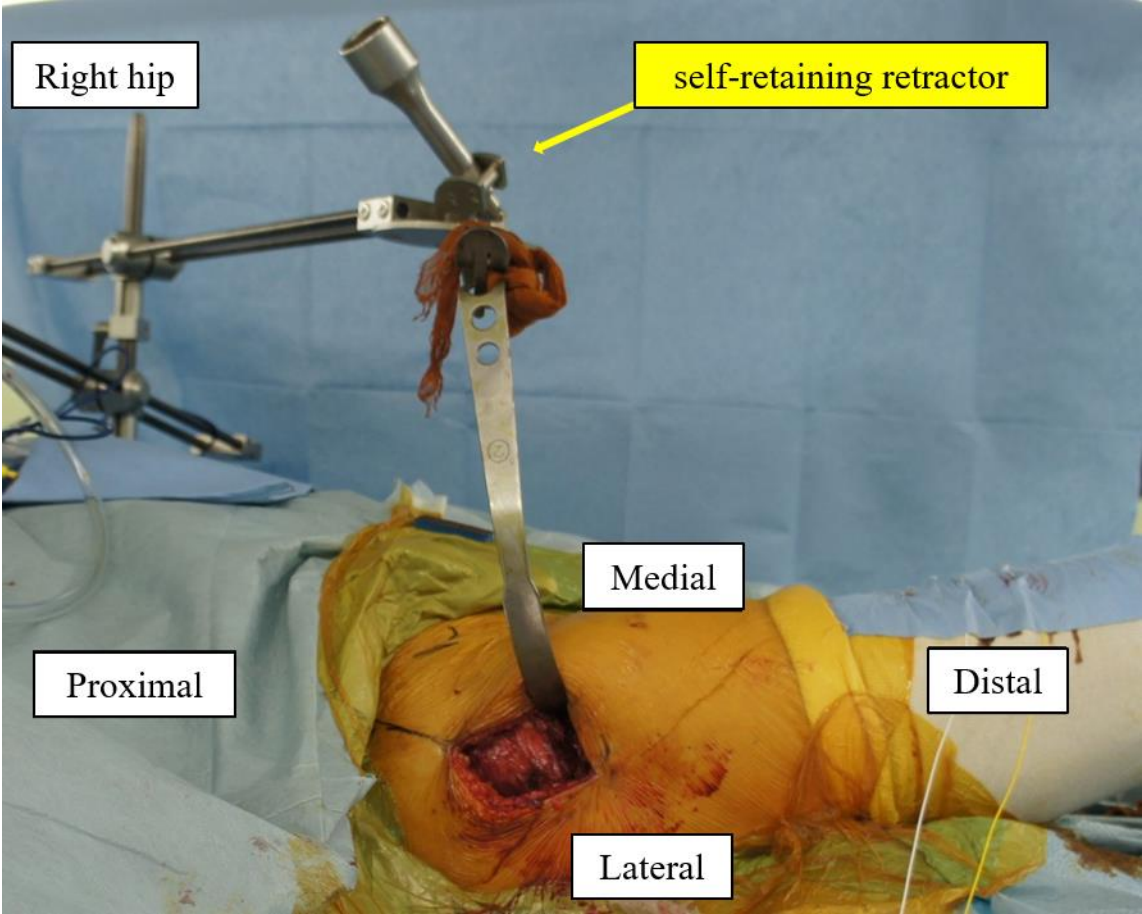
^bSignificant difference (p < 0.05) between the <50% and ≥50% group.

Figure captions

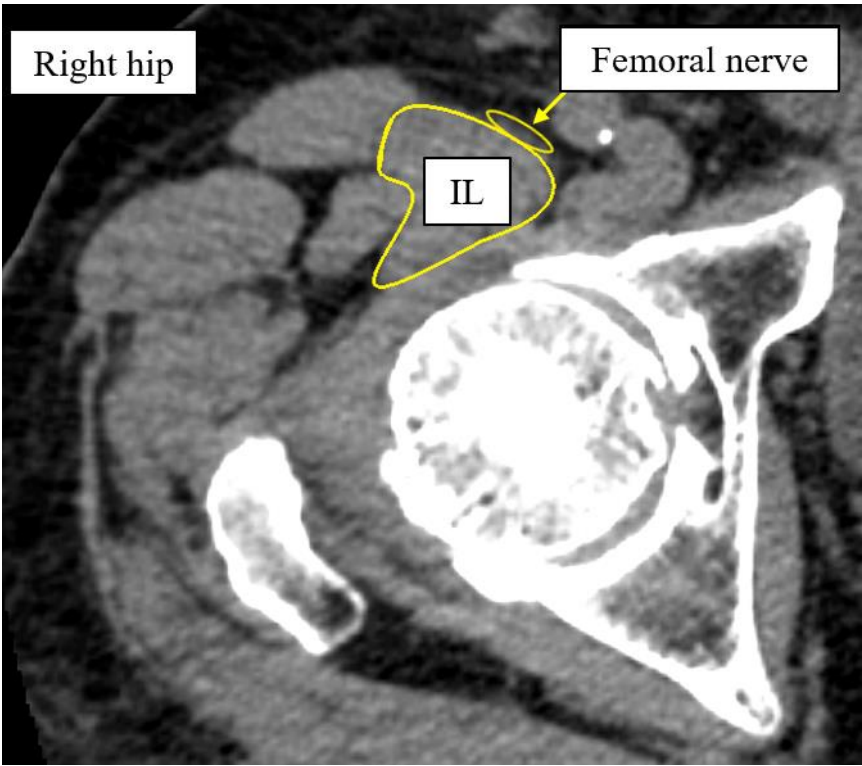
Fig. 1. Photograph showing intraoperative use of a self-retaining retractor in a right hip.

Fig. 2. Location for the muscle cross-sectional area measurement of the iliopsoas muscle (IL) in a right hip joint evaluated on a preoperative computed tomography slice located at 15 mm proximal to the anterior horn tip of the acetabulum.

396 Fig. 1.



405 Fig. 2.



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