Precise Intra-operative Assessment of Rotation in Femoral Fracture Nailing

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Citation

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Abstract

Background: A novel modification of an existing technique was developed to allow precise fluoroscopic assessment of rotational alignment of the fractured femur during intramedullary nailing. It is hypothesized that this will reduce the incidence of rotational malalignment which is reported to occur in 20-30 % of femoral fractures managed with intramedullary nails. The neck lateral technique has been described to assess the rotational alignment of the femur, however, observation error renders it increasingly inaccurate with C arm obliquity or hip flexion. Method: The neck lateral technique was modified with a calculation to correct for the observation error that occurs with obliquity of the C arm to the femur. This was tested on an adjustable radiopaque sawbone model in a blinded fashion. Results: When tested on the sawbone at random settings of anteversion between 0º and 60° the mean error was 2.1° (std error 1.8º). Conclusion: Femoral anteversion can be accurately assessed intra-operatively with fluoroscopy by measuring the femoral neck lateral with consideration of hip flexion and the obliquity of the X-ray tube.

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BACKGROUND

Femoral shaft fractures are common injuries. [1] Closed reduction and locked intramedullary nailing is the gold standard treatment [1-5] and is associated with high rates of union and low rates of complications[2]. Intramedullary devices aid in coronal and sagittal plane reduction of diaphyseal fractures but reduction in the axial plane is determined operatively, and is much more difficult to assess accurately.

Malrotation (when defined as > 15º of rotational malalignment) in nailed femoral fractures has been reported to occur in 20-30 % of cases [3]. Clinically, a large deformity may cause patient dissatisfaction, functional impairments [3, 4] and secondary osteoarthritis [5].

Anteversion (AV) was defined by Dunn as the angle of the neck, if one were to look longitudinally up a stripped femur. [6]. The mean anteversion is reported as 10 to 15 with a large range of -4 to 36. The standard deviation is 10 [7, 8]. There is typically a narrow side-to-side difference in any one person (1-4°) [8-10]. Rotational malalignment may be expressed as the side to side difference in anteversion after fracture fixation.

Many techniques exist to measure rotational alignment during intramedullary nailing of the femur. These include the Tornetta neck lateral technique[11], the Braten floor neck angle[12], the Deshmukh mirror normal limb technique[13], the Jaarsma lesser trochanter estimation[14], the "patella to the sky technique," the cortical width technique[15] and computer navigation[16].

Computer navigation and the mirror normal technique are the most mathematically accurate methods. However, navigation clearly relies on resources and the mirror normal technique may be inflexible regarding intra-operative manipulation. The neck lateral technique and the floor neck angle technique have observation errors and the floor neck angle is also influenced by the neck shaft angle. The remaining techniques involve some element of estimation

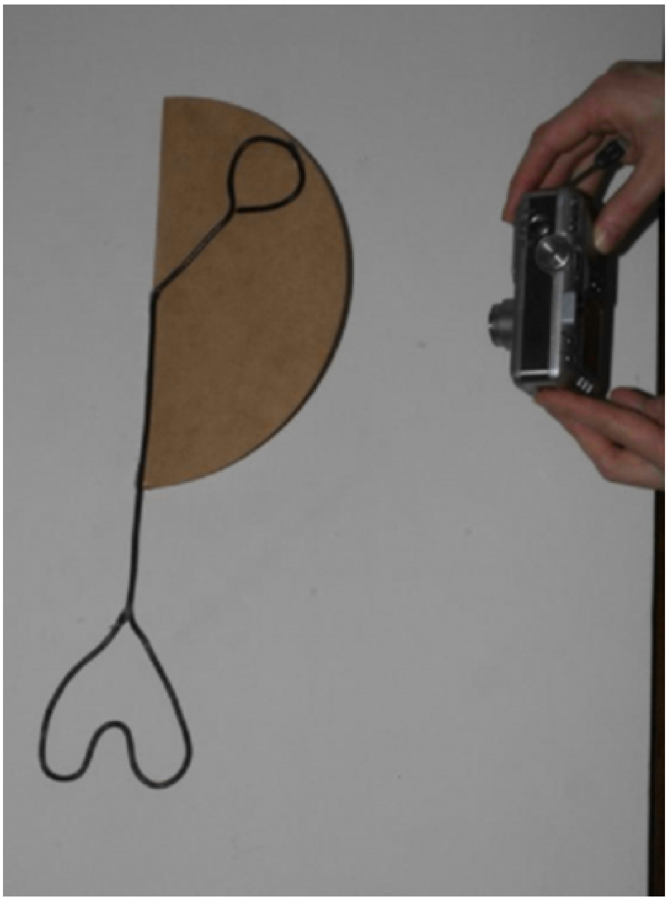
The aim of our study was to demonstrate that a modification of the neck lateral technique corrects for an observation error and allows precise intra-operative assessment of the rotational alignment of the proximal femur with the C arm.

The neck lateral technique is based on the angle required to take a lateral image of the proximal femur where the shaft and neck appear as a straight line with the image intensifier (II). The inclination required for this image describes the anteversion of the femur but errors are introduced if the observation is not made perpendicularly to the femoral shaft or if there is flexion or extension. This is significant because intraoperatively it is usually not possible to position the C arm square to the shaft of the femur for the lateral images.

Figure 1

The observation error may be modelled by using a digital camera and wire model femur. The neck lateral shows the neck and shaft in line with the II position (figure 1A).

Figure 2



This angle of observation describes the inclination of the plane of anteversion, where the observation is 90° to the shaft with no flexion. (figure 1B).

As the observation becomes more oblique a neck lateral is obtained at a lower inclination, thus underestimating true anteversion (figure 2A.)

Figure 4

It may be seen with the model that an oblique observation will result in an underestimation of the anteversion and that flexion will result in an overestimation of the anteversion

METHODS

A calculation was developed to predict and adjust for the observation error. A bearing calculator for great circle flight paths (commonly used in aviation) was modified to describe the relationship between different points on the same inclined plane. At any moment in time, the position for the neck lateral fluoroscopic image was broken down into longitude (obliquity to the shaft of the II machine) and latitude (roll of the II tube) required for the image. The initial bearing for a hypothetical flight from the origin (0,0) to the point described above is the same as the inclination of the entire great circle and gives the plane of anteversion. Changes in origin latitude allow for changes in flexion of the proximal fragment. These calculations were performed using Microsoft Excel.

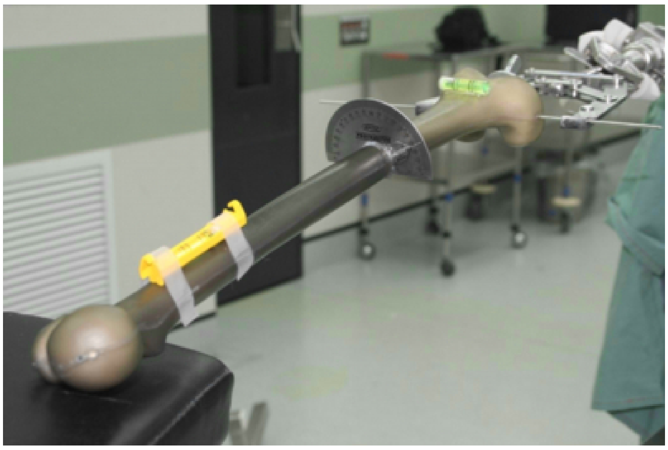
The accuracy of the calculation was then tested on a radiopaque saw bone model with adjustable anteversion. The sawbone (Sawbones® Pacific Research Laboratories, Inc., Washington) was divided transversely in the diaphysis. A rotation dial was fashioned from a marker and a protractor and the two parts of the dial were attached to the segments of the model using navigation to ensure correct rotational alignment of the dial. The two segments of the bone were then reconnected in an adjustable fashion. A CT scan of the model through the neck of femur and knee was taken to confirm that readings from the dial corresponded to the anteversion of the model.

The calculation was tested on the model in two sessions of

30 measurements each. The model was fixed to the theatre table and set to random degrees of anteversion between 0º and 45º for the first session and 0º and 60º for the second session (Figure 3). The II machine was placed at

Figure 5

Figure 3



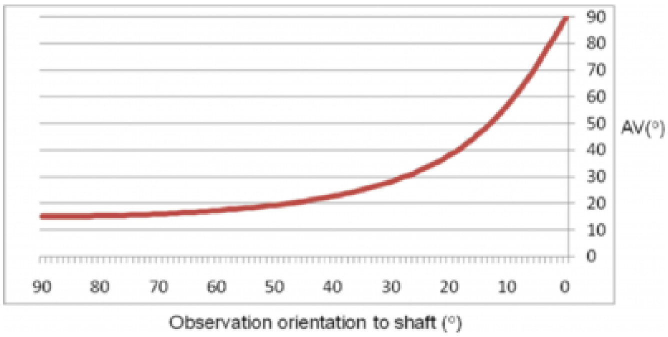
45º to the femoral shaft. The model was then draped and an examiner blinded to the setting of anteversion of the model examined it with the fluoroscope (Figure 4). The results were then corrected for observation error using the Excel calculation to give the anteversion of themodel.

Figure 6

Figure 4

Figure 7

Figure 5



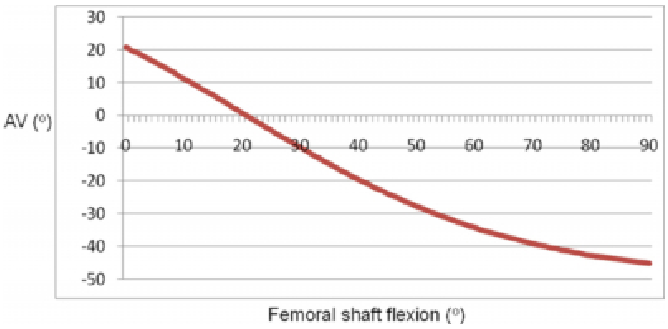
RESULTS

Graphical output from the Excel calculation demonstrates the observation error. Tube obliquity causes an underestimation of the actual anteversion (Figure 5). It is seen that if the anteversion appears to be 15º based on the neck lateral the actual anteversion may be much higher unless the observation is made from perpendicular to the shaft. Flexion causes an overestimation of the actual anteversion (Figure 6). There is a point at which these effects cancel out. With the tube orientated at 45º to the femur and proximal fragment flexion of 6º if a neck lateral is obtained at 15º then the true anteversion is also 15º. With flexion beyond this the actual anteversion is much less than it appears.

When tested on the radiopaque sawbone for random settings between 0º and 45° the mean error was 1.9º (std error 1.6º) from 30 measurements. When tested on random setting between 0º and 60° the mean error was 2.2º (std error 1.9º), also from 30 measurements.

Figure 8

Figure 6



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DISCUSSION

Proximal femoral rotational alignment becomes increasingly inaccurate with greater tube obliquity or flexion when using the neck lateral technique. The modification that has been described allows accurate assessment of rotational alignment of the proximal femur in a radio-opaque sawbone model, confirmed with a modest mean error of 2.1° over 60 measurements.

Here we describe the operative steps in relation to the assessment of rotation during Intra-medullary nailing of the femur. At the commencement of the procedure the anteversion of the intact contralateral femur should be measured. To correct for the observation error it is necessary to determine the obliquity of the II tube to the shaft of the femur and shaft flexion. A pen and a metal pointer are used to mark the position of the femur. The angle of obliquity of the II machine is measured and the table or limb adjusted to ensure that the shaft is parallel to the ground (flexion 0º). The neck lateral image is obtained and the rotational alignment of the proximal femur calculated as described for the model. The image intensifier is used to assess the rotational axis of the posterior femoral condyles using a true lateral at the knee and the reading from the II tube. Subtracting this axis from the rotational alignment of the proximal femur gives the anteversion of the intact limb.

The fractured limb is fixed according to standard intramedullary nailing technique. In addition the rotational alignment of the proximal segment of the fractured femur is measured by taking a femoral neck lateral view, recording the tube inclination and obliquity, and controlling for or measuring flexion of the proximal segment. Prior to distal locking the rotation of the distal segment is assessed and adjusted to recreate the anteversion measured in the intact limb as described by Tornetta.

There are several elements involved in the technique which may introduce error into the measurement. Performing intraoperative measurements of the hip flexion, true neck lateral and the angle of the C arm to the femur shaft will involve some error. Anteversion has been shown to be altered during distal locking. [1]

Given these variables it is unlikely that mean clinical malrotation is likely to improve much on such results. The authors of this article would hypothesise that if greater numbers of subjects were studied in the Tornetta (n=12) study, the method modification would reduce outliers and produce a favourable mean malrotation. Demonstration of this requires greater sample size.

Clinical implementation, particularly the rotational assessment of the unbroken limb is time consuming. A significant amount of time would be saved with the described technique if it were not necessary to assess the contralateral femur. As the range of native anteversion is large we feel it is important to do this.

It remains unclear whether there are long term detrimental effects following subclinical rotational malunion of femoral shaft fractures. In any case, techniques that achieve an accurate rotational reduction will reduce the number of potentially adverse clinical results.

CONCLUSION

The described modification of an existing technique may be a useful adjunct to established procedure. It is possible to precisely measure the rotational alignment of the proximal femur using fluoroscopy.

References

1. Winquist, R.A. and S.T. Hansen, Jr., Comminuted fractures of the femoral shaft
treated by intramedullary nailing. Orthopedic Clinics of North America, 1980. 11(3): p. 633-48.
2. Webb, L.X., A.G. Gristina, and H.L. Fowler, Unstable femoral shaft fractures: a
comparison of interlocking nailing versus traction and casting methods. Journal of Orthopaedic Trauma, 1988. 2(1): p. 10-2.
3. Jaarsma, R.L., et al., Rotational malalignment after intramedullary nailing of
femoral fractures. Journal of Orthopaedic Trauma, 2004. 18(7): p. 403-9.
4. Braten, M., T. Terjesen, and I. Rossvoll, Femoral shaft fractures treated by
intramedullary nailing. A follow-up study focusing on problems related to the method. Injury, 1995. 26(6): p. 379-83.
5. Eckhoff, D.G., et al., Femoral anteversion and arthritis of the knee.[see
comment]. Journal of Pediatric Orthopedics, 1994. 14(5): p. 608-10.
6. Dunlap, K., et al., A new method for determination of torsion of the femur. Journal of Bone & Joint Surgery - American Volume, 1953. 35-A(2): p. 289-311.
7. Murphy, S.B., et al., Femoral anteversion. Journal of Bone & Joint Surgery - American Volume, 1987. 69(8): p. 1169-76.
8. Hoaglund, F.T. and W.D. Low, Anatomy of the femoral neck and head, with
comparative data from Caucasians and Hong Kong Chinese. Clinical Orthopaedics & Related Research, 1980(152): p. 10-6.
9. Fabry, G., G.D. MacEwen, and A.R. Shands, Jr., Torsion of the femur. A followup
study in normal and abnormal conditions. Journal of Bone & Joint Surgery - American Volume, 1973. 55(8): p. 1726-38.
10. Dunn, D.M., Anteversion of the neck of the femur; a method of measurement. Journal of Bone & Joint Surgery - British Volume, 1952. 34-B(2): p. 181-6.
11. Tornetta, P., 3rd, G. Ritz, and A. Kantor, Femoral torsion after interlocked

nailing of unstable femoral fractures. Journal of Trauma-Injury Infection & Critical Care, 1995. 38(2): p. 213-9.
12. Braten, M., et al., The role of fluoroscopy in avoiding rotational deformity of
treated femoral shaft fractures: an anatomical and clinical study. Injury, 2000. 31(5): p. 311-5.
13. Deshmukh, R.G., et al., A technique to obtain correct rotational alignment during
closed locked intramedullary nailing of the femur. Injury, 1998. 29(3): p. 207-10.
14. Jaarsma, R.L., et al., Avoiding rotational malalignment after fractures of the
femur by using the profile of the lesser trochanter: an in vitro study. Archives of Orthopaedic & Trauma Surgery, 2005. 125(3): p. 184-7.
15. Krettek, C., et al., Intraoperative control of axes, rotation and length in femoral
and tibial fractures. Technical note. Injury, 1998. 29 Suppl 3: p. C29-39.
16. Hofstetter, R., et al., Computer-assisted fluoroscopy-based reduction of femoral
fractures and antetorsion correction. Computer Aided Surgery, 2000. 5(5): p. 311-25.
17. Alanah S. Kirby, W.A.W.A.M.R.G.B., Comparison of four methods for
measuring femoral anteversion. Clinical Anatomy, 1993. 6(5): p. 280-288.
18. Gardner, M.J., et al., Femoral fracture malrotation caused by freehand versus
navigated distal interlocking. Injury, 2008. 39(2): p. 176-80.

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