Rzeszów University Press 2025
ISSN 2544-1361 (online)
doi: 10.15584/ejcem.2025.3.5

http://www.ejcem.ur.edu.pl
European Journal of Clinical and Experimental Medicine
Eur J Clin Exp Med 2025; 23 (3): 562–569

ORIGINAL PAPER

Safety zone for surgical procedures for the prevention of neurovascular injury in minimally invasive total hip arthroplasty

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ABSTRACT

Introduction and aim. With the development of minimally invasive surgery (MIS), decreased incision size produces limited visualization leading to an increased risk of adjacent neurovascular structures during the procedure.

The aim was to identify the safest zones of surgical procedures for the prevention of major neurovascular structures around the acetabulum.

Material and methods. 84 cadaver pelvic specimens with 168 hips were used to analyze the anatomic relationship between the sciatic nerve and the piriformis muscle in the normal Korean population according to sex and height. We performed a qualitative and quantitative analysis of the anatomic relationship between the acetabulum and the sciatic nerve, based on the clockwise direction method, to identify the safety zones of the surgical procedure's proximity to the acetabulum.

Results. The prevalence of type I (normal type) was more than 79% and 88% in males and females, respectively. Distances A, B and E were 7.1±0.78 mm between the 3 and 4 o'clock position, 14.2±0.67 mm between the 8 and 9 o'clock position, 17.0±1.22 mm in the 9 o'clock position, respectively, on the left side, whereas 6.0±0.69 mm between the 8 and 9 o'clock position, 14.8±0.59mm in the 7 o'clock position, 17.9±1.08 mm in the 3 o'clock position on the right side. The proximity of the retractors to acetabulum should be placed with careful and proper retraction between the 3 and 5 o'clock position on the left side and between the 7 and 9 o'clock position on the right side, in which the placement in the 9 and 3 o'clock position should be cautious on the right and left side, respectively. The cautious use of electrocautery between the 3 and 5 o'clock position on the left side, and between the 7 and 9 o'clock position on the right side, is recommended. However, performing the electrocauterization in the 9 o'clock and 3 o'clock position respectively on the left and right side should be avoided. It is forbidden between the 10 and 12 on the left side and between 12 and 2 o'clock position on the right side. The absolute safety zones for the placement of the transacetabular screw were between 1 and 3, and between the position 5 and the 6 o'clock position on the left side and between the position 9 and 11, and between the 6 and 7 on the right side. Relative safe zones were between 12 and 1, and between the 6 and 7 o'clock position on the left and between the 11 and 12, and between the 5 and 6 o'clock positions on the right side. Screws with a length of <24mm could be safely inserted between the 3 and 5 o'clock position on the left side and between the 7 and 9 o'clock position on the right side. The risk zones were between 7 and 9, and between the 9 and 12 hours on the left side, and between 3 and 5, and between the 12 and 3 o'clock position on the right side. In cases with highly elevated trochanter major, the distances between the acetabulum and adjacent neurovascular structures changed and the risk of the SN increased.

Conclusion. These data could be helpful for arthroplasty surgeons in avoiding neurovascular injuries in MIS THA.

Keywords. femoral artery, minimally invasive total hip arthroplasty obturator nerve, piriformis muscle, sciatic nerve

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Received: 18.02.2025 / Revised: 18.03.2025 / Accepted: 26.03.2025 / Published: 30.09.2025

Pak H-U, Ri K-C, Choe T-H, Pak C-J, Ri W-J. Safety zone for surgical procedures for the prevention of neurovascular injury in minimally invasive total hip arthroplasty. *Eur J Clin Exp Med.* 2025;23(3):562–569. doi: 10.15584/ejcem.2025.3.5.

Introduction

Since the superiority of minimally invasive surgery over conventional surgery has been known as less damage and rapid functional recovery, it has been introduced to many orthopedic surgeries with the help of advanced surgical techniques and instruments.[1-6] Despite advancements in specialized instruments, limited incisions and a narrow surgical field can increase the risk of injury to adjacent neurovascular structures due to the potential for blind procedures, and the success of MIS-THA depends on arthroplasty surgeon's experience.[3,4,7]

The injury of the neurovascular structure close to the acetabulum is one of the major complications after hip surgery and total hip arthroplasty (THA).[7] The incidence of nerve injury in primary total hip arthroplasty ranges from 0 to 3 percent, in which the injury to the sciatic nerve (SN) is the most common.[8,9] Vascular injury during conventional THA is relatively rare (0.2-0.3%), but can result in considerable morbidity or even mortality.[10,11] It is reported that the incidence of neurovascular injury proximity to the acetabulum is higher in patients with hip dislocation and pelvic fracture, and superior gluteal neurovascular injury is relatively more common among them.[11-13]

There has been many literatures on the neurovascular injury around the acetabulum during surgery around the whole world.[12-16] Injury of the sciatic nerve injury is common in THA with a posterior approach, osteosynthesis of acetabular fracture and open reduction of hip dislocation, which could result in severe functional impairment of the hip and lower limb.[8,9] In THA, the most common identifiable cause of intraoperative SN injury is direct and indirect mechanical damage, including compression by malpositioned retractors, excessive/prolonged retraction, and inappropriate electrocauterization.[13] Furthermore, specific anatomic variations between the piriformis muscle (PM) and the SN have long been studied in cadaveric specimens, CT and MRI findings, all of which were focused on the prevention of the nerve injury during surgical procedure.[17-20] In early 1990s, Wasielewski et al. suggested the safe zone and depth of transacetabular screw fixation based on the quartering method of the acetabulum.[17] However, in MIS-THA with limited incision, the landmarks recommended by Wasielewski could not be identified due to small window and it has been an important issue especially for young arthroplasty surgeons with less experience. Aforementioned results have been limited to the sporadic identification of the anatomic relationship between the acetabulum and individual neurovascular structures including femoral artery (FA), SN and obturator nerve (ON), based on either quantitative or qualitative method, which did not include the practical mapping of safe zone for surgical procedure. There is a paucity of comprehensive literature that guides safe surgical procedures during THA.

Aim

Therefore, this study is designed to identify the anatomic relationship between the acetabulum and adjacent neurovascular structures and to determine the relative and absolute safety zone with the forbidden zone, quantitatively and qualitatively.

Material and methods

The anatomy of the acetabulum and adjacent neurovascular structures was examined in 168 hips derived from 84 formalin embalmed cadavers in our university's anatomy laboratory with an intact lower extremity for this study. Institutional Review/Ethics Board approval was obtained for the present study (2024-PRK-A10245, Ethics Assembly, Pyongyang University of Medical Sciences). The dissections were performed by the skilled anatomist (D.K.S.). Each cadaver was placed in a lateral position, and skin and the subcutaneous fat on the gluteus maximus were cut and completely removed to reveal the gluteus maximus. The gluteus maximus was dissected at its origin from the iliac crest. Its insertion in the iliotibial tract and the gluteal tuberosity was released to reflect the gluteus maximus inferiorly and medially. The gluteus medius was dissected from its insertion and laterally retracted to identify the course and the branches of the sciatic nerve. The connective tissue and fat were dissected to give a full demonstration of the anatomic course and branches of the SN in relation to PM. Cadavers with a history of surgery for hip osteoarthritis or intrapelvic viscera were excluded from this study, as surgery could have remarkably changed the relationship between the acetabulum and pelvic vessels remarkably. 48 male and 36 female cadavers, with an equal distribution of left and right lower extremities, were randomly selected from the available cadavers (Table 1). There was no significant difference in age between males and females (p>0.05).

Table 1. Characteristics of the cadaveric specimens

	Male (n=48)	Female (n=36)
Age (years)		
Mean±standard deviation	54.8±16.8	58.4±17.2
Min–Max	37–72	41–76
Height		
<155 cm	0 (0%)	9 (25%)
156–160 cm	5 (10.4%)	19 (52.8%)
161–165 cm	17 (35.4%)	7 (19.4%)
166–170 cm	19 (39.5%)	1 (2.8%)
>171 cm	7 (14.7%)	0 (0%)

Anatomical variations were analyzed according to the classification as follows:[18,19]

I – SN exits the pelvis undivided below the PM,

II – SN divides in the pelvis, the common peroneal nerve (CPN) passes through the bifid PM, and the tibial nerve(TN) lies below the PM,

III – SN divides in the pelvis, CPN courses over the PM, and TN lies below the PM,
IV – SN exits the pelvis undivided piercing the PM,
V – SN divides in the pelvis, CPN courses over the PM, and TN passes through the bifid PM,
VI – SN exits the pelvis undivided coursing over the PM,
VII – SN divides in the pelvis, both CPN and TN coursing separately below the PM.

For the identification of the anatomic relationship between the acetabulum and its adjacent neurovascular structures, such as SN, ON and FA, the intersection point (iliofemoral ligament attachment site) between the acetabular rim and the line connecting the anterior superior iliac spine and the anterior inferior iliac spine was used as 12 o'clock position to determine clockwise directions. Magnifying glass (×5) and the pin with ruler function were utilized to measure the distance measurement between the neurovascular structures and the acetabulum. The distance parameters used in the analysis of the anatomic relationship were as follows.
A – the shortest distance between the inferior margin and the inner surface of the acetabular floor at the site 24 mm below the greater sciatic foramen along SN,
B – the shortest distance between the inferior margin of the SN and the acetabular rim,
C – the shortest distance between the surface of the acetabular floor and the greater sciatic foramen,
D – the shortest distance between the FA and the acetabular rim,
E – the shortest distance between the ON and the acetabular rim,
X – the shortest distance between the SN and the trochanter major,
Y – the shortest distance between the SN and ischial tuberosity,
Z – the shortest distance between the SN and the sacral hiatus,
W – diameter of SN at the site 24 mm below the greater sciatic foramen along SN.

A pin with a ruler function was inserted vertically on the surface to measure the safe zone and depth of the transacetabular screw according to the clockwise direction method in the acetabulum of the cadaver. Intraoperative measurement was performed in 42 femoral neck nonunions with a highly elevated trochanter major, all who underwent THA with the posterolateral approach of the HU between November 2020 and June 2022. Post hoc power analysis was performed to assess the statistical power of the primary outcome measure. Analysis showed that with the current sample size of 42 patients, the study had adequate power (>80%) to detect clinically significant differences, with an effect size at a significance level of 0.05. There were 34 men (80.9%) and 8 women (19.1%) with a height of 169.3±13.2 cm and 158.8±13.2 cm, respectively, who had an elevated trochanter major with a mean height of 13.5±3.5 mm. Distances A, B, and X were measured during conventional primary THA according to clockwise direction in patients with femoral neck nonunion, based on which safe zone was determined. All distance values were presented as mean±standard deviation.

We retrospectively reviewed the operative note of 36 cases with transient sciatic nerve palsy after THA, based on the clockwise location and duration of retractor placement since we started the clinical measuring trial to determine the safe zone of surgical procedures during MIS-THA. All sciatic nerve palsy was recovered within 4 weeks. The duration of retractor placement was calculated as the time of acetabular preparation.

Results

Anatomic variations between SN and PM

In this study a total of 84 cadavers with 168 hips were examined. The normal type I variation in which the SN exits the pelvis as a single entity below the PM was the most common with a pooled prevalence of 83.3% followed by type II with 10.7%, type III with 2.4%, and type V with 1.8% (Table 2). The remaining types had a pooled prevalence of <1%. The abnormal type was observed in 20 hips (20.8%) of 12 male cadavers and in 8 hips (11.1%) of 6 female cadavers, demonstrating that its prevalence was lower in women than in men. Furthermore, abnormal type was observed in 18 (90%) and 7 (87.5%) left hips, respectively, in male and female cadavers, indicating that the left side was more prevalent (89.2% in total) in abnormal type. In male cadavers with height of >165cm, prevalence of abnormal type was 73.6% (56/76) and in female cadavers with >160cm it was 87.5% (7/8), indicating that the prevalence of abnormal type increased with height.

Table 2. Anatomical relationship between the sciatic nerve and the piriformis muscle*

Gender	n	Type I (cadavers/hips)	Abnormal type					
			Type II	Type III	Type IV	Type V	Type VI	Type VII
Male	48	40/76 (79.2%)	6/12 (12.5%)	2/3 (3.2%)	1/1 (1%)	1/2 (2.1%)	1/1 (1%)	1/1 (1%)
Female	36	34/64 (88.9%)	4/6 (8.3%)	1/1 (1.4%)	0/0 (0%)	1/1 (1.4%)	0/0 (0%)	0/0 (0%)
Overall	84	74/140 (83.3%)	10/18 (10.7%)	3/4 (2.4%)	1/1 (0.6%)	2/3 (1.8%)	1/1 (0.6%)	1/1 (0.6%)

* percentages in the parenthesis mean the proportion of individual variants among total number of hips

Anatomical relationship between the acetabulum and adjacent neurovascular structures (SN, ON, FA)

The acetabulum had anatomic relationship with sciatic nerve,, obturator nerve and femoral artery, as presented in Table 3. The other distance parameters measured in the female and male cadavers are shown in Table 4.

There was no significant difference in all distance parameters between the left and right sides. All parameters showed the tendency of increasing distances with height and being longer distances in males than in females.

Table 3. Anatomical relationship between the acetabulum and adjacent nerves (SN, ON)

Distance parameter	Distance			Position (clockwise direction)	
	Left (mm)	Right (mm)	p	Left	Right
A	7.1±0.78	7.0±0.69	0.86	3–4 o'clock	8–9 o'clock
B	14.2±0.67	14.8±0.59	0.81	5 o'clock	7 o'clock
E	17.0±1.22	17.9±1.08	0.78	9 o'clock	3 o'clock

Table 4. Anatomical relationship between the pelvis and the adjacent neurovascular structures (FA, SN)

Distance parameter	Left (mm)	Range (mm)	Right (mm)	Range (mm)	p
C	29.9±1.27	23.5–31.5	30±0.96	23.5–32	0.85
D	18.8±1.41	16–20.5	19.0±1.19	16.0–20.5	0.91
X	30.1±0.52	28–31	30.4±0.13	29.0–31	0.88
Y	18.1±0.99	16–19.5	18.2±0.87	16.0–19.5	0.94
Z	69.2±1.64	65–71	69.1±1.59	66.5–71	0.95
W	31.2±1.87	28.5–33.5	31.1±1.94	27.0–33	0.92

Electrocauterization safety zone and retractor placement in THA

On the basis of the aforementioned results, the safety zone was determined by clockwise method. When the iliofemoral ligament attachment site was determined as 12 o'clock position, the retractors should be careful to place the retractors between 3 and 5 o'clock position on the left side (L) and between 7 and 9 o'clock position on the right side (R) because there was SN and superior gluteal neurovascular bundle close to this position. Retractors should be placed carefully at the 9 o'clock position (L) and 3 o'clock position (R) to prevent the injury of FA and ON injury. If retractors are to be placed in this position, the use of electrocautery should be forbidden because of the potential injury owing to current conductivity. Electrocautery should not be used between 10 and 12 o'clock on the left side and between 12 and 2 o'clock position, because the femoral nerve (FN) passes close to this position.

Safety zone of screw fixation for acetabular cup in THA

Our recommended safety zone for screw fixation of the acetabular cup is summarized in Table 5. The absolute safety zone was between 1 and 3 (L) and between 9 and 11 o'clock on the right side (R) when the screw with length of >40 mm was inserted posterolaterally and superiorly. In the case of post-inferior screw insertion, the absolute safety zone was between 5 and 6 o'clock (L) and between 6 and 7 o'clock (R) while the safe length of screw was more than 35 mm. The relative safety zone was between 3 and 5 o'clock (L) and between 7 and 9 o'clock (R) when the screw with a length of <24 mm was inserted posterolaterally and superiorly. Based on safe depths, it was safe when the screw was inserted posterolaterally and superiorly between the 12 and 1 o'clock position (L) and between the 11 and 12 o'clock position (R), laterally and inferiorly between the 6 and 7 o'clock position (L) and between 5 and 6 o'clock position (R). Screw insertion was forbidden between the 7 and 9 o'clock position (L) and between the 3 and 5 o'clock position (R), to prevent the iliac and obturator to acetabular floor. It was also forbidden to insert the screw between 9 and 12 o'clock positions (L) and between 12 and 3 o'clock positions (R), due to the thin pelvic wall.

Table 5. Safety zone for transacetabular screw fixation

	Left	Right
Posterolateral and superior		
Relative safety zone	12–1 o'clock	11–12 o'clock
Absolute safety zone	1–3 o'clock	9–11 o'clock
Posterolateral and inferior(<24mm)		
Relative safety zone	3–5 o'clock	7–9 o'clock
Absolute safety zone	5–6 o'clock	6–7 o'clock
Forbidden zone	7–9 o'clock, 9–12 o'clock	12–3 o'clock, 3–5 o'clock

Anatomical relationship between SN and the acetabulum in femoral neck nonunion with a highly elevated trochanter major

The anatomical relationship was analyzed intraoperatively with regard to the anatomical relationship between SN and the acetabulum in 42 patients with THA with highly elevated trochanter major (Table 6). There were no significant differences in most distance parameters between cadavers and patients, however, a significant difference was observed in distance A, B, and X between them (p<0.01). Distance A was the shortest (>4 mm) between 2 and 3 o'clock positions (L) and between 9 and 10 o'clock positions (R). Distance B was the shortest (>9 mm) in the 4 and 8 o'clock position, respectively, on the left and right side. The distance between the SN and the trochanter major was more than 42mm. The three distance parameters were significantly longer than the cadaver results (p<0.01) and the direction of the shortest distance was different from the cadaver results.

Table 6. Anatomical relationship between the SN and the acetabulum

Distance parameter	Distance			Direction (clockwise method)	
	Left (mm)	Right (mm)	p	Left	Right
A	4.3±0.29	4.4±0.31	0.89	2–3 o'clock	9–10 o'clock
B	9.2±0.34	9.5±0.45	0.84	4 o'clock	8 o'clock
X	42.3±1.87	44.1±1.82	0.79	–	–

Relationship between the risk zone of retractor placement and sciatic nerve palsy

When the retractor was placed in the aforementioned risk zones during the acetabular preparation, the prevalence of transient SN palsy was 8.3%, 19.4%, 72.3%, respectively, when the retractor was placed for 25, 30, 35 minutes (Table 7). Most SN palsy occurred in the case with retractors placed in risk zones (63.9% vs 8.4%). The mean duration of retractor placement for transient SN palsy was 31.2±2.8 minutes.

Table 7. Sciatic nerve palsy in different risk zones of retractor placement with various duration of retraction*

Duration (min)	Left (n=19)			Right (n=17)			Overall
	1–3 o'clock	3–5 o'clock	5–7 o'clock	5–7 o'clock	7–9 o'clock	9–11 o'clock	
25	0	2 (5.5)	0	0	1 (2.8)	0	3 (8.3)
30	0	3 (8.3)	0	0	4 (11.1)	0	7 (19.4)
35	1 (2.8)	12 (33.3)	1(2.8)	1 (2.8)	11 (30.6)	0	26 (72.3)

* The numbers in parenthesis present the percentage of cases of SN palsy

Discussion

To reduce the intraoperative neurovascular injury during THA, many qualitative and quantitative analyses of the anatomic relationship around the hip have been performed with increasing attention to MIS-THA.[14,20,21] Especially, the anatomic relationship between SN and mini-incision posterolateral approach has been studied among several authors.[2,3,20-22] The sciatic nerve (SN), the largest nerve in the human body, is formed in the pelvis from the union of L4-S3 ventral nerve L4-S3 and it normally courses as a single trunk following its union and exits as the most lateral structure from the upper sciatic foramen below the piriform muscle (PM). Thereafter, it continues its course inferiorly and the tibial and common peroneal components of the SN typically bifurcate at the apex of the popliteal fossa.[23] Many studies have proved the existence of several anatomic variants of the relationship between SN and PM, by cadaver examination and imaging such as CT and MRI.[23,24] There are seven anatomic variants and type I, a normal type is a most common with the prevalence of 80 to 90% followed by type II with 10 to 15%, type III with 1 to 3% and type IVVI with 1% or less in cadaveric studies.[23,25,26] In addition, there is a specific type (type VII) that shows unusual anatomic split into the tibial nerve and peroneal nerve passing separately below the PM.[27] Our results suggested that type I had a prevalence of 83.3% and abnormal type had a pooled prevalence of 16.7% among the Korean population, which was comparable with the previous studies.[21-27] The prevalence of the abnormal type showed the tendency of being higher in male than in female and higher with height.

We evaluated the anatomic relationship between SN and the acetabulum, qualitatively with clockwise direction method and quantitatively with several distance parameters. The SN was located at the site about 6mm far away from the inner surface of the acetabular floor, between 3 and 4 o'clock position (L) and between 8 and 9 o'clock position (R). The mean value of the shortest distance between the SN and the acetabular rim was greater than 13mm at 5 (L) and 7 (R) o'clock position. The ON exits from the obturator foramen to pass anteroinferiorly above the transverse acetabular ligament, while the mean value of the shortest distance from the ON to the acetabular rim was approximately 16 mm at 9 (L) and 3(R) o'clock position. The shortest distance between ON and the acetabular rim was measured at 13 mm in a hip of a female cadaver, indicating that electrocauterization of the ligament of femoral head could cause sudden and unexpected internal rotation of patient's hip in THA with anterolateral approach due to current conductivity by the retractor placed in this position. Therefore, we recommend that the retractors should be placed carefully around this area, and the utilization of electrocautery on the acetabular rim should be limited to a defined distance. This result presented the difference from the other previous results because they use the MRI and CT slices to measure the distance between the anatomic structures; however, they showed the same tendency in measured values.[8,19]

The femoral artery (FA) begins at the common iliac artery which continues inferiorly into the femoral artery at the level of the inguinal ligament, giving deep branches around the acetabulum.[20] The deep femoral artery bifurcates into the lateral circumflex artery at the level of the obturator foramen, passing anteriorly to the femoral neck with the mean value of the shortest distance of 18 mm to the acetabulum. With its running parallel to the ON, FA was very close to the acetabulum in 9 (L) and 3(R) o'clock position. In 2 hips of 2 female cadavers, the shortest distance was 16mm, indicating that electrocauterization in the area less than 16mm away from the acetabular rim might induce ON injury and abnormal contraction of muscle innervated by ON.

The shortest distance between the SN and bony structures, including ischial tuberosity, trochanter major, and sacral hiatus were over 17 mm, 29 mm and 67 mm, respectively. The thickness of the SN was measured as approximately 31 mm in the lateral position which was different from the previous results due to the different preparation and measuring posture. Several authors measured the sciatic nerve by width and thickness, which could be varied with different embalming methods.[22] However, these distance parameters could be important in determining the site for safe placement of retractors in the trochanter major and around the acetabulum.[8]

From the aforementioned results, we determined the safe zone of electrocauterization and retractor placement by identifying the risk zone. Proper retraction should be applied to the retractor placed between 3 and 5 o'clock position (L) and between 7 and 9 o'clock position (R) because the SN and the superior gluteal neurovascular bundle pass through this region. Prolonged and excessive retraction could cause nerve palsy in this region by compression-induced ischemia.[28] This suggests that if electrocauterization was applied near the retractor placed in this direction, current conduction might cause the indirect SN injury. Moderate retraction at 9 (L) and 3 (R) o'clock position could reduce the injury of FA and ON injury; however, excessive procedures could cause deep venous thrombosis and obturator nerve syndrome. The use of the electrocautery was forbidden between 10 and 12 o'clock position (L) and between 12 and 2 o'clock position (R) because the FN lies in this direction, which coincided with previous results.[19,28]

The mean value of the shortest distance between the greater sciatic foramen and the surface of the acetabular floor, reflecting the thickness of acetabular wall, was approximately 29 mm, which was larger in men than in female and with height. In a female cadaver with height of 142 cm, the shortest distance was 24 mm on the left side, demonstrating that the fixation screw with length of <24 mm could be absolutely safe in the acetabulum. Wasielewski et al. introduced the quartering method of the acetabulum for the determination of the safe zone of transacetabular screw fixation.[17] Our results suggested that screw fixation should be prohibited between 3 and 5 o'clock position (L) and between 7 and 9 o'clock position (R) due to the short distance to the SN. The absolute safety zone for screw fixation was between 1 and 3 o'clock position (L) and between 9 and 11 o'clock position (R) when a screw with the length of 40mm was inserted posterolaterally and superiorly, which was similar to the results (35 mm). The relative safety zone was between the 5 and the 6 o'clock position (L) and 6 and 7 o'clock position (R) when a screw with the length of <35 mm was inserted posteroinferiorly, comparable to the previous results.[17] The safe fixation of the screw with length of <24 mm was possible posterolaterally between the position 3 and 5 0'clock and between 7 and 9 o'clock position which was agreed with the fact that the shortest distance between greater sciatic foramen and the surface of the acetabular floor was 29 mm. Wasielewski et al. suggested that a screw with length of >25 mm could be fixed safely in this direction but this difference might come from the difference in skeletal phenotype between the European and Asian population.[17] In addition, posterolateral screw fixation was relatively safe between the position of 12 and 1 o'clock (L) and 11 and 12 o'clock position (R), respectively, superiorly and inferiorly. It might be explained by the fact that the safe direction of screw fixation was superior and inferiorly in posterolateral direction. An author reported that screw fixation should be avoided in this direction because this area had a thin wall (<25 mm), indicating the conflict with our results.[20] This conflict could come from variation in study subjects. Screw fixation was forbidden between the 7 and 9 o'clock position (L) and the 3 and 5 o'clock position (R) while it was avoided between the 9 and 12 o'clock position (L) and between the 12 and 3 o'clock position (R) because of thin wall and femoral neurovascular bundle close to it. Previous studies suggested the safety zone for transacetabular screw by mapping, but it was too complicated to understand and clinical application was limited.[17,20] In contrast, our recommended clockwise direction carries simplicity and practicality.

To identify the altered anatomic relationship between SN and adjacent structures, we measured three distance parameters during primary THA in patients with femoral neck nonunion. Our results demonstrated that among the distances from the SN to the inner surface of the acetabular floor, the acetabular rim and the trochanter major, two former were shorter and later was longer than the cadaveric results. The altered direction indicates that the surgeon should extrapolate the safe zone based on cadaveric results and care should be taken during surgical procedures such as retractor placement and electrocauterization.

For validation of the significance of the risk zones, we retrospectively reviewed a operative notes with the focus on the location and duration of retractors around the acetabulum during the acetabular preparation in THA. Our results suggest that SN was more vulnerable in the prolonged placement of the retractors in risk zones for more than 30 minutes, proving that our recommended zone for the safe procedure was practically significant.

However, the present study has certain limitations. The sample size was small and there may be a variation in the measurement of the cadaver specimens owing to the embalming process. Since cadaver samples are from a single institution, generalizability to other ethnic populations is limited. Despite this limitation, this study provides new information on the identification of safe zone of surgical procedures based on the qualitative and quantitative analysis of many anatomic parameters, which could contribute to the improvement of complications after MIS-THA with limited visualization, especially among unexperienced arthroplasty surgeons.

Conclusion

This study provides useful information to perform surgical procedures without causing neurovascular injury during MIS-THA, based on a comprehensive anatomic analysis of the acetabulum and the adjacent neurovascular structures.

Declarations

Funding

There is no funding support for this study.

Author contributions
Conceptualization, P.H-U. and R.K-C.; Methodology, P.H-U. and R.K-C.; Software, R.W-J.; Validation, P.H-U. and R.K-C.; Formal Analysis, C.T-H.; Data Curation, C.T-H.; Writing – Original Draft Preparation, P.H-U., P.C-J., C.T-H., R.W-J. and R.K-C.; Writing – Review & Editing, P.H-U.; Visualization, P.H-U. and R.K-C.; Supervision, P.C-J. and R.K-C.; Project Administration, P.H-U.

Conflicts of interest
The authors have no conflicts of interest to declare.

Data availability
Data available within the article or its supplementary materials.

Ethics approval
Institutional Review/Ethics Board approval was obtained for the present study (2024-PRK-A10245, Ethics Assembly, Pyongyang University of Medical Sciences).

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