IATROGENIC FRACTURES OF THE FEMORAL NECK DURING CLOSED NAILING OF THE FEMORAL SHAFT

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We have reviewed our experience of four iatrogenic femoral neck fractures in 315 consecutive closed intramedullary nailings with the AO/ASIF universal femoral nail. The average neck-shaft angle in the bones that fractured was $139.3^\circ \pm 1.2^\circ$ SD (136 to 141); in the whole series the average neck-shaft angle was $125.3^\circ \pm 8.6^\circ$ and only 11 had angles of more than 135° . The upper ends of the nails in the four which fractured were 17 mm, 5 mm, 3 mm, and 1 mm below the tip of the greater trochanter.

In the seven patients with neck-shaft angles greater than 135° but with no fracture, none of the nails had been inserted beyond the tip of the greater trochanter.

We nailed six cadaver femora to simulate the forces produced by intramedullary nailing. Despite deep insertion, only one of the six sustained a neck fracture. This specimen had a radiographic neck-shaft angle of 140° against an average of $127.3^\circ \pm 4.0^\circ$ for the other five.

We believe that the medial prong of the AO insertion jig, with its medial overhang of 2 to 3 mm, may impinge on the superior aspect of a valgus femoral neck during final impaction, causing a neck fracture. This may be avoided by leaving the end of the nail above the tip of the trochanter in such cases.

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Closed intramedullary nailing of the femur for shaft fracture has considerable advantages, but the selection of the starting point is important. Küntscher (1967) recommended insertion of his nail through the tip of the greater trochanter to avoid possible damage to the hip. Winquist, Hansen and Clawson (1984) found that this was associated with increased proximal and medial comminution in some cases, and recommended introduction through the piriformis fossa. Many other authors have also advocated nail entry medially and posteriorly at the base of the greater trochanter (McMaster, Prietto and Rovner 1980; King and Rush 1981; Winquist et al 1984; Harper 1985).

In 1986, Harper and Henstorf reported two cases of iatrogenic fracture of the femoral neck during closed intramedullary nailing of the femur. The radiographs in their paper appeared to show the use of Sampson nails, and they considered that the fractures were due to misdirection of the nails with damage to the medial aspect of the femoral neck. Christie and Court-Brown (1988) found four femoral neck fractures in 143 consecutive closed nailings, and thought that insertion had been oblique in all four, with too lateral a starting point. The neck fractures were vertical, becoming extracapsular inferiorly, and only slightly displaced; the radiographs appear to show Grosse-Kempf nails.

There have been many studies of ipsilateral hip and femoral shaft fracture (Dencker 1965; Casey and Chapman 1979; Zettas and Zettas 1981; Swiontkowski, Hansen and Kellam 1984; Friedman and Wyman 1986; Swiontkowski 1987) and failure to recognise the neck fracture until later has been reported in up to 30% of cases. Avascular necrosis is uncommon in combined ipsilateral fractures because of the more lateral position of the fracture line (Böhler and Aichner 1959).

Radiographs with the hip internally rotated are necessary to give the best visualisation of the medial femoral neck; most emergency anteroposterior (AP) radiographs of the pelvis fail to show a concomitant neck fracture, because they are taken in external rotation.

In the four cases that we report, there was no evidence of femoral neck fracture in the preoperative or immediate postoperative radiographs. All four were diagnosed at routine follow-up about two weeks later and we postulate that they were iatrogenic and related to a valgus neck-shaft angle which allowed the insertion jig to impinge on

Fig. 1

Cadaver specimen to show the position of the insertion jig.

the superior femoral neck during impaction of the femoral nail.

PATIENTS AND METHODS

We reviewed our experience of closed femoral nailing and made radiographic measurements of neck-shaft angles in a blind manner as to the occurrence of neck fracture. We also performed experiments on six cadaver femora.

Clinical study. In a four-year period, 315 closed intramedullary nailings were performed for femoral shaft fractures, using the AO/ASIF universal femoral nail. There were 96 females and 219 males; their average age was 29 years (13 to 75). The average radiographic neck-shaft angle in the whole series was $125.3^\circ \pm 8.6^\circ$ SD. Only 11 patients had neck-shaft angles greater than 136° , and all four iatrogenic neck fractures were in this group. There were three females and one male; their average age was 34 years. Two of the patients had been nailed in the supine position and two in the lateral position; one 11 mm, two 12 mm and one 13 mm nail had been used. Preoperative and immediate postoperative radiographs showed no neck fractures, but they became apparent on radiographs taken at 11, 12, 14 and 17 days respectively. The average radiographic neck-shaft angle measured in these four was $139.3^\circ \pm 1.2^\circ$ (136 to 141).

The seven patients with neck-shaft angles of more than 135° but no neck fracture had an angle of $138.1^\circ \pm 1.7^\circ$ (136 to 143); their average age was 29 years. Five

patients were nailed in the lateral position and two in the supine position. Three were female and four were male.

Cadaver study. We studied six fresh-frozen femora, still attached to the pelvis by the hip capsule, from cadavers of average age 76 years. The femur in each specimen was cut at mid-shaft level, and the pelvis was mounted in a holding clamp. An AO nail was inserted (Fig. 1). The starting point, directly seen, was the piriformis fossa. A T-handled reamer was used to penetrate the proximal metaphyseal bone and a guide wire was placed in the femoral canal. Progressive reaming was done with care to avoid eccentric placement. An AO nail was then placed in the AO jig in the proper orientation and impacted with the slap hammer. Impaction continued using maximum force until advancement was no longer possible because the nail-end was flush with the femoral neck.

RESULTS

Clinical study. The four iatrogenic fractures were all of Pauwel's type III with varying degrees of displacement. Nail insertion had been to 17 mm, 5 mm, 3 mm, and 1 mm below the tip of the great trochanter. The starting points for nailing were in the piriformis fossa in both views in three cases and 2 to 3 mm posterior in one.

In the seven other patients with neck-shaft angles of greater than 136° and no neck fractures, the nails were never beyond the tip of the greater trochanter.

Three of the fractures were treated by percutaneous cannulated screw fixation; one required open reduction and internal fixation. After an average follow-up of 6.7 months there have been no complications, such as AVN or nonunion.

Cadaver study. Of the six cadaver femurs nailed in the laboratory, only one sustained a femoral neck fracture on inspection and radiography. This had the same vertical orientation as those in the clinical study (Fig. 2). The

Fig. 2

Femoral neck fracture produced in a cadaver specimen with an excessively valgus femoral neck by impaction of an intramedullary AO nail.

Fig. 3

The AO universal insertion jig, showing the 2 to 3 mm overhang medial and lateral to the upper end of the nail.

average radiographic neck-shaft angle was 130° in the unfractured group and 140° in the fractured specimen.

DISCUSSION

Closed intramedullary nailing has become the treatment of choice for virtually all femoral shaft fractures (Rothwell 1982; Winkler et al 1984; Hooper and Lyon 1988).

Küntschner originally advised starting the nail at the tip of the greater trochanter to avoid damage to the blood supply of the femoral head and to avoid opening the capsule of the hip which might lead to infection (Küntschner 1967). The piriformis fossa, however, is now the preferred site. Biomechanical studies have shown that an anterior placement increases hoop stresses (Thompson et al 1985; Johnson, Tencer and Sherman 1987) and this was recently confirmed by Miller et al (1993) in a cadaver study which also showed that an anterior entry is more likely to result in femoral neck fracture. An oblique position of the nail with a starting point too lateral in the trochanteric region has also been associated with intraoperative neck fractures (Christie and Court-Brown 1988).

In our total series, the average neck-shaft angle was $125.3^\circ \pm 8.6^\circ$, agreeing with previously reported values (Noble et al 1988). Only 11 patients had neck-shaft angles over 136° and four of these sustained neck fractures.

In both the clinical and cadaver series the starting hole was in the piriformis fossa, but in the clinical series

two nails were impacted too deeply, to 12 and 17 mm below the tip of the greater trochanter. In the cadaver series we impacted each nail as deeply as possible, flush with the femoral neck, but only one of the six specimens fractured. It therefore seems likely that femoral neck fractures are not entirely due either to an improper starting point or excess depth of insertion.

A femoral neck fracture discovered after shaft nailing may be caused by injury at the time of the accident (Wu and Shih 1991; Johnson 1992). These fractures may be undisplaced, and it is essential that the femoral neck is imaged adequately before shaft nailing. In our series all the femoral necks were well seen on films taken in internal rotation and centred on the femoral neck but we did not confirm the absence of fractures by isotope or CT scans.

The four clinical and one cadaver femoral neck that fractured all had a relatively valgus neck-shaft angle and an increased depth of insertion of the AO nail. It seems that the insertion jig with its medial prong overhang of 2 to 3 mm (Fig. 3) may impinge on the upper aspect of a valgus femoral neck during final impaction, providing an unrecognised contact point. Given the potential consequences of an untreated or unrecognised femoral neck fracture (Swiontkowski et al 1984; Swiontkowski 1987), we recommend that special care should be taken when the femoral neck is in a valgus position. The depth of insertion of the intramedullary nail should be carefully imaged during final impaction and this should stop before the jig assembly can make contact with the femoral neck. In such cases, this may occur before the upper end of the nail is flush with the tip of the greater trochanter, and it is preferable that the nail should remain proud.

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