

■ ASPECTS OF CURRENT MANAGEMENT

Rotational malalignment after fractures of the femur

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Intramedullary (IM) nailing has become the preferred method of treatment for fractures of the femur in adults. It requires a small incision and minimum dissection, gives excellent healing of the fracture and rapid recovery.¹⁻⁵ Interlocking provides rotational stability and maintains length thus ensuring the conditions for an early return to full weight-bearing and union of the fracture.^{3,6} The semi-closed approach makes IM nailing a technically demanding procedure.^{1,3,7-9} It is impossible to secure an anatomical reduction under direct vision, resulting in less rotational control in comparison to the classical method of fixation by a plate.^{3,6,10} IM nailing has practically replaced plating in the management of fractures more than 7 cm from the joint lines. However, plating does have a role in the treatment of nonunions.¹¹⁻¹³

Rotational malalignment or torsional deformity of the femur is expressed as a difference in femoral anteversion between the injured and uninjured leg. It can be measured clinically^{3,4,14-16} and by radiography,¹⁷⁻¹⁹ ultrasound²⁰⁻²³ and computed tomography (CT).²⁴⁻²⁷

Assessment of femoral rotational malalignment

Clinical measurement. Clinically rotational malalignment of the femur can be determined by comparing the internal and external rotation of the injured and uninjured hip. These measurements can be done with the patient supine or prone, with the hip flexed to 90° or extended. A change in range of movement towards internal or external rotation indicates rotational malalignment of the femur. A poor correlation between femoral torsion and clinical measurements of rotation of the hip has been reported.^{20,28} We have found a strong correlation between the direction of malrotation and the clinical measurements, but the accuracy of these measurements was poor in a series of patients who had suffered a femoral fracture.²⁹ The 95% confidence interval (CI) of the clinical method with the patient supine compared to the CT measurement

was $\pm 21^\circ$ and the method with the patient prone $\pm 19^\circ$. The poor sensitivity and specificity of these clinical measurements indicates that physical examination alone is not reliable in determining the amount of rotational malalignment.

Radiographic measurement. In order to measure torsional deformity accurately using the radiographic technique described by Dunn¹⁸ and Rippstein,¹⁹ exact positioning of the patient is necessary. This may be difficult because of post-traumatic axial deformities and restriction in mobility due to pain.^{18,19,27} The technique was primarily developed to determine anteversion of the femoral neck and not to evaluate differences in femoral torsion. Two radiographs of the pelvis are made, an anteroposterior (AP) view to determine the angle between the femur and femoral neck (CCD angle) and a special view in which the hips and knees are both flexed to 90°, with each leg in 20° abduction, to determine antetorsion. A special table, which combines the measured CCD angle and the measured antetorsion angle, is used to calculate the angle of anteversion of the femoral neck. By fixing the upper legs in a symmetrical way, an indirect method of determining femoral torsion is established.

Ultrasound measurement. Although ultrasound has been shown to be reliable,^{20,21} it cannot be used widely since it relies heavily on the experience of the ultrasound technician. The upper legs are fixed symmetrically while ultrasound is used to determine the anteversion of the femoral neck. Again, this is an indirect method to determine femoral torsion and requires exact positioning of the patient. We have no experience of this technique.

CT measurement. This is currently the method of choice because of its supposed reliability and reproducibility.³⁰⁻³² Rotational malalignment is often determined by the method described by Jeanmart et al²⁴ (Fig. 1) which determines the angle between a line tangential to the dorsal bony contours of the femoral condyles and a line drawn through the axis of the femoral neck. We use this in our hospitals. Although

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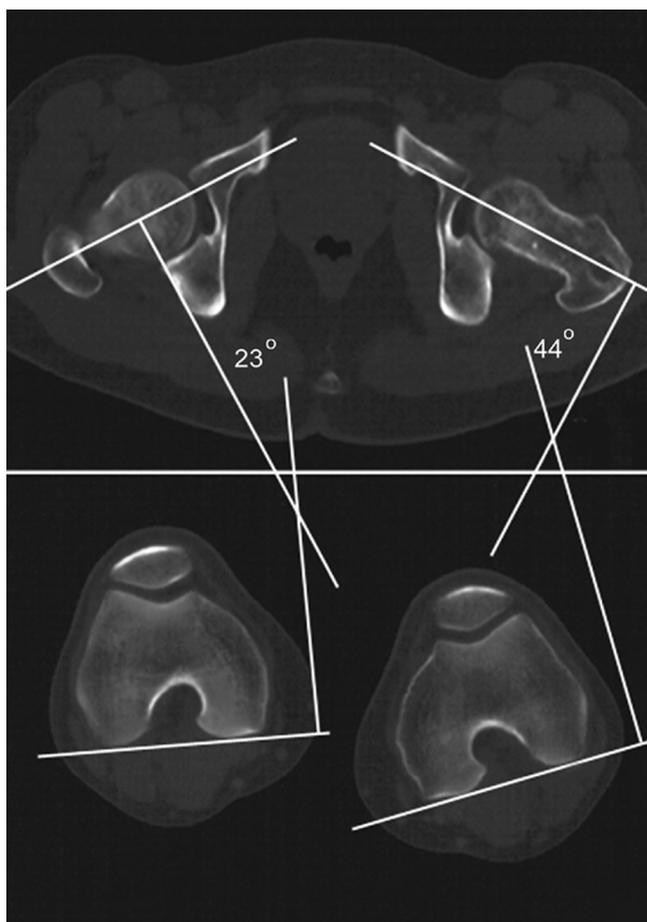


Fig. 1a

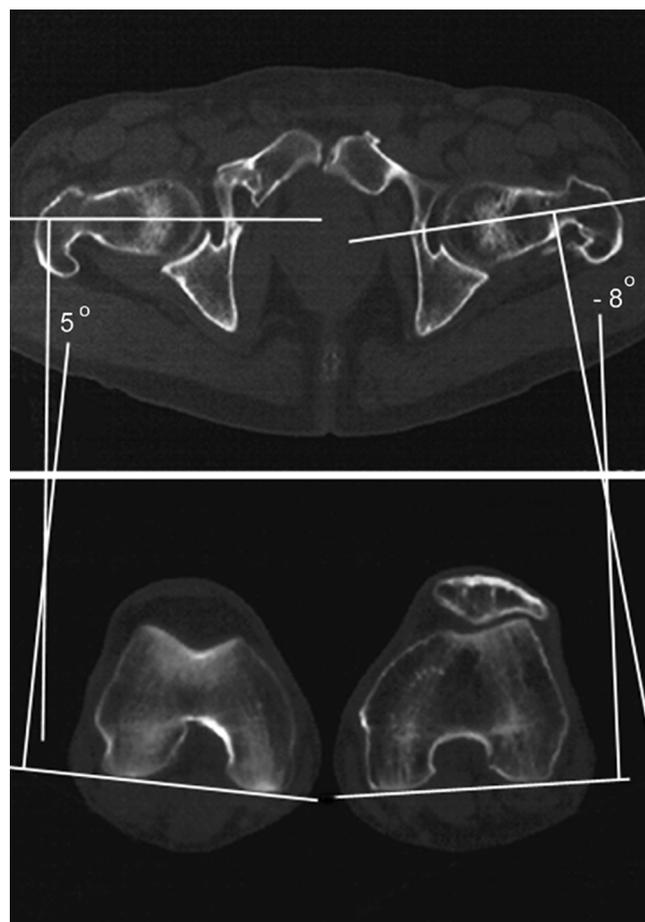


Fig. 1b

Determining femoral malrotation using CT-torsion measurements according to Jeanmart et al.²⁴ Figure 1a - On the injured left side there is an increase in the rotation angle of 21° (44° , -23°). This denotes internal rotational malalignment of 21° . Figure 1b - On the injured left side there is a decrease in the rotation angle of -13° (-8° , -5°). This denotes external malrotation of 13° .

other methods have been described,³¹ they are all based on the same principle and differ only in the way the line is drawn through the centre or along the femoral neck. The difference in angle between the fractured and unaffected side determines the rotational malalignment. A decrease in anteversion of the femoral neck of the fractured side implies increased external rotation and an increase denotes increased internal rotation of the distal femoral fragment.

Unlike when using radiography or ultrasound, the position of the patient does not influence the accuracy of CT measurement of femoral torsion.

Torsional differences of less than 10° are considered variations of normal.^{20,33} Between 10° and 14° denotes a possible deformity, and 15° or more indicates a true torsional deformity.^{20,33}

Although Starker et al³¹ questioned their precision in the literature,^{25-28,34} in daily practice CT measurements are considered highly accurate. Proper measurement is necessary when considering osteotomies to correct post-traumatic rotational deformities. Jaarsma et al³⁵ showed that

the accuracy of CT in determining rotational malalignment of the femur is questionable. There is a 95% repeatability coefficient of 10.8° for two measurements of one observer. Between two measurements of different observers there is a 95% repeatability coefficient of 15.6° . The intra-observer variability determines the major part of the inaccuracy.

Inaccuracies are mostly related to difficulty in drawing a precise line along the middle of the femoral neck on a CT image. The 95% repeatability coefficient of this line is 6.9° and that of the line along the posterior border of the condyles is 2.9° .

In order to obtain more accurate measurements of femoral malalignment the accuracy of the line drawn along the middle of the femoral neck should be improved. This can be done by multi-image projection of the CT images in which the images are superimposed and a line along the middle of the femoral neck can probably be drawn more accurately.

The accuracy can also be improved by taking the average of more measurements. We have found that even when an average of six measurements was taken, the recording of

rotational malalignment can still differ by 4.4°. Ideally even more measurements should be done, but our practice is to measure CT studies twice in each patient on two separate occasions, or use multi-image projection in the radiology department, if an exact measurement is needed.

Incidence of femoral rotational malalignment

Studies using clinical assessment have described a very low incidence of rotational malalignment after IM nailing of fractures of the shaft of the femur. Kempf et al¹⁵ and Johnson and Greenberg¹⁴ found none, Wiss et al³ noted 7% with more than 10° and Alho et al⁴ found only one patient in a series of 123 with a rotational malalignment of more than 20°. The inaccuracy of the clinical assessment of femoral rotational deformity might be the cause of this low incidence.^{18,28,29} Studies using ultrasound or CT have noted higher incidences.

In a series of 45 patients with a femoral fracture treated with an intramedullary nail, Sennerich et al²⁵ found an incidence of rotational malalignment of more than 10° of 40% and more than 20° of 16%. Bråten et al²¹ in a series of 110 patients found an incidence of rotational malalignment of more than 10° of 43% and more than 15° of 19%. In a series of 76 patients we found that 21 (28%) had rotational malalignment of 15° or more; nine had an internal rotational deformity and 12 an external rotational deformity.³⁰

Although higher incidences of rotational malalignment have been observed in fractures of the distal femur,³⁶ our review did not confirm this.²⁹

Since measurement by CT is superior to clinical assessment, it is reasonable to judge the incidence of a significant ($\geq 15^\circ$) malrotation after IM nailing of fractures of the femur as between 20% and 30%.

Causes of rotational malalignment

It is more difficult to control rotation of the fracture with IM nailing than with plate fixation.^{3,6,10} Since the possible torsion of a locked femoral nail itself is too small to be the cause of rotational malalignment,³⁷ the deformity is established during the operation, indicating inadequate reduction of the fracture.^{4,21,25} In a proximal fracture the initial rotation of the proximal fragment will be towards external rotation because of the action of the glutei, iliopsoas and the external rotators of the hip. In a distal fracture the distal fragment rotates outward because of the action of the plantaris and lateral gastrocnemius muscles. Based on this one could expect a relation between the site of the fracture and the amount or direction of malalignment. Without adequate reduction a proximal fracture will thus produce internal malrotation and a distal fracture external malrotation of the femur. However, we could not establish this pattern and no other studies comment on this assumption.

How to avoid rotational malalignment

Rotational malalignment is established during the operation because of inadequate reduction of the frac-

ture.^{4,21,25} Although IM nailing may be accomplished by applying manual traction,³⁸ a fracture table is often used for antegrade nailing of a fracture. Traction is applied to the femur using a traction shoe or a Steinmann pin passed either through the femoral condyles or the proximal tibia.

Traction determines the neutral position of the distal part of the fracture. In order to align the fracture, the proximal femur is rotated until a neutral position is obtained as judged by the radiographic profile of the lesser trochanter. Generally, a C-arm image posterior-anterior view showing a small area of the lesser trochanter denotes internal rotation and a larger area indicates external rotation of the proximal part of the femur. Based on this knowledge the neutral position of the proximal fragment of the fracture can be estimated during operation.^{39,40}

The profile of the lesser trochanter on the fractured side can be compared with that of the opposite femur using the image intensifier. Reproducing the profile of the lesser trochanter of the unaffected side increases the accuracy of reduction.⁴¹

Other methods based on fluoroscopy have been described. Tornetta, Ritz and Kantor⁴² used two C-arm images, one with a true lateral image of the femoral neck and the other with the posterior condyles aligned. The difference in inclination of the position of the C-arm reflects the angle of anteversion of the femoral neck. CT examination at follow-up revealed only 5° (0 to 8) of rotational inaccuracy.

Bråten et al⁴³ described another fluoroscopic technique to control femoral rotation.⁴² The proximal femur was imaged with a horizontal beam at an angle of 30°, 45° or 60° to the long axis of the shaft. The angle between the horizontal plane and the central head-neck axis showed a good correlation with the real angle of anteversion. Ultrasound examination at follow-up revealed an average inaccuracy of 4.8° (0 to 10). Although these methods are reasonably accurate, they both have the same disadvantage. Neither Bråten et al,⁴³ nor Tornetta et al⁴² takes account of the angle of anteversion of the unaffected side. The angle of femoral anteversion varies between 0° and 30°, with an average of 10° to 15°,^{34,44,45} which is used as the standard for comparison. When assessing the degree of rotational malalignment following a fracture it is essential to determine the degree of anteversion on the opposite side so that a true calculation can be made.

Hofstetter et al⁴⁶ described reduction of femoral fractures and correction of antetorsion using computer-assisted fluoroscopy. Optoelectronic markers track the position of the bone fragments, the drill and the femoral nail. The method allows three-dimensional measurement of anatomical landmarks and thus calculation of anteversion with a high degree of precision. If femoral anteversion is not related to the standard 10° to 15° range but to that of the uninjured side, computer-assisted surgery may eliminate rotational malalignment.

Clinical consequences of rotational malalignment

Rotational deformities may cause problems of clinical significance.^{1-3,7,8,22} Although deformities of less than 15° give rise to less complaints than larger degrees of malrotation, many patients tolerate abnormal torsion surprisingly well.^{7,22,30} Pain in the hip and knee with limitation of movement may occur and cause functional impairment,⁴⁷ especially in more demanding activities such as climbing stairs, running and playing sports.²⁹ Degenerative arthritis of the hip and knee are well recognised long term complications of rotational malalignment of the femur.^{48,49} In extreme cases the disability is such that surgical correction by means of a derotational osteotomy is required.^{1,47,50,51}

Why do some patients with rotational malalignment have symptoms and others do not? The degree of rotation certainly plays a role,^{7,22,30} but the most important observation is that patients with external rotational deformities have significantly more symptoms than those with internal rotation.^{15,29} Although many patients tolerate abnormal torsion well, most studies have not related groups with internal or external rotation to the clinical symptoms.^{1-4,7,8,22,30} Patients with external malrotation score significantly worse on functional scores such as the Oxford 12-item and the Knee Society scores compared to those with internal malrotation.²⁹

Johnson and Greenberg¹⁴ observed that patients could compensate well for internal rotational deformities but tolerate external rotational deformities poorly. Malrotation gives rise to an abnormally rotated foot.^{52,53} The torsion of the femoral neck and the foot progression angle are related in adults.⁵² We found that all patients compensate towards normal values of the foot progression angle but those with external malrotation are more restricted.⁵³ While compensating for external rotational malalignment with internal rotation of the leg, there is retroversion of the femoral neck in the hip joint. In hip studies an increase in retroversion is known to cause more symptoms^{48,54} than an increase in anteversion which would occur when compensating for internal malrotation.

The American Medical Association's Guide to the evaluation of permanent impairment⁵⁵ recognises 15° to 19° of malrotation after a fracture of the shaft of the femur as 18% whole person impairment. Malrotation of 20° or more adds 1% of whole person impairment per degree up to a maximum of 25%. However, it is wrong not to differentiate between internal and external rotation malalignment. External malrotation is underrated and internal malrotation may be overrated, if the impairment is solely determined on the degree of malrotation and the direction is not taken into account.

Conclusions

Rotational malalignment is found in between 20% and 30% of patients after intramedullary nailing of femoral fractures. The accuracy of rotational malalignment determined clinically is poor compared to that using CT. Other

methods using radiographs or ultrasound are technically demanding, leaving CT as the method of choice, but even these measurements have low intra- and inter-observer reliability. Averaging more measurements or using multiple image projection systems may increase the accuracy.

Deformities of more than 15° may cause problems with higher demand activities such as sports, running and climbing stairs. Patients with external malrotation have significantly more symptoms than those with internal malrotation. Although all patients compensate towards neutral foot progression angles, patients with external malrotation are less able to do so.

Efforts should be made to avoid rotational malalignment intra-operatively. Using a C-arm to compare the profile of the lesser trochanter of the affected and unaffected sides is a good way to control rotation of the proximal part of the femur. Computer-assisted fluoroscopy is a promising technique.

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