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Safe zone for the superficial femoral artery demonstrated on computed tomography angiography

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ABSTRACT

Introduction: Internal or external fixation of the femur is common following trauma. Neurovascular structures around the shaft of the femur are at risk, particularly the superficial femoral artery (SFA). Damage to this structure, when it is medial to the femur, can occur during the lateral approach, when drills, pins or screws are inserted. This anatomical study aims to delineate a safe zone for operative intervention to the shaft of the femur with respect to the SFA, and describe the relationship between this zone and the width and length of the femur.

Materials and methods: 41 limbs from 22 patients were examined using Computed Tomography Angiography to determine the relationship between the SFA and the medial shaft of the femur. The danger zone where the SFA lies medial to the shaft of the femur in the sagittal plane was identified and measured, and the width and length of the femur were measured for reference points.

Results: The SFA begins anterior to the shaft of the femur proximally and passes posteriorly, crossing the shaft of the femur in the sagittal plane at points 239.6 ± 39.8 mm and 172.5 ± 40.9 mm proximal to the adductor tubercle (AT). The width of the femur correlates to the inferior crossing point of the SFA on the femur with a mean ratio of 1:2.05, $p = 0.000$, the length of the femur correlates to the mid crossing point of the SFA on the femur with a ratio of 2.00:1, $p = 0.000$.

Conclusions: There is a safe zone along the medial shaft of the femur, which can be estimated intraoperatively using anatomical reference points.

Introduction

The advent of intramedullary femoral nailing with proximal and distal cross-fixation has caused a number of associated iatrogenic deep and superficial femoral artery injuries [1–7]. Injury to the SFA has also been reported following the insertion of external fixation pins, cerclage wires, plate and screw fixation, and as a result of bone fragments [2,8–11]. The consequences of injury to the SFA include bleeding from arterial laceration, arterial occlusion, pseudoaneurysm, and arteriovenous fistula [1,6,8,9,11].

A number of anatomical studies have described the relations of the medial femur and associated anatomical landmarks, with several studies attempting to delineate a safe zone for percutaneous screw or pin placement [12–17]. However, to our knowledge, there are no studies in the literature that quantitatively describe the transition of the femoral artery from anterior to posterior in relation to the shaft of the femur in the sagittal plane for a safe surgical approach to this area. The aim of this study is to describe the relationship of the SFA to the medial shaft of the femur, and identify a safe zone for placement of screws or pins from the lateral direction, that can be estimated intraoperatively using radiologically identifiable anatomical reference points on the femur.

Materials and methods

Lower limb Computed Tomographic Angiograms (CTA) of 22 consecutive patients were reviewed. Patients' limbs were excluded from the study if they had any anatomy or image-distorting factors from pre-existing limb pathology such as femoral nails, sliding hip screws, joint replacements, fractures or severe peripheral vascular disease. All scans had been previously performed for diagnostic or monitoringpurposes

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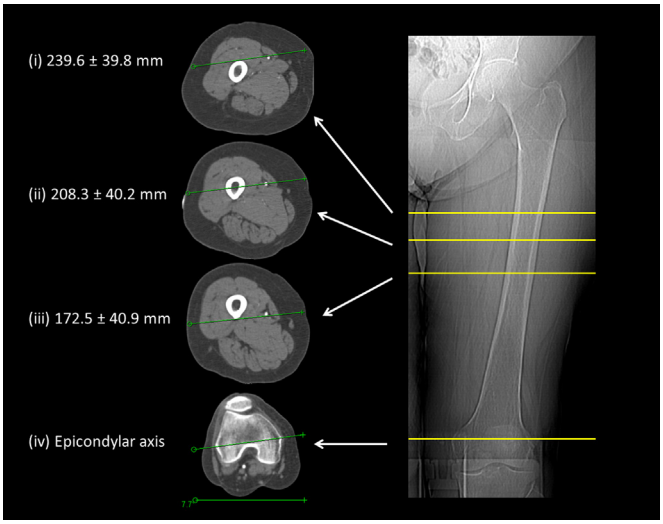

Fig. 1. *Right panel:* scanogram of the left thigh with transverse cutlines corresponding to axial sections. *Left panel:* axial images of the left thigh showing key points with distances from the AT listed in millimetres. The region from (i) to (iii) corresponds to the danger zone, the region distal to (iii) corresponds to the safe zone.**(i).** The superior crossing point of the SFA in relation to the shaft of the femur as it traverses from anterior to posterior in the sagittal plane.**(ii).** The middle crossing point of the SFA on the shaft of the femur.**(iii).** The inferior crossing point of the SFA in relation to the shaft of the femur as it passes posterior to the femur in the sagittal plane.**(iv).** The epidcondylar axis which is demonstrated to be 7.7 degrees from the horizontal axis of the CT gantry in this patient.

which were unrelated to the study. CTA was chosen as the modality for imaging as it produces precisely calibrated images without geometric magnification or parallax effect [18]. This allowed for precise measurements of vascular and osseous structures without the intervention and distortion of cadaveric dissection. Ethical approval was granted through the local Human Research Ethics Committee. Images were accessed and analysed using Centricity PACS (Version 3.0, GE Healthcare, Sydney) by two Orthopaedic Registrars conducting independent measurements.

Reference measurements for the width of the femur were taken from the widest portion of the distal femur on the axial reconstructions, and the measurements for the length of the femur were taken from the tip of the greater trochanter (GT) to the adductor tubercle (AT) on the scanograms. The AT was chosen as the main reference point because it is a constant bony landmark, which is easily palpable [15]. The epicondylar axis was determined from a straight line connecting the medial and lateral epicondyles on the axial reconstructions and this axis was used as the reference to set the sagittal plane for the femur. To set this plane the angle between the epicondylar axis and the horizontal section of the CT gantry was measured and subsequently adjusted for (Fig. 1).

The superior, middle and inferior points at which the entire diameter of the SFA lay directly medial to the shaft of the femur in the sagittal plane were measured as a distance from the AT. The SFA mid point represents the point at which the SFA was halfway between the anterior and posterior femoral cortices when viewed in the sagittal plane (Figs. 1 and 2). The distance between the shaft of the femur and the SFA in the axial plane was also measured at the superior and inferior crossing points of the SFA. The area from the superior to the inferior crossing point of the SFA on the shaft of the femur where the SFA lies directly medial to the shaft of the femur was designated as the danger zone. The area distal to the inferior crossing point of the SFA where the SFA lies posterior to the shaft of the femur was designated as the safe zone (Fig. 1).

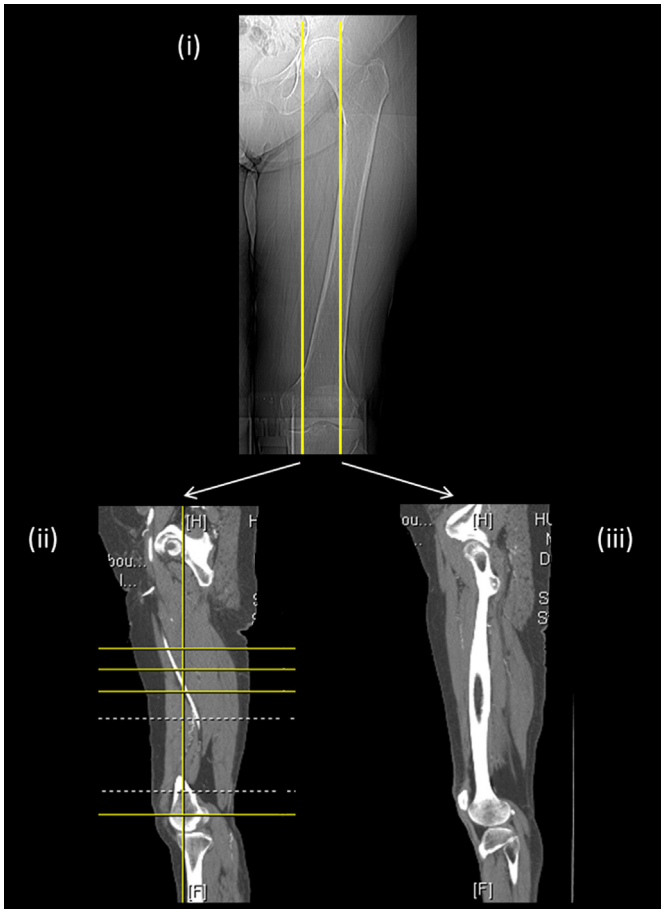

Fig. 2. (i) Scanogram of the left thigh with vertical cuts indicating corresponding sagittal sections. (ii) Sagittal section of the left thigh showing the course of the SFA from anterior to posterior in relation to the femoral shaft with yellow axial cut lines indicating the axial reference points from Fig. 1. (iii) Sagittal section of the left thigh indicating the position of the shaft of the femur deep to the SFA. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Statistical analysis on the data was performed using IBM SPSS statistical package for Macintosh (version 22.0, SPSS, Chicago, IL). Pearson's correlation coefficient and Student's *t*-test were used for statistical analysis with a p value of <0.05 considered significant. All data are summarised as mean ± standard deviations (SD) along with the range of values.

Results

The study group of 22 patients was comprised of 16 men and 6 women, giving 30 male and 11 female limbs with a mean age of 69.5 years (range 51 to 89 years). Of the 44 limbs examined, three were excluded from the study; one had a total knee replacement in situ, one had an occlusion of the SFA, and one had an acute femoral shaft fracture. Primary measurements of the anatomical landmarks are listed in Table 1 with comparison between male and female participants and right and left legs.

For the 41 limbs measured, the superior crossing point of the SFA in relation to the shaft of the femur in the sagittal plane was a mean of 239.6 ± 39.8 mm (range 150–348 mm) proximal to the AT, the midpoint was a mean of 208.3 ± 40.2 mm (range 105–294 mm) proximal to the AT, and the inferior crossing point was a mean of 172.5 ± 40.9 mm (range 70–258 mm) proximal to the AT (Table 1, Fig. 1). These three points describe a danger zone of 67.1 ± 18.1 mm starting 239.6 mm proximal to the AT and ending 172.5 mm proximal