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ORIGINAL STUDY

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Safe and dangerous zones for the superficial femoral artery in femoral surgery

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The proximity of the superficial femoral artery (SFA) to the femur exposes the SFA to risks that have serious complications. Although surgeons have used the lateral or medial approach to lessen these risks, they have not been eliminated. Therefore, this study aimed to identify dangerous and safe zones in terms of the SFA that can be used during femoral surgical procedures, using anatomical reference points. Computed tomography angiography (CTA) of 50 patients aged between 16 and 60 years obtained from the local institution's database was examined. Radiological and clinical measurements were performed to determine the position of the SFA relative to the femur. The mean age of the patients included in this study was 38.08 ± 9.44 (16–60) years. The average ratio of the distance between the proximal and distal borders of the dangerous zone and the lateral joint spaces (LJS) to the distance between the greater trochanter (GT) and LJS was 0.5722 ± 0.053, respectively. The average ratio of the distance between the end of the dangerous zone and LJS to the distance between the GT and LJS was 0.4108 ± 0.05026. This study found that 40% and 60% of the clinically measured distance between the GT and LJS can be used to determine safe and dangerous zones during femoral surgery. Additionally, the half distance between the anterior superior iliac spine (ASIS) and medial joint space (MJS) and one-fourth of the distance between the ASIS and LJS can be used to determine safe and dangerous zones in patients whose GT are not easily palpated.

Keywords : Dangerous zone, safe zone, superficial femoral artery.

INTRODUCTION

The proximity of the superficial femoral artery (SFA) to the femur leads to risks during femoral orthopedic surgery *(1)*. To minimize these risks, lateral approaches to surgery are used *(2)*. However, the drilling and screw penetration used in this procedure can injure the SFA, which may also happen during external fixator procedures *(2,3)*. In contrast, a medial approach may be required in periprosthetic fractures where sufficient stability cannot be achieved with the lateral plate or in cases wherein closed wedge osteotomy is planned from

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the medial of the femur *(4,5)*. In this approach, the SFA and its branches are close to the incision site, which may lead to surgical exposure and iatrogenic damage *(6,7)*. In recent years, the increased use of nails in femoral fractures have led to a decrease of these risks during the medial approach; however, nail locking or cerclage procedure may still damage the SFA *(8,9)*. The significance of the SFA has led numerous studies to identify a safe zone for surgical exposure of the SFA *(8,10)*. The region wherein the SFA is medial to the femur is called the dangerous zone; specifically, it is the area between the point where the SFA crosses the anterior cortex of the femur in the sagittal plane and the point where the femur crosses the posterior cortex distally.

Conversely, the distance between the point where the SFA crosses to the posterior cortex of the femur and the medial joint space (MJS) of the knee is called the safe zone *(7,8,10)*.

This study aimed to determine the dangerous and safe zones to be used during femoral surgical procedures without additional preoperative study such as computed tomography angiography (CTA).

MATERIALS AND METHODS

This study was approved by the local institutional review board and conducted in accordance with the principles of the Declaration of Helsinki. The CTA images of the lower extremities of 50 patients obtained from the local institution's database were examined. Patients aged between 16 and 60 who underwent lower extremity CTA were included in this study. Patients with lower extremity deformity and peripheral vascular disease and those unwilling to participate in this study were excluded. To determine the position of the SFA in relation to the femur, axial CTA images with 3D reconstruction of both femurs were analyzed by two orthopedic surgeons. These surgeons independently analyzed the images which were compared to ascertain the consistency of the data. Interobserver and intraobserver reliability for radiographic measurements were assessed using intraclass correlation coefficients (ICC) calculated from three sets of repeat measurements on a subset of 50 radiographs, each at least 1 week apart for each observer. The following scores were used: ICC >0.80, excellent; 0.70–0.80, very good; 0.60–0.70, good; 0.40–0.60, fair; and <0.40, poor.

While making measurements in this study, anatomical points that can be easily determined clinically were referenced. For this reason, the GT and ASIS in the proximal and the MJS and LJS in the distal area were used as reference points.

The SFA runs from proximal to distal and anterior to posterior. In the axial plane, three different levels were determined relative to the posterior condylar axis, where the SFA crosses the front and the middle of the bone and the posterior incision of the bone. The distance between the point where the SFA crosses the anterior cortex of the femur and the point where it crosses the posterior cortex in the sagittal plane was defined as the dangerous zone. In contrast, the distance between the point where the SFA crosses the posterior cortex of the femur in the sagittal plane and the MJS was defined as the safe zone (Figure 1).

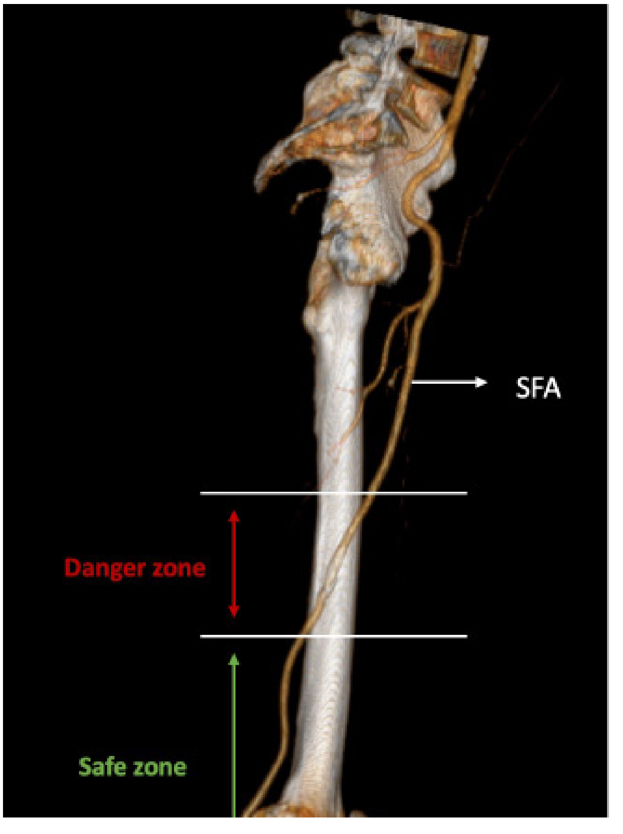

Fig. 1. – Demonstration of dangerous and safe zones in 3D CTA sagittal plane image.

The following measurements were used to determine the position of the SFA relative to the femur.

1. The posterior condylar axis was determined with a line intersecting the posterior borders of the medial and lateral condyles in the axial CTA.

2. Joint spaces were found in the axial CTA and the specific slice number was recorded.

3. The posterior condylar axis was used as the reference, and the anterior crossing point of the SFA with respect to the femur shaft while passing from anterior to posterior and posterior crossing points of the SFA with respect to the femur shaft in the axial plane were determined, and the slice numbers of the CTA were recorded (Figure 2).

4. The difference between the determined slice numbers was multiplied by the slice thickness, and the distances were measured.

The following measurements were performed using the CTA

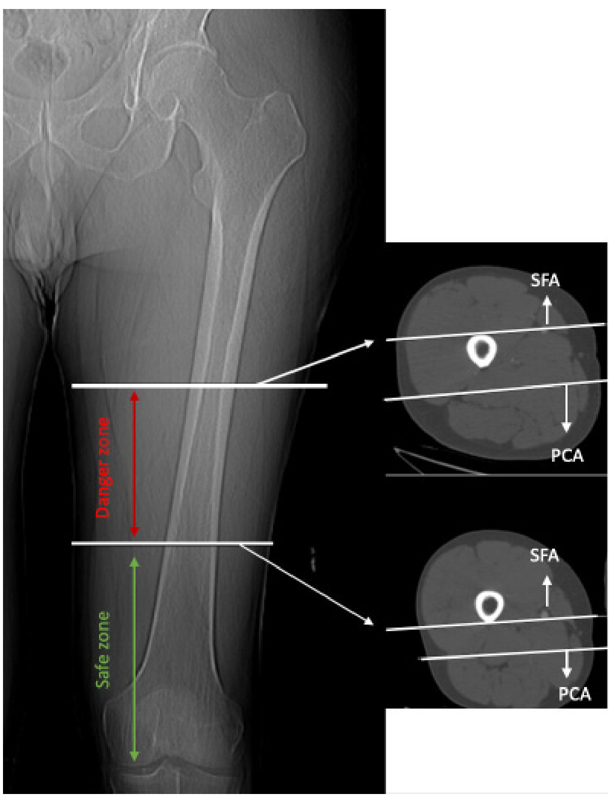

Fig. 2. – Demonstration of safe and dangerous zones with the points where the SFA crosses the anterior and posterior of the femur with reference to the posterior condylar axis.

1. Femoral width (FW): The distance between the most prominent points of the medial and lateral epicondyles.

2. Lower limb length (ASİS-MM): The distance between the ASIS and the medial malleolus.

3. The vertical distance between the GT to the LJS.

4. The distance between the tip of the femoral head (FH) and the intercondylar notch(IN).

5. The distance between the GT to the AT.

6. The distance between the ASIS and LJS.

7. The distance between the ASIS and the MJS.

8. The distance between the SFA and the femur in the dangerous zone.

The following measurements are manual measurements at clinical controls.

1. The distance between the ASIS and the LJS

2. The distance between the GT and the LJS

3. The distance between the ASIS and MJS

Statistical analysis was performed using SPSS (version 22, SPSS Inc., Chicago, IL) for Windows. For descriptive statistics, categorical variables area presented as number and percentage while continuous variables were presented as mean, standard deviation, minimum and maximum values. Statistical significance level of alpha was set at $p<0.05$

RESULTS

The mean age of the patients included in this study was 38.08 (range, 16–60) years. Forty-two (84%) of the 50 patients were males and 8 (16%) were females. The right lower extremity was measured in 20 (40%) patients, whereas the left was measured in 30 (60%).

The mean distance between the GT-LJS was 423 ± 25.6 mm. The mean distance between the FH-IN was 437.2 ± 27.5 mm. The average distance between the lower limb length (ASIS-MM) of the patients was 889.5 ± 53.8. The average distance between the ASIS and LJS was 529.52 ± 25.6 mm. The average distance between the ASIS and MJS was 535.02 ± 25.6 mm. In addition, the distance between the GT-AT was 407.2 ± 25.4. The average distance between the SFA and femur was 26,94 ± 6,05.

The average distance between the GT-LJS was 423.6 ± 24.6. The average distance between the

ASIS and LJS, was 532.26± 25.6. The average distance between the ASIS and MJS was 536.42± 25.6.

The average distance between the MJS and the point where the SFA crosses the posterior or anterior cortex of the femur in the sagittal plane was measured at 174.9±22.5 (range, 141–225) and 250.9±24.6 (range, 202.5–300), respectively.

The mean ratio of the distance between the start of the dangerous zone and LJS to the distance between the GT and LJS was 0.5722 ± 0.053 (95% CI, 0.55–0.59). The mean ratio of the distance between the end of the dangerous zone and LJS to the distance between the GT and LJS was 0.4108 ± 0.05026 (95% CI, 0.4–0.43). The mean ratio of the distance between the start of the dangerous zone and MJS to the distance between ASIS and MJS was 0.47 ± 0.04 (95% CI, 0.32–0.34). The mean ratio of the distance between the end of the dangerous zone and MJS to the distance between ASIS and MJS was 0.33 ± 0.04 (95% CI, 0.47–0.49) (Table I).

DISCUSSION

The close proximity of the SFA and femur leads to SFA injury during femoral surgery; these injuries include occlusion, aneurysm, and perforation which may lead to serious consequences *(1,2,11)*. The lateral approach is the preferred method to avoid the risks presented by the close proximity of these two structures *(12)*. Although the lateral approach itself does not expose the SFA to injury, specific procedures including drilling or screw penetration may still damage the SFA *(2,3)*. According to Narulla et al., the area where the SFA is located medial to the femur in the sagittal plane is the most dangerous area prone to these injuries (8). The persistence of the risks of the lateral approach prompt some surgeons to use the medial approach in multi-part unstable fractures, periprosthetic fractures, and deformity correction *(4,13)*. The anatomical relationship between the SFA and the femur is crucial in the medial approach *(10)*. The distance between the point where the SFA turns to the posterior cortex of the femur and the MJS of the knee is called the safe zone. There have been numerous radiological and cadaveric studies performed to determine the safe and dangerous zone *(7,8,10,14,15)*.

Kim et al. studied the relationship between the femur and the femoral artery (FA) and deep femoral artery (DFA) using CTA and evaluated the safe zone for the medial minimally invasive plate osteosynthesis (MIPO) technique in the distal femur *(10)*. In their study, the area from the adductor tubercle up to 15 cm below the lesser trochanter was determined as a safe area. However, the height of the patients was not considered in determining the safe zone in their studies. The difference of our study from the study is that instead of giving a fixed numerical value to determine the safe zone, it gives a ratio to determine the safe zone and evaluates the usability of this ratio in clinical practice. In addition, the trochanter minor was used as a reference point in determining the safe zone in the study of Kim et al. *(10)*. In this study, the determination of the safe zone is dependent on radiological measurements

Table I. – Statistical analysis

	Mean	Std. deviation
The ratio of the distance between the GT – LJS and the LJS to the start of the safe zone	,4108	,00711
The ratio of the distance between the ASIS – LJS and the LJS to the start of the safe zone	,3296	,00581
The ratio of the distance between the GT - LJS and the LJS to the start of the dangerous zone	,5878	,00760
The ratio of the distance between the ASIS – MJS and the LJS to the start of the dangerous zone	,4725	,00760

GT: Greater trochanter; LJS: Lateral joint space; ASIS: Anterior spina iliaca superior; MJS: Medial joint space; Std.= standart since clinical detection of the trochanter minor is not possible.

Jiamton et al. *(7)* attempted to identify a safe zone for osteosynthesis with a medial minimally invasive plate. In their study, the distance between the point where the SFA crosses with the posterior cortex of the femur in the sagittal plane and the MJS was accepted as the safe zone *(7)*. It was found that this safe zone is approximately 40% of the GT-LJS and that the distal 40% of the femur is safe. This was consistent with this study; however, the advantage of this study was that it was performed using clinical measurements. In this study, the distances between GT-LJS, ASIS-LJS, and ASIS-MJS were measured clinically by two different surgeons, and the correlation of the measurements was evaluated and found an 80% correlation.

Narulla et al. *(8)* reported practical results for the detection of safe and dangerous areas. For a personalized estimate of the onset of the safe zone during surgery, the width of the femoral condyles at the widest point on a true anteroposterior (AP) X-ray can be doubled to estimate the proximal distance to the AT, which is safe for intervention. In this study, it was determined that the distance from AT to the middle point of the danger zone can be estimated by measuring the distance from the GT to the AT with a real AP X-ray or manually then halving this distance. However, clinical measurements of GT and AT or femur width were not reported in this study.

In all the patients in this study, the ratio of the distance between the start of the dangerous zone and MJS to the distance between the GT and LJS was 60%. Using 60% of the distance between the GT and LJS and 40% of the distance between the GT and LJS, the danger zone was determined as the middle 20% of the distance between the GT-LJS. Further, the ratio of the distance between the end of the dangerous zone and MJS to the distance between the GT and LJS was 40% in all the patients. The ratio presented the opportunity to use 40% of the distance between the GT and LJS to determine the safe zone (Figure 3).

In all the patients, the ratio of the distance between the start of the mean dangerous zone and MJS to the distance between ASIS and MJS was less than 50%. Thus, the distance between 50% of the distance between ASIS and MJS and 25% of the distance between ASIS and LJS was defined as a dangerous zone. Further, the ratio of the safe zone length to the distance between ASIS and LJS was greater than 25% of the distance between the ASIS and LJS in all the patients. This ratio gave us the opportunity to use 25% of the distance between ASIS and LJS to determine the safe zone (Figure 3).

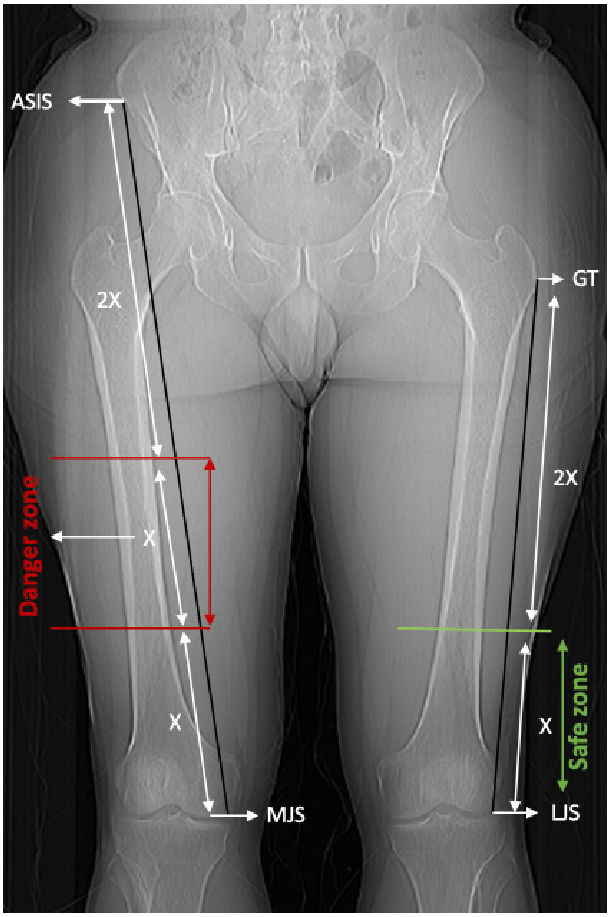

Fig. 3. – Maintenance of safe and danger zones in the CTA scanogram.

Another advantage of the ratios being 1 in 4 and 1 in 2 is that it allows the determination of both the safe and danger zone by using any cable, such as a cautery cable, during the procedure. In this way, the use of a ruler or tape measure in determining the safe and dangerous areas using anatomical reference points during surgery is unnecessary. The results obtained in this limited study series must be confirmed by future studies on a larger series of patients.

Our study had a few limitations. First, it is not supported by anatomical cadaver studies. Second, measurements of the deep femoral artery cannot be made. Third, the measurements were performed according to the SFA would only be at risk of penetration within a plane that is parallel to the posterior condylar axis of the distal femur. If a drill bit were to be passed through the femur in any other plane than the posterior condylar axis of the distal femur, then the location of "safe" and "dangerous" zones would of course be entirely different from those described in this study. Though obvious, this could be thought as another limitation. Despite the limitations, this study had several strengths. To the best of our knowledge, this is the largest case series describing safe and dangerous zones for the SFA with detailed analysis of literature. In addition, we described the course of SFA in our study by the ratios of various lengths in the lower extremities to each other. These ratios allow safe and dangerous zones of SFA to be easily detected intraoperatively.

CONCLUSION

In conclusion, 40% and 60% of the clinically measured distance between the GT and LJS can be used to detect the safe and dangerous zone during the medial approach and when drilling the femur during the lateral approach. In addition, in patients where GT cannot be detected by palpation, safe and dangerous areas can be easily detected by using half the distance between the ASIS and the MJS and one-fourth of the distance between the ASIS and the LJS.

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