



# Identification of the medial femoral safe zone for drilling during dynamic hip screw side plate fixation: A CT angiogram tracing of the profunda femoris artery

Samer S.S. Mahmoud<sup>a,1,\*</sup>, Bessam Ahmed<sup>b,1</sup>, Khalid Hamid<sup>c,1</sup>, Simon Milburn<sup>d,1</sup>, Paul Baker<sup>e,1</sup>

<sup>a</sup> MB BCH, MRCS, MSc, SICOT Dip, Specialty registrar of trauma and Orthopaedics, Health Education North East, United Kingdom

<sup>b</sup> Specialty registrar of trauma and Orthopaedics, Health Education North East, United Kingdom

<sup>c</sup> MRCS Edinburgh, Clinical Fellow in general surgery, Queen Elizabeth Hospital, Gateshead, United Kingdom

<sup>d</sup> Consultant radiologist, South Tees Hospital NHS Foundation Trust, United Kingdom

<sup>e</sup> DipStat PGCert(Clin Res) FRCS(Trauma and Orthopaedics), Consultant Orthopaedic Surgeon, South Tees Hospitals NHS Foundation Trust, Clinical Research University of York, United Kingdom

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## ABSTRACT

**Objectives:** Iatrogenic injury of the Profunda Femoris Artery (PFA) at time of hip fixation surgery can increase morbidity and mortality and prolong the hospital stay. This is an injury that tends to pass unnoticed as a cause of postoperative deterioration despite being frequently reported in the literature. Our study aims to describe the anatomy of the PFA in relation to the medial femoral cortex with specific emphasis on its orientation relative to the position of a sliding hip screw side plate construct. By doing so we are able to present clear guidance to orthopaedic surgeons on how to avoid iatrogenic PFA injury at the time of hip fracture fixation.

**Methods:** Using Computed Tomography Angiographic (CTA) studies, the course of the PFA in relation to the medial femoral cortex was traced in 44 patients (28 males and 16 females) with mean age of 65.6 years. Coronal and axial CT sections were cross-linked to specify the position of the PFA at 1 cm intervals.

**Results:** The course of the artery could be divided into three parts relative to a fixed reference point. Proximal and distal parts of the artery were in a safer position in comparison to the middle part of the artery that was found very close to the femoral cortex and along the coronal axis of the femur (mean angle 2.9° from the femoral coronal axis and 13.8 mm from the medial femoral cortex). Using the commercially available side plate constructs, this part of the artery corresponded to the distal part of the plate (third and fourth holes).

**Conclusion:** Special attention needs to be practiced by the operating surgeon while drilling into the third and fourth holes of the side plate.

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## Introduction

Optimization of the operative techniques of hip fracture fixation is a key component of improving healthcare in the face of a globally aging population. During the year 2016, 40.6% of hip fractures in the UK were extracapsular (AO/OTA 31 A), 79.8% of these were treated by Sliding Hip Screw construct (SHS) [1]. On

2017, sliding hip screw construct was the most commonly used device for management of neck of femur fractures accounting to 32.1% of all operative techniques employed [2]. Injury of the profunda femoris artery (PFA) at time of fixation of proximal femoral fractures has been frequently reported in the current literature [3–6]. Most of those reports are at level 4 of the evidence hierarchy; hence, they tend to be overlooked by the treating surgeons. Therefore, less is known about the existence and outcomes of this significant life threatening complication.

The lack of awareness and specific clinical presentation of this complication means the complication is often diagnosed late. A high level of suspicion is needed to enable early diagnosis and management of profunda femoris artery lacerations. Knowledge of the anatomy of the artery and its relation to the medial femoral

\* Corresponding author at: University Hospital North Tees, Hardwick Rd, Hardwick, Stockton-on-Tees, United Kingdom.

E-mail address: [samermahmoud@me.com](mailto:samermahmoud@me.com) (S.S.S. Mahmoud).

<sup>1</sup> Study performed at, Department of Trauma and Orthopaedics, James Cook University Hospital, Marton Road, Middlesbrough, England, TS4 3BW, United Kingdom.

cortex will help surgeons to predict the danger zones and practice prudent drilling on insertion of the femoral shaft screws.

Computed Tomography Angiographic (CTA) studies were previously used successfully to predict safe zones while drilling for fixation of bones in proximity to major vessels, e.g.: clavicle [7].

Previous cadaveric studies investigated the anatomy of the profunda femoris artery including origin and branches [8,9]. However, none of these have correlated the course of the artery to the medial femoral cortex to establish the medial safe zone during drilling.

We carried out this project using CTA to trace the course of the PFA in relation to the medial femoral cortex. Our main aims were A) to raise awareness of such a significant complication that could be life threatening to elderly patients and B) To help surgeons to avoid this complication by highlighting the danger zones where deep drilling could result in iatrogenic laceration of the vessel wall.

## Materials and methods

We used the local radiology archiving software (IMPAX<sup>®</sup>, AGFA Healthcare, NV Belgium) to identify patients who underwent peripheral lower limb Computerized Tomography Angiogram (CTA) between July 2015 and July 2016. Radiologists' reports were reviewed and Images inspected to exclude patients with previous metal implants, femoral fractures, vascular anomalies, stenosis or previous surgical intervention proximal to the PFA. Patients with scans not including the distal femur were also excluded for methodology purposes.

A reference point for measurement was identified on the coronal images as the midpoint of the base of the lesser trochanter. The length of the base of the lesser trochanter was measured (in mm) on the coronal cut and the midpoint of this measurement was identified as the reference point. Axial section corresponding to the reference point was identified through cross-linking function of the software and this was labelled as the reference level from which the measurement would start (1 and 2).

Length of the PFA was taken as the vertical distance between the reference point and the termination of the PFA on the coronal CTA sections (Fig. 3).

Axial CTA sections at 1 cm intervals starting from the reference point, and down to the termination of the artery, were used to trace the course of the PFA. On each axial section, the coronal axis of the



**Fig. 1.** Axial cut showing the identification of the PFA, superficial femoral artery, Femur and lesser trochanter.

femur was referenced to the femoral transepicondylar axis (TEA) as defined by Berger et al [10]. This was labelled as line A. The position of the PFA relative to Line A was noted and initially recorded as Anteromedial, Medial or Posteromedial.

A second line through the centre of the PFA and meeting Line A at the lateral femoral cortex was labelled as line B. Line B represents the straight line of lateral to medial drilling.

Angle subtended between the lines A and B was measured (in degrees) and labelled as Angle X.

Angle X was Zero degrees when the centre of the PFA was found along the Line A and assigned positive values for anteromedial angles and negative for the posteromedial positions. The distance between the medial femoral cortex and the lateral wall of the PFA along Line B was recorded in millimetres and labelled as Distance D (Fig. 4).

The course of the PFA in relation to the femoral shaft was then correlated to the most commercially available DHS (Dynamic Hip Screw side plate) construct designs (Stryker<sup>®</sup>, MI, USA and DePuy Synthes<sup>®</sup>, Leeds, United Kingdom). This was aimed at identifying the dangerous screws on the plate where careful drilling must be practiced, a key clinical component of the study.

We postulated that the danger zone of drilling, if identified by our results, will be a zone where the artery lies within 15 mm of the femoral medial cortex and within 15° (Anterior or posterior) of the femoral midcoronal plane.

## Statistical analysis

Microsoft Excel (Microsoft<sup>®</sup>, Redmond, Washington) was used to calculate the mean, median and Standard Deviation values of the angle X and distance D.

## Results

Out of 99 CTA scans reviewed, 51 were excluded because of vascular or bony abnormalities. We further excluded four scans, of 4 female patients, because the sections did not include the distal femur. Scans of 28 males and 16 females with mean age of 65.6 (19–96) years (SD = 17.3) were eligible for inclusion. The average length of the PFA was 11.3 (8.1–16.2) cm (SD = 2). Only one of the scans showed a PFA of 16 cm long while the rest of the scans demonstrated arteries that terminated between 13–14 cm point. This case was excluded on calculation of the overall means to avoid deviation of the mean values because of the abnormally long length of the artery; however, the angles and distances of the distal 2 cm were noted for this case separately.

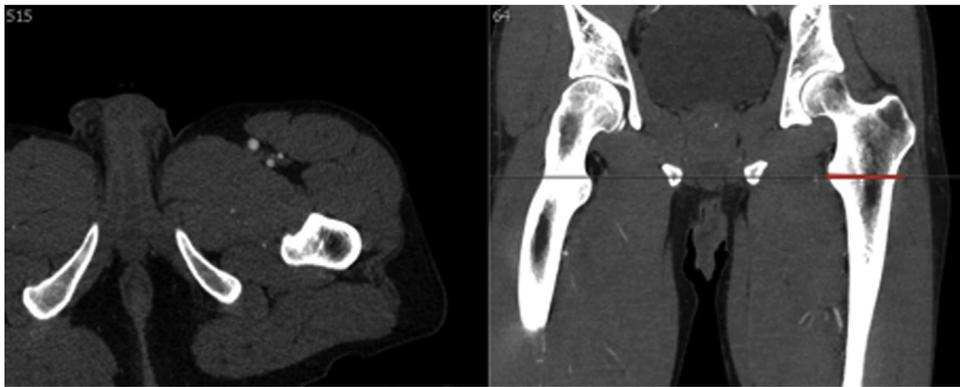
Our results showed that the course of the artery could be further divided into proximal, middle and distal parts as the PFA acquired different positions in each third.

### Proximal third

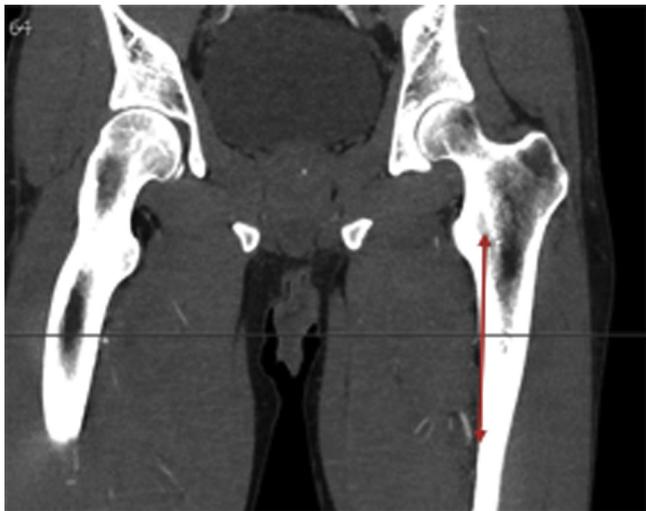
At the proximal 4 cm, the mean angle (X) of the artery in relation to the femoral TEA was 17.7° decreasing from 22.72° at 1 cm from the reference point to 11.66° at 4 cm distal to it. The mean distance (D) has changed from 31.4 (15.7–58) mm proximally to 20.1 (9.5–32.1) mm at the 4 cm level. The overall mean of the proximal 4 cm was 25.6 mm (Table 1). Figs. 5 and 6 shows example of sections of the proximal third of the artery.

### Middle third

At the next 4 cm of the length of the artery (5–8 cm from the reference point), the overall mean angle (X) was -2.97 with the PFA curving posteriorly, from a mean angle of 6.66 deg at 5 cm from the reference point to -12.8 deg at 8 cm. The overall mean of the



**Fig. 2.** Coronal section with the red line representing the reference level (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).



**Fig. 3.** Double headed arrow representing the measurement of the length of the PFA.



**Fig. 4.** Methodology lines and angles.  
Line A: Femoral midcoronal plane parallel to the TEA, Line B: meeting line A at the lateral femoral cortex and passing through the centre of the PFA, Distance D (mm): distance between the near femoral cortex and the lateral wall of the PFA along line B and angle X: Subtended between lines A and B.

distance (D) over the middle part was 13.86 mm. This decreased from 16.7 mm at 5 cm to 11.36 mm at 8 cm. (Table 2)

Fig. 7 shows an example of section through the middle third of the artery length.

### Distal third

Between 9–14 cm distal to the reference point, the mean angle (X) continued to regress from -17.2 at 9 cm to -46.43 deg at 14 cm (Overall mean -33.73 deg). The distance (D) continued to decrease from 10.6 at 9 cm to 7.1 mm at 14 cm (Overall mean 8.9 mm). (Table 3)

In the scan showing a 16 cm long PFA, the artery was found at X angles of -52.6 and -50.4 deg and at a distance D of 7.3 and 6.6 mm at the 15 and 16 cm points respectively. Figs. 8 and 9 showing sections of the distal third of the arterial length.

We reviewed the postoperative X-rays for patients who underwent Sliding Hip screw side plate fixation for proximal femoral fractures and found that in all X-rays, the barrel of the side plate was approximately at the level of the lesser trochanter. Hence, the centre of the barrel will be at, or very close to, our reference point. Using the plate construct in vitro, we measured the distance between the centre of the barrel and the centres of the screw holes on the shaft of side plate. This showed that the proximal two screws of the commercially available Sliding Hip screw constructs were at the region of the proximal third of the PFA while the distal two screws were related to the middle third of the artery. (Table 4)

### Discussion

Our study confirms that the PFA is at risk of damage during the procedure of fixation of proximal femoral fracture. However, it contradicts the previously established thought among orthopaedic surgeons that the risk of injury is more while drilling the proximal screws.

Angiographic studies were previously used to guide safe drilling during fixation of fractures in close proximity to vital structures [7].

In comparison to the previously published studies [7], ours had a satisfactory number of patients (n=44). In addition, the age distribution of our cohort was representative of the age group expected to undergo proximal femoral fixation (mean age = 65.6 and median age = 63 years).

It is understood that CT Angiogram is a static radiographic imaging and it will provide the position of the artery at the point in time when the image was obtained. This varies from the intra-

**Table 1**

Values of the angle (X) and the distance (D) at the proximal 4 cm of the course of the PFA.

Proximal Third Angles (X) (Degrees)				
	1 cm	2 cm	3 cm	4 cm
Mean (Range)	22.72 (7.1 - 58)	19.8 (1.9-57.4)	16.5 (-3.9-55.1)	11.66 (-10.3-50)
SD	9.7	10	11.4	12
Proximal Third distances (D) (mm)				
	1 cm	2 cm	3 cm	4 cm
Mean (Range)	31.4 (15.7-58)	27.3 (15.6-43.5)	23.6 (12.6-38.2)	20.1 (9.5-32.1)
SD	8.6	6.6	5.8	4.72

**Figs. 5 and 6.** Examples of sections of the proximal third of the arterial length showing the anteromedial position of the PFA in relation to the femur.**Table 2**

Values of the angle (X) and the distance (D) at the middle 4 cm of the course of the PFA.

Middle Third Angles (X) (degrees)				
	5 cm	6 cm	7 cm	8 cm
Mean (Range)	6.66 (-18.2-45.1)	0.4 (-34-39)	-6.25 (-38-31)	-12.8 (-46.8-22.4)
SD	12.9	14.3	14.1	15
Middle Third distances (D) (mm)				
	5 cm	6 cm	7 cm	8 cm
Mean (Range)	16.7 (6.7-24.7)	14.4 (5-23.2)	13 (4.1-25.9)	11.36 (3.1-25.1)
SD	5	4.4	4.8	4.4

operative environment where the patient is on traction and the lower limb is internally or externally rotated. Being aware of those two facts, we aimed at providing an image of the artery with an expected position in relation to the femur identifying the safe part

(far from the femoral cortex and line of drilling), the proximal and distal segments in our results, and the dangerous part (near the femoral cortex and in line with mid-coronal axis), the middle segment.

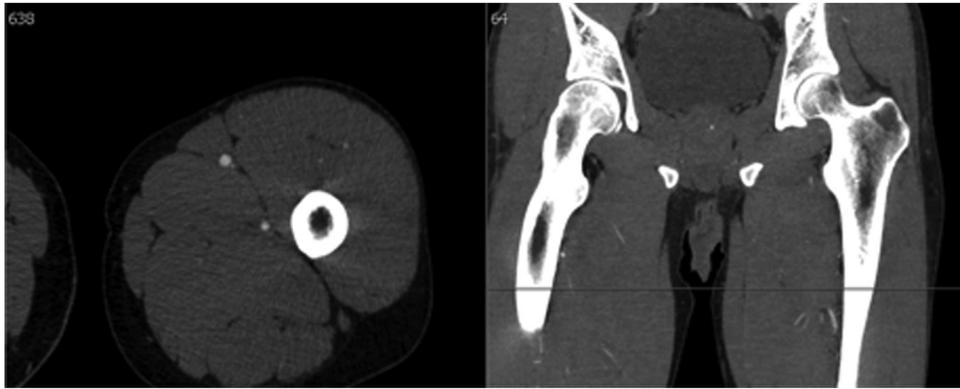


Fig. 7. Example of a section through the middle part of the PFA with the artery being close to the femoral cortex and along the mid-coronal plane of the femur.

**Table 3**

Values of the angle (X) and the distance (D) at the distal part of the course of the PFA.

Distal Third Angles (X) (degrees)								
	9 cm	10 cm	11 cm	12 cm	13 cm	14 cm	15 cm (one patient)	16 cm (one patient)
Mean	-17.2 (-42.6-	-22.48 (-47.8-	-31 (-60.9-	-38.9 (-64.6:-	-46.37 (-67.9:-	-46.43 (-52.8:-	-52.4	-50.4
(Range)	16.4)	14.2)	6.2)	13.1)	24)	35.8)		
SD	14.7	16.21	15	15.7	13.13	9.3		
Distal Third distances (D) (mm)								
	9 cm	10 cm	11 cm	12 cm	13 cm	14 cm	15 cm (one patient)	16 cm (one patient)
Mean (Range)	10.6 (3.8-22)	9.6 (1.9-18.9)	9.35 (1-23.5)	7.91 (3.1:15.6)	8.8 (6.3:13.7)	7.1 (4.7:10)	7.3	6.6
SD	4.1	4.3	5.4	3.44	2.5	2.7		



Figs. 8 and 9. Examples of the PFA distal third (figure 8) and near its termination (figure 9) where it lies posterior to the mid-coronal plane.

**Table 4**

The distances between the centre of the barrel and the centres of the screw holes of the commercially available sliding hip screw side plate constructs.

	AO Synthes®	Stryker®
Screw 1	19 mm	22 mm
Screw 2	35 mm	38 mm
Screw 3	51 mm	54 mm
Screw 4	67 mm	70 mm

The design of the study methodology was discussed among the authors and there was an agreement that this would be the most precise approach to trace the course of the artery.

To our knowledge, this is the first study to investigate the relationship of the PFA to the femoral cortex to enhance safety of the fixation procedure of proximal femoral fractures.

Published reports demonstrates that PFA injuries are commonly missed or diagnosed at a late stage (Up to 3–4 weeks post-operatively [11,12]). The uncertain presentation following PFA perforation is a major contributor to missing the injury. The commonly reported presentations were thigh swelling, hematoma and persistent anaemia [3,5,6,11–16]. Other unusual presentations included thigh compartment syndrome [17].

United Kingdom's 2016 NHFD (National Hip Fracture Database) report showed 6.7 percent 30 day mortality rate following the hip fracture [1]. Identifying complications that are commonly overlooked, like injury to the PFA, can reduce mortality rates during the early post-operative period.

More than 45 percent of the patients admitted to hospitals with hip fractures are anaemic [18]. Iatrogenic injury to the PFA can add to their established comorbidities and represent a life threatening injury.

Iatrogenic perforation of the PFA was reported with various fixation procedures for different femoral fractures. It was most commonly associated with SHS constructs [3,5,6,11,13], however, other different procedures, for instance, intramedullary nail fixation [12,14,19] and external fixation [20] could not avoid the PFA injury. PFA was also reported with placement of the proximal locking screw of a retrograde femoral intramedullary nail for distal femoral fractures [21]. Edges of the displaced fracture fragments can equally lacerate the PFA with excessive manipulation of the fracture or during fracture reduction [4,16].

We offered a guide to avoid injury of the PFA on operative fixation, of proximal femoral fractures, using the most commonly used implant (SHS).

In addition, we presented a short review of the presentations of this injury. One should have a high index of suspicion and awareness of PFA lacerations whilst performing any proximal femoral intervention. This is particularly required in the presence of the modern minimally invasive embolization techniques that could be life saving to the affected patient once the injury is diagnosed [22,23].

## Conclusion

Our results showed that the PFA acquires a posteriorly spiralling course that starts proximally anteromedial to the femur, then gradually descends medially where it becomes in close proximity to the medial femoral cortex before winding posteriorly and terminating as the fourth perforator.

The middle part of the artery (5–8 cm) from the reference point lies in close proximity to the medial femoral cortex and is closely aligned with the mid-coronal axis of the femur. Hence, this is the arterial segment at the highest risk of injury on drilling at time of proximal femoral fixation. i.e.: the danger zone.

This part corresponds to the distal part of the plate (both designs), specifically, the third and fourth screw holes on the shaft of the plate. Thus, excessive care needs to be practiced by the operating surgeon while drilling those screws to avoid arterial injury.

## Conflict of interest

All authors declare no conflict of interest.

This includes any financial or personal relationships that could inappropriately influence our work.

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