RESEARCH

An anatomical study of the entry point in the greater trochanter for intramedullary nailing


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Malpositioning of the trochanteric entry point during the introduction of an intramedullary nail may cause iatrogenic fracture or malreduction. Although the optimal point of insertion in the coronal plane has been well described, positioning in the sagittal plane is poorly defined.

The paired femora from 374 cadavers were placed both in the anatomical position and in internal rotation to neutralise femoral anteversion. A marker was placed at the apparent apex of the greater trochanter, and the lateral and anterior offsets from the axis of the femoral shaft were measured on anteroposterior and lateral photographs. Greater trochanteric morphology and trochanteric overhang were graded.

The mean anterior offset of the apex of the trochanter relative to the axis of the femoral shaft was 5.1 mm (SD 4.0) and 4.6 mm (SD 4.2) for the anatomical and neutralised positions, respectively. The mean lateral offset of the apex was 7.1 mm (SD 4.6) and 6.4 mm (SD 4.6), respectively.

Placement of the entry position at the apex of the greater trochanter in the anteroposterior view does not reliably centre an intramedullary nail in the sagittal plane. Based on our findings, the site of insertion should be about 5 mm posterior to the apex for its anterior offset.

Cite this article: Bone Joint J 2014;96-B:??–??.

The treatment of fractures of the femoral shaft has progressed since the advent of intramedullary nailing. It has been reported that intramedullary nails are preferable for the management of unstable intertrochanteric fractures, although significant differences in outcome following the use of intra- and extra-medullary devices are unclear. However, intramedullary devices offer a clear benefit in the management of subtrochanteric fractures where the medial buttress is compromised.

The greater trochanter and piriform fossa are the common entry points for femoral antegrade nailing. The piriform fossa is co-linear with the femoral shaft but places the medial femoral circumflex artery at risk, particularly in adolescents, and is technically more difficult to access. The introduction into the clinical practice of intramedullary nails with a proximal lateral bend has facilitated transtrochanteric insertion. The trochanteric starting point potentially offers reduced rates of complications and technical ease, especially in obese patients. The abductor muscles and tendons, branches of the medial circumflex femoral artery and the capsule of the hip joint are at risk during insertion through the apex of the greater trochanter.

When inserting a nail through the greater trochanter, the site is identified fluoroscopically and the nail is inserted either at the apex or slightly medial to it, depending on the design of the nail. However, the relative position of the greater trochanter can vary to some degree relative to the intramedullary canal. If the lateral or anterior displacement of the apex of the greater trochanter is not considered during nailing, a deformity will be created during fixation. A lateral entry position increases the risk of varus malreduction, and an anterior entry position increases the risk of iatrogenic fracture. Additionally, trochanteric overhang (i.e., medial with respect to the femoral shaft) may result in a more medial entry point than intended, increasing the risk of avascular necrosis of the femoral head or additional fracture. Complications arising during intramedullary nailing can be reduced by identifying an appropriate entry position for each individual patient.

We performed a cadaver study of the greater trochanter and considered the variability in general morphology, anterior and lateral displacement, and the extent of overhang over the...
piriform fossa. Our primary aim was to quantify the degree of lateral and anterior offset of the apex of the greater trochanter relative to the femoral shaft in the context of introduction of an intramedullary nail through the greater trochanter. Secondary aims were to determine whether the morphology of the greater trochanter has a consistent relationship with the extent of lateral and anterior offset of the apex; whether anatomical versus neutral positioning of the femur affects the insertion site and whether the characteristics of the greater trochanter are symmetrical bilaterally.

Materials and Methods
Human cadaveric femora from the Hamann–Todd Osteological Collection at the Cleveland Museum of Natural History were analysed. This collection contains approximately 3000 well-preserved skeletons, from which we randomly
selected 374 (748 femora) with a mean age of 56 years (22 to 79; SD 11) at the time of death. This number was based on the specimens that could be studied in the time available in the collection. A gross examination of specimens was performed to exclude those with obvious deformity, metabolic disease or incomplete femora. A total of ten specimens were excluded from determination of morphology and overhang due to fracture or preservation damage.

**Morphology of the greater trochanter.** Characterisation of the morphology of the greater trochanter was based on its general shape from a lateral view. The specimens were positioned to neutralise proximal femoral version, with supports placed beneath the distal condyles such that the femoral neck was parallel to the table. As shown in Figure 1, four shapes were identified: anterior leaning (AL), posterior leaning (PL), centred (C) and flat (F). A few greater trochanters had an additional, far-anterior protrusion that resulted in a false double apical appearance (D)(Fig. 1).

**Type of overhang.** Characterisation of the greater trochanteric overhang was based on the cover over the standard entry point in the piriform fossa from the cranial aspect. Although the trochanteric fossa is technically the more correct term, this entry point is commonly referred to as the piriform fossa and we use this term in this paper. Axial photographs of the specimens in the anatomical position were taken from the cranial view for determination of the overhang group, as illustrated in Figure 2. The greater trochanteric overhang groups were originally described by Grechenig et al as: group 1, with full access to the entry point; group 2, where the outline of the spine is projected laterally; group 3, where the entry point is partially covered and group 4, where the entry point is completely covered.

**Femoral version.** The technique for measuring the femoral version has previously been reported. The specimen was positioned in the anatomical position, resting on the posterior aspects of the condyles and the most posterior aspect of the proximal femur. It was photographed from the cranial aspect in the axial plane. Using ImageJ version 1.46r digital software (National Institutes of Health, Bethesda, Maryland), lines were drawn in the axial plane both along the
posterior aspect of the condyles and the centre of the femoral neck, with the angle of the intersection representing the version.

**Lateral and anterior offset.** In order to determine the magnitude of lateral greater trochanteric apical offset, the specimen was first positioned so that it rested in the anatomical position with an appropriately placed metric scale. A temporary clay marker was placed on the most superior point of the greater trochanter. On an anteroposterior (AP) photograph, ImageJ software (National Institutes of Health) was used to draw a line through the centre of the femoral shaft, as shown in Figure 3. A perpendicular line was drawn to the centre of the marker on the greater trochanter, and the distance was measured. In order to determine the anterior offset of the apex of the greater trochanter, the marker was left in place. The femur was placed in the anatomical position and photographed from the lateral view. Using ImageJ software (National Institutes of Health), a line was drawn through the centre of the femoral shaft, as shown in Figure 4. A line perpendicular to the centre of the marker was drawn, and the distance measured to represent anterior offset.

The measurement of lateral offset was repeated after placing a support beneath the distal condyles to neutralise femoral version in the AP view. A new temporary clay marker was placed at the apparent apex of the greater trochanter, and the offset from the femoral shaft was again measured. The marker was retained in place for the measurements of anterior offset, when the femur was kept in the neutralised, position and photographed from the lateral view. In most femora, the apparent apex of the greater trochanter moved slightly between the anatomical position and the positions with the neutralised version, owing to the generally graduated (rather than pointed) shape of the greater trochanter.

**Statistical analysis.** All statistical analyses were performed using SPSS statistical package v21 (IBM, Armonk, New York). Comparisons between age, gender, race, femoral version and greater trochanteric morphology versus lateral and anterior displacement were evaluated with Pearson’s multivariate product-moment correlation analysis. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) were used to compare the right- and left-sided femoral characteristics and the measurements of the anatomical and neutral versions. We considered an ICC of < 0.40 as poor, 0.40 to 0.59 as fair, 0.60 to 0.74 as good and > 0.74 as excellent. All p-values were derived from paired t-tests, p < 0.05 was considered significant. In the event of any missing values, the pair-wise data set was excluded.

**Results**
A total of 60 skeletons (16%) were female, and 115 (31%) were African-American, while the remainder were Caucasian. The mean femoral anteverision was 12° (SD 13). The mean anterior offset of the apex of the trochanter relative to the axis of the femoral shaft was 5.1 mm (SD 4.0) and 4.6 mm (SD 4.2) for the positions of the anatomical and neutralised versions, respectively (ICC 0.72; 95% CI 0.69 to 0.76; p < 0.001). The mean lateral
offset of the apex was 7.1 mm (SD 4.6) for the anatomical position and 6.4 mm (SD 4.6) for the neutral position (ICC 0.83; 95% CI 0.81 to 0.86; p < 0.0001). The ICC for lateral offset when comparing the right and left femora was 0.67 (95% CI 0.61 to 0.73) with the femora positioned anatomically, and 0.74 (95% CI 0.68 to 0.78) when in the neutral position. Repeated left versus right comparisons for anterior offset yielded a moderate ICC of 0.32 (95%CI 0.23 to 0.41) (anatomical position) and 0.40 (95%CI 0.31 to 0.48) (neutral position).

Assessment of the morphology of the greater trochanter revealed the following distribution: AL apex, 92 (12%); PL apex, 250 (34%); C apex, 260 (35%) and F, 116 (16%). There were also 20 femora with an additional far-anterior protrusion that resulted in the appearance of a false-double apex (3%). The extra far-anterior bump was either aligned with or less protuberant than the true apex, and was disregarded for the purpose of the calculations of the location of the apex. The morphology of the apex was poorly conserved between the right and left femora (ICC 0.38, 95% CI 0.30 to 0.47).

Analysis of the overhang of the greater trochanter yielded the following distribution: 328 (44%) free entry (Group 1), 162 (22%) spine projected laterally (Group 2), 149 (20%) partial entry point coverage (Group 3), and 100 (14%) complete entry point coverage (Group 4). The degree of overhang was highly consistent between right and left femora (ICC 0.83, 95% CI 0.80 to 0.87). There was a modest correlation between some overhang groups and greater trochanteric morphologies, as shown in Table I below.

In both the anatomical and the neutral views, there was a positive association between AL morphology and anterior offset (r = 0.19; r = 0.23) and a negative association between PL morphology and anterior offset (r = –0.12; r = –0.20). There was a weakly positive association between F morphology and lateral offset (anatomical r = 0.13; neutral r = 0.10) and a weakly negative association between C morphology and lateral offset (anatomical r = –0.15; neutral r = –0.14) (Table II).

The African-American ethnicity correlated with increased anteversion (r = 0.15, p < 0.001), PL morphology (r = 0.19, p < 0.001), medial offset of the trochanteric apex (anatomical r = –0.10, p < 0.001, neutral r = –0.14, p < 0.001) and increased trochanteric overhang (Group 1 r = –0.12, p = 0.001; Group 2 r = –0.10, p = 0.006; Group 3 r = 0.09, p = 0.021; Group 4 r = 0.20, p < 0.001). Female gender correlated weakly with double apex morphology (r = –0.07, p = 0.048) and Group 2 trochanteric overhang (r = –0.14, p < 0.001). Increased age correlated positively with AL morphology (r = 0.12, p = 0.001), and negatively with PL morphology (r = –0.16, p < 0.001).

**Discussion**

The correct introduction of an intramedullary nail in the treatment of fractures of the long bone prevents malrotation, iatrogenic fracture, gapping and hoop stresses.

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**Fig. 5**

Graphs showing lateral and anterior offset. The slight difference between them in all measured variables is statistically significant but numerically small. Lateral offset of the apex of the greater trochanter is associated with centred and flat morphologies, and also has a tendency to reduce with increased overhang. Anterior offset is associated with AL and PL morphology, as well as most types of overhang. However, these correlations are also small and do not have a large impact on the offset of the apex.
The intramedullary nail with a slight proximal bend for trochanteric entry is typically inserted at the apex of the greater trochanter, on the assumption that this point is consistently located relative to the intramedullary canal. Our data showed a mean lateral offset of 7.1 mm in the anatomical position that weakly correlated with greater trochanteric overhang, and a mean anterior offset of 5.1 mm in the anatomical position that weakly correlated with greater trochanteric morphology. ICC analysis yielded high bilateral agreement for lateral offset but not for anterior offset. Rotating the specimens to neutralise the mean femoral anteversion of 12° resulted in a slight but statistically insignificant reduction in lateral and anterior offset.

To our knowledge, greater trochanteric morphology in the sagittal plane has not previously been described in the literature. Although all morphologies were found to have a generally anterior offset of 7.1 mm in the anatomical position that weakly correlated with greater trochanteric overhang, and a mean anterior offset of 5.1 mm in the anatomical position that weakly correlated with greater trochanteric morphology. ICC analysis yielded high bilateral agreement for lateral offset but not for anterior offset. Rotating the specimens to neutralise the mean femoral anteversion of 12° resulted in a slight but statistically insignificant reduction in lateral and anterior offset.

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Our greater trochanteric lateral offset data agree with previous data which have shown that the axis of the shaft is generally medial to the apex of the greater trochanter. Our data differ from those of Streubel et al., who quantified greater trochanteric offset from the axis of the femoral shaft and reported a mean greater trochanteric lateral offset of 15 mm. However, their measurements were taken from radiographs and it is likely that there was variability in positioning when acquiring these measurements. Our lateral displacement of approximately 7 mm is in agreement with the lateral offset present in contemporary intramedullary nails, such as the Trochanteric Antegrade Nail (TAN, Smith & Nephew, Memphis, Tennessee) at 6.12 mm, the Gamma nail (second and third generations, Howmedica/Osteonics, Mahwah, New Jersey) at 6.29 mm, and the Trochanteric Fixation Nail (TFN, Synthes, Paoli, Pennsylvania) at 8.93 mm lateral offset.

The anterior offset of the apex of the trochanter has been discussed but not anatomically quantified in other studies. In a retrospective study of 227 insertions of intramedullary nails through the greater trochanter, Prasarn et al. reported that 44% of 154 concordant pairs of femora showed nails which were inserted in the anterior third of the trochanter. These anterior insertion sites were more likely to cause iatrogenic fractures than were middle entry sites. The proximal bend found in modern intramedullary nails allows for the lateral position of the greater trochanter relative to the axis of the femoral shaft, but does not appear to significantly affect the anterior offset.
and shape of human bones have been reported in the scapula, 23 thorax, 24 spinal vertebrae 25 and proximal femur. 26 These subtle differences may be due to micro-architectural changes in the ageing skeleton, which generate remodelling in response to the traction of the abductor attachments. 27 Based on our data, we recommend that close attention is paid to positioning in the sagittal plane in elderly patients, where weaker bone stock may make the patient more vulnerable to iatrogenic fracture as a result of malpositioning of the starting point.

The study is limited in that intra-operative fluoroscopic views may not reproduce the perfect AP and lateral views that we were able to obtain in this study. However, as greater trochanteric overhang and lateral trochanteric offset are moderately consistent between right and left femora, the contralateral femur may be used to estimate positioning of the affected side. Adolescent specimens were not included in our study, so we cannot be confident that it is applicable to that population.

In summary, we have determined that the apex of the greater trochanter is consistently anterior to the intramedullary canal, especially for certain morphologies and with advanced age. We have characterised the greater trochanter based on lateral-view morphology and greater trochanteric overhang over the piriform fossa, which were weakly correlated with anterior and lateral offset, respectively. Trochanteric overhang and lateral offset were moderately consistent bilaterally, such that the contralateral femur may be used to estimate positioning of the affected apex of the greater trochanter relative to the intramedullary canal, despite a fractured or slightly rotated proximal femur. Based on these findings, we recommend that entry points be placed about 5 mm posterior to the apparent apex of the greater trochanter, and subsequent adjustment based on intra-operative fluoroscopic findings.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

This article was primarily edited by G. Scott and first proof edited by J. Scott.

References


