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Research Article

Safety Zone of Surgical Procedure for the Prevention of Neurovascular Injury in Minimally Invasive Total Hip Arthroplasty

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Abstract

Background: With the development of minimally invasive surgery (MIS), decreased incision produces the limited visualization leading to increasing injury risk of adjacent neurovascular structures during procedure. Especially, it has become an important issue in the case of MIS total hip arthroplasty (MIS-THA) with its deep surgical field surrounded by major neurovascular structures. The aim of this study is to identify the safest zones of surgical procedures for the prevention of major neurovascular structures around the acetabulum.

Materials and Method: 84 cadaveric pelvic specimens with 168 hips were used to analyze the anatomic relationship between sciatic nerve and the piriformis muscle in normal Korean population according to gender and height. We performed the qualitative and quantitative analysis of the anatomic relationship between the acetabulum and sciatic nerve, based on the clockwise direction method, in order to identify the safety zones of surgical procedure proximity to acetabulum. During primary THA, 3 distance parameters between SN and bony structures were measured in 42 patients with highly elevated trochanter major. Retrospective analysis of retractor placement was performed in operative notes of 36 cases with transient SN palsy following THA.

Results: The prevalence of Type I(normal type) were over 79% and 88%, respectively, in male and female. The distance A, B and E were 7.1±0.78mm in between 3 and 4 o'clock position, 14.2±0.67mm between 8 and 9 o'clock position, 17.0±1.22mm in 9 o'clock position, respectively on the left side, whereas 6.0±0.69mm between 8 and 9 o'clock position, 14.8±0.59mm in 7 o'clock position, 17.9±1.08mm in 3 o'clock position on the right side. The retractors proximity to acetabulum should be placed with careful and proper retraction between 3 and 5 o'clock position on the left side and between 7 and 9 o'clock position on the right side, in which the placement in 9 and 3 o'clock position should be cautious respectively, on the right and left side. The utilization of electrocautery could be cautious between 3 and 5 o'clock position on the left side, and between 7 and 9 o'clock position on the right side. However, it should be avoided to perform the electrocauterization in 9 o'clock and 3 o'clock position respectively, on the left and right side, while it was forbidden between 10 and 12 on the left side and between 12 and 2 o'clock position on the right side.

Absolute safety zones for transacetabular screw placement were between 1 and 3, and between 5 and 6 o'clock position on the left side whereas between 9 and 11, and between 6 and 7 o'clock position on the right side. Relative safe zones were between 12 and 1, and between 6 and 7 o'clock position on the left whereas between 11 and 12, and between 5 and 6 o'clock position on the right side. Screw with length of <24mm could be safely inserted between 3 and 5 o'clock position on the left side and between 7 and 9 o'clock position on the right side. Risk zones were between 7 and 9, and between 9 and 12 o'clock position on the left side, while between 3 and 5, and between

12 and 3 o'clock position on the right side. In the cases with highly elevated trochanter major, distances between the acetabulum and adjacent neurovascular structures was changed and the risk of the SN increased. The placement of the retractors in the risk zone for 30 minutes or more caused the transient SN palsy in primary THA (91.7%).

Conclusion: Better understanding of anatomic relationship between acetabulum and adjacent neurovascular structure could provide a potential tool for full display of superiority of MIS in THA, based on the identification of safety zone and forbidden zone for avoiding the neurovascular injury during MIS-THA with limited incision length.

Keywords: sciatic nerve; piriformis muscle; obturator nerve; femoral artery; minimally invasive total hip arthroplasty

Introduction

Since the superiority of minimally invasive surgery over conventional surgery had been known as less damage and rapid functional recovery, it has been introduced to many orthopedic surgeries with the help of advanced surgical technique and instruments [1-6]. Especially, in minimally invasive total hip arthroplasty (MIS-THA) limited incision and narrow surgical field could cause the injury of adjacent neurovascular structures due to blind procedures in spite of the development in specialized instruments, and the success of MIS-THA is dependent on arthroplasty surgeon's experience [3,4,7].

The injury of neurovascular structure proximity to the acetabulum is one of the major complications following 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 most common [8,9]. Vascular injury during conventional THA is relatively rare (0.2-0.3%), but may result in considerable morbidity or even mortality [10]. It is reported that the incidence of neurovascular injury proximity to the acetabulum is higher in the patients with hip dislocation and pelvic fracture, and superior gluteal neurovascular injury is relatively more common among them [11,12,13].

There have been many literatures on the neurovascular injury around the acetabulum during surgery over the whole world [12-16]. Injury of sciatic nerve is common in THA with posterior approach, osteosynthesis of acetabular fracture and open reduction of hip dislocation, which could result in the severe functional impairment of hip and lower limb [8,9]. In THA, the most common identifiable cause of intraoperative SN injury is the direct and indirect mechanical damage including compression by malpositioned retractors, excessive/prolonged retraction and inappropriate electro-cauterization [13]. In addition, the 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 guiding safe surgical procedures during THA. Therefore, this study is designed to identify the anatomic relationship between the acetabulum and the adjacent neurovascular structures, and determine the relative and absolute safety zone with forbidden zone, quantitatively and qualitatively.

Materials and Method

The anatomy of the acetabulum and the adjacent neurovascular structures was examined in 168 hips derived from 84 adult formalin embalmed cadavers in our university's anatomy laboratory with an intact lower extremity were utilized for this study. An Institutional Review/Ethics Board approval was obtained for the present study. The dissections were performed by the skilled anatomist (D.K.S.). Each cadaver was placed in lateral position and the skin and the subcutaneous fat over the gluteus maximus were cut and removed completely to reveal the gluteus maximus. The gluteus maximus was dissected from its origin from the iliac crest. Its insertion on the iliotibial tract and the gluteal tuberosity was released to reflect the gluteus maximus inferiorly and medially. Next, the gluteus medius was dissected from its insertion and retracted laterally to identify the course and the branches of the sciatic nerve. The connective tissue and fat were dissected away 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 changed the relationship between the acetabulum and the 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 (Table1).

	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		
<155cm	0(0.0%)	9(25.0%)
156-160cm	5(10.4%)	19(52.8%)
161-165cm	17(35.4%)	7(19.4%)
166-170cm	19(39.5%)	1(2.8%)
>171cm	7(14.7%)	0(0.0%)

Table 1 Characteristics of cadaveric specimen

The anatomic variations were analyzed based on the classification as follows [18,19]:

I. ISN exits the pelvis undivided below the PM
II. SN divides in the pelvis, common peroneal nerve (CPN) pass through the bifid PM, and 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 pass 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 identification of the anatomic relationship between the acetabulum and its adjacent neurovascular structures such as SN, ON and FA, the intersection point (attachment site of iliofemoral ligament) between the acetabular rim and line connecting the anterior superior iliac spine and anterior inferior iliac spine was used as 12 o'clock position to determine the directions clockwise. Magnifying glass (×5) and the pin with ruler function was utilized to perform the distance measurement between neurovascular structures and the acetabulum. Distance parameters used in the analysis of anatomic relationship were as follows:

A- the shortest distance between the inferior margin and 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 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 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

Pin with ruler function was inserted vertically on the surface to measure the safe zone and depth of transacetabular screw according to the clockwise direction method in the cadaver's acetabulum. Intraoperative measurement was performed in 42 femoral neck nonunions with highly elevated trochanter major all of who underwent THA with posterolateral approach by P.H.U between November 2020 and June 2022. There were 34 men (80.9%) and 8 women (19.1%) with height of 169.3±13.2cm and 158.8±13.2cm, respectively, who had elevated trochanter major with mean height of 13.5±3.5mm. 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 reviewed retrospectively the operative note of 36 cases with transient sciatic nerve palsy following THA, based on the clockwise location and duration of retractor placement since we started the clinical measuring trial for determining the safe zone of surgical procedures during MIS-THA. All sciatic nerve palsy was recovered within 4 weeks. Duration of retractor placement was calculated as the time of the acetabular preparation.

Results

Anatomic variations between SN and PM

A total of 84 cadavers with 168 hips were examined in this study. The normal Type I variation where 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 seen 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. In addition, the abnormal type was observed on 18(90%) and 7(87.5%) left hips, respectively, in male and female cadavers, indicating that 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.

Gender	N	Type I (cadavers/hips)	Abnormal type					
			TypeII	TypeIII	TypeIV	TypeV	TypeVI	TypeVII
Male	48	40/76 (79.2%)	6/12 (12.5%)	2/3 (3.2%)	1/1 (1.0%)	1/2 (2.1%)	1/1 (1.0%)	1/1 (1.0%)
Female	36	34/64 (88.9%)	4/6 (8.3%)	1/1 (1.4%)	0/0 (0.0%)	1/1 (1.4%)	0/0 (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%)

Table 2 Anatomic relationship between the sciatic nerve and piriformis muscle

Percentanges in the parenthesis mean the proportion of individual variant among total number of hips.

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

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

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

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

Table 4: Anatomic relationship between the pelvis and the adjacent neurovascular structures (FA, SN)

Distance parameter	Left (mm)	Range(mm)	Right (mm)	Range(mm)
C	29.9±1.27	23.5-31.5	30.0±0.96	23.5-32.0
D	18.8±1.41	16.0-20.5	19.0±1.19	16.0-20.5
X	30.1±0.52	28.0-31.0	30.4±0.13	29.0-31.0
Y	18.1±0.99	16.0-19.5	18.2±0.87	16.0-19.5
Z	69.2±1.64	65.0-71.0	69.1±1.59	66.5-71.0
W	31.2±1.87	28.5-33.5	31.1±1.94	27.0-33.0

Table 3: Anatomic relationship between the acetabulum and the adjacent nerves (SN, ON)

Safety zone of electrocauterization and retractor placement in THA

Based on aforementioned results, the safety zone was determined by clockwise method. When the attachment site of iliofemoral ligament was determined as 12 o'clock position, it 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 were SN and superior gluteal neurovascular bundle proximity to this position. Retractors should be placed carefully in 9 o'clock position (L) and 3 o'clock position (R) in order to prevent the injury of FA and ON. If retractors must be placed in this position, utilization of electrocautery should be forbidden because of 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 the screw fixation for acetabular cup in THA

Our recommended safety zone of the screw fixation of the acetabular cup was summarized in Table 5. 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 posteroinferior insertion of screw, absolute safety zone was between 5 and 6 o'clock (L) and between 6 and 7 o'clock (R) whereas the safe length of screw was over 35 mm. Relative safety zone was between 3 and 5 o'clock (L) and between 7 and 9 o'clock (R) when the screw with length of <24mm was inserted posterolaterally and superiorly. Based on the safe depths, it was safe when the screw was inserted posterolaterally and superiorly between 12 and 1 o'clock position (L) and between 11 and 12 o'clock position (R), laterally and inferiorly between 6 and 7 o'clock position (L) and between 5 and 6 o'clock position (R). Screw insertion was forbidden between 7 and 9 o'clock position (L) and between 3 and 5 o'clock position (R), in order to prevent the iliac and obturator neurovascular bundle proximity to acetabular floor. It was also forbidden to insert the screw between 9 and 12 o'clock position (L) and between 12 and 3 o'clock position (R), due to thin pelvic wall.

	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

Table 5: Safety zone for transacetabular screw fixation

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

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

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

Table 6: Anatomic relationship between the SN and the acetabulum

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

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

Duration (Min)	Left(n=19)			Right(n=17)			Overall
	1-o'clock	3-5 o'clock	5-7o'clock	5-7o'clock	7-9 o'clock	9-11o'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)

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

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

Discussion

In order to reduce the intraoperative neurovascular injury during THA, many qualitative and quantitative analyses of anatomic relationship around the hip have been performed with increasing attention about MIS-THA [14,20,21]. Especially, the anatomic relationship between the 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 roots and it normally courses as a single trunk following its union and exits as the most lateral structure from the greater sciatic foramen below the piriformis 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 proved the existence of several anatomic variants of relationship between SN and PM, by cadaveric examination and imaging such as CT and MRI [23,24]. There are seven anatomic variants and type I, a normal type is the 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 IV-VI with 1% or less in cadaveric studies [23,25,26]. In addition, there is a specific type (type VII) which shows unusual anatomic split into 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 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 being 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 over 13mm in 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 ON to the acetabular rim was approximately 16mm in 9 (L) and 3(R) o'clock position. The shortest distance between ON and the acetabular rim was measured as 13mm in a hip of a female cadaver, indicating that electrocauterization on the ligament of femoral head could cause the sudden and unexpected internal rotation of patient's hip in THA with anterolateral approach due to current conductivity by retractor placed in this position. Therefore, we recommend that the retractors should be placed carefully around this area and utilization of electrocautery on the acetabular rim should be limited to 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].

Femoral artery (FA) begins at the common iliac artery which continues inferiorly into the femoral artery at the level of inguinal ligament, giving deep branches around the acetabulum [20]. Deep femoral artery bifurcates into 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 far away from the acetabular rim might induce the ON injury and abnormal contraction of muscle innervated by the ON.

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

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

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

In order to identify the altered anatomic relationship between the 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 trochanter major, two formers were shorter and later was longer than cadaveric results. The altered direction indicates that 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 significance of risk zones, we reviewed retrospectively the 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 longer than 30 minutes, proving that our recommended zone for safe procedure was practically significant.

However, present study has certain limitation. Sample size was small and there might be a variation in measurement of cadaveric specimens owing to embalm process. Despite this limitation, this study provides the new insight into 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 following MIS-THA with limited visualization, especially among unexperienced arthroplasty surgeons.

Conclusion

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

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