INTRAMEDULLARY NAILING OF THE FEMUR IN CHILDREN

EFFECTS ON ITS PROXIMAL END

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We have studied the medium- and long-term effects of femoral intramedullary nailing in 34 children. There was a high incidence of abnormality at the proximal end of the femur, including coxa valga, arrest of growth of the greater trochanter and thinning of the neck of the femur, because of damage to the trochanterocervical growth plate. These disorders affected 30% of the patients, mostly under the age of 13 years ($p < 0.05$), and were seen more frequently when the nail had been introduced through the piriform fossa. Other factors, such as the side, gender, aetiology, proximal or retrograde insertion, the size of nail and removal of the implant did not influence the result.

We recommend that in patients under the age of 13 years other methods of management should be used to avoid damage to the growth plate.

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Femoral fractures in children have usually been treated conservatively (Tachdjian 1990). To improve the management of such children in intensive-care units, however, more aggressive methods have been proposed which stabilise the fracture without the need for traction or a plaster cast (Saxer 1980; Reeves, Ballard and Hughes 1990). Intramedullary (IM) fixation has been used, employing Küntscher or Rush nails with proximal insertion or retrograde passage through the greater trochanter or piriform fossa, depending on whether reduction was open or closed (Junge 1951; Vontobel, Genton and Schmid 1961; Küntscher 1965; Weber 1969; Vinz 1972; Herzog, Affolter and Jani 1976; Kirby, Winquist and Hansen 1981; Herndon et al 1989;

Maruenda-Paulino et al 1993). This method has also been used in children during limb-preserving operations for sarcomas in the femur or tibia. In such cases, femoral or femorotibial IM nailing has been used (Campanacci et al 1990).

The early results in fractures were good since the Küntscher nail provides immediate stability which does not require an additional cast (Junge 1951; Küntscher 1965; Ziv, Blackburn and Rang 1984; Hansen 1990). There are, however, few reports on the medium- to long-term effects on the proximal end of the growing femur (Fig. 1) partic-

Fig. 1

Diagram of the proximal end of the growing femur. TRC, triradiate cartilage; LGP, longitudinal growth plate; TGP, trochanteric growth plate; IGP, neck isthmus growth plate.

ularly on the growth cartilage of the greater trochanter and the neck of the femur (Merki 1968; von Ansorg and Graner 1976; Herzog et al 1976; Ziv et al 1984; Raney, Ogden and Grogan 1993).

We analysed the effect of IM nailing on the growth plate of the proximal end of the femur and assessed the clinical and radiological changes in patients with fractures and tumours.

PATIENTS AND METHODS

Between 1978 and 1988, we performed IM nailing of the femur on 34 children in the Ramón y Cajal Hospital. In 22, operation was for fracture of the femur and in 12 for

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osteogenic sarcoma, these latter patients having limb-preservation surgery stabilised by IM nailing. Patients with previous hip problems such as congenital dislocation and Perthes' disease, those with osteogenesis imperfecta, and those with a follow-up of less than five years were excluded, as were bilateral cases.

Details of the 34 patients are shown in Table I. The average age of the children was 10.8 years (3 to 14) and the average length of follow-up 6.2 years (5 to 13). Twenty were boys (58%), and the right side was affected in 18 (52%). A Küntscher nail measuring between 7 and 14 mm in diameter was used in all except a three-year-old boy in whom a 3 mm Rush nail was used. The implant was removed in all of the fracture group at 17 months (5 to 26), but was left in situ in patients with tumours. The hips of all the patients were evaluated clinically for pain, walking and mobility by the criteria of Merle D'Aubigné and Postel (1954). All the patients had radiography of the legs and PA views of the pelvis, using the healthy, contralateral hip as a control (Edgren 1965; Langenskiöld and Salenius 1967; Gage and Cary 1980; Ziv et al 1984). Measurements included the cervicodiaphyseal angle (CDA), the articulo-trochanteric distance (ATD), the intertrochanteric distance (TTD), the articulo-lesser trochanter distance (ALD), the distance from the centre of the head to the spur (CSD), the femoral neck diameter (FND), and the femoral head diameter (FHD) (Fig. 2). The hip was considered to be abnormal when measurements of the affected hip and normal hip showed differences of 10° or more in the CDA, 10 mm or more in the ATD, a reduction of 10 mm or more in the TTD, ALD and CSD or a reduction of 5 mm or more in FND and FHD. These values were analysed statistically as regards age, gender, side, fracture, aetiology of the tumour, proximal or retrograde insertion of the nail, point of entry at the piriform fossa or tip of the trochanter, and nail diameter, using the PC-1992 PRESTA Program vs 2.2 (Fondo de Investigaciones Sanitarias, Abraña-Zaplann, Madrid).

RESULTS

At the final review clinical examination was normal in 30 patients (88%). Four (12%) in the tumour group had discomfort from trochanteric bursitis where the nail had been too long.

Radiological examination (Fig. 3) showed an increase in the CDA of between 10° and 25° in ten patients (30%), an increase in the ATD of between 10 and 29 mm in six (18%), a reduction in the diameter of the FND of between 5 and 18 mm in eight (23%), and a reduction in the TTD of between 10 and 25 mm in five (15%). The ALD was altered only in one patient, and the CSD and the FHD were both altered in two patients.

Shortening of the femur was seen in 37% of the fracture group with a mean of 32 mm (5 to 65). This was seen on the initial radiograph which showed a highly comminuted

Table I. Details of 34 children who had intramedullary nailing of the femur

	Fractures	Tumours	All cases
Number of cases	22	12	34
Mean age (years)	10.5	11	10.8
Male:female	12:10	8:4	20:14
Mean diameter of nail (mm)	9.7	11.5	10.3
Proximal: retrograde	19:3	0:12	19:15
Trochanter: piriform fossa	12:10	5:7	17:17
Reaming	11 (50%)	12 (100%)	23 (68%)
Implant removed	22 (100%)	0 (0%)	22 (65%)
Mean follow-up (years)	6.3	5.9	6.2
CDA > 10	6 (27%)	4 (33%)	10 (30%)
ATD > 10 mm	4 (18%)	2 (17%)	6 (18%)
FND < 5 mm	4 (18%)	4 (33%)	8 (23%)
TTD < 10 mm	5 (23%)	1 (8%)	6 (15%)
ALD < 10 mm	0 (0%)	1 (8%)	1 (3%)
CSD < 10 mm	2 (9%)	0 (0%)	2 (6%)
FHD < 5 mm	0 (0%)	2 (17%)	2 (6%)

Fig. 2

Diagram showing measurements made on radiographs. CDA, cervicodiaphyseal angle; ATD, articulotrochanteric distance; TTD, intertrochanteric distance; ALD, articulo-lesser trochanter distance; CSD, distance from centre of head to lesser trochanter; FND, femoral neck diameter; FHD, femoral head diameter.

fracture with loss of length at the time of reduction and fixation. Overgrowth was also seen in 37% with a mean of 11.4 mm (5 to 20 mm). All patients in the tumour group had notable shortening of between 20 and 250 mm due to epiphyseodesis about the knee.

Statistical analysis showed differences in the CDA, ATD, TTD and FND with regard to age. Significant differences were only seen in patients under 13 years of age. Comparison between the over-13 and under-13 age groups showed

Fig. 3a

Fig. 3b

Fig. 3c

Fig. 3d

Fig. 3e

Figure 3a – A diaphyseal fracture of the middle third of the right femur in a six-year-old boy. Figure 3b – Fixation with a 7 mm intramedullary Küntscher nail. Figure 3c – After removal of the nail, the old area of entry through the piriform fossa (arrow) is seen. Figure 3d – Twelve years later there is coxa valga, arrested growth of the greater trochanter, a decreased intertrochanteric distance and considerable thinning of the neck of the femur. Figure 3e – After subtrochanteric varus osteotomy.

Fig. 4

The effect of age of the patient on the CDA. No changes were seen in children aged 13 or 14 years.

significant differences in the CDA ($p < 0.05$) (Fig. 4). No differences were seen as regards gender, laterality, the aetiology, proximal or retrograde insertion of the nail, nail diameter, effects of removal of the implant and reaming (Table I). Changes in the CDA, ATD and TTD were seen

twice as often in patients in whom the nail had been inserted through the piriform fossa rather than the tip of the trochanter, although no difference in the FND was seen. These differences were not statistically significant.

A statistical association ($p < 0.05$) was found in those

patients who showed a change in the CDA, ATD, TTD and FND.

DISCUSSION

The Küntscher IM nail has been used successfully in adults for decades (Winquist, Hansen and Clawson 1984). Küntscher (1965) recommended its use for femoral fractures in children and adolescents, and this has continued with little regard to its effect on the growth plate (Junge 1951; Kirby et al 1981; Herndon et al 1989; Hansen 1990; Reeves et al 1990; Maruenda-Paulino et al 1993). Experiments by Campbell, Grisolia and Zanconato (1959), however, have confirmed that damage can be caused when the growth plate is pierced by implants. Arrested growth of the greater trochanter and coxa valga as a result of trochanteric epiphysiodesis of the growth plate was demonstrated by Compere, Garrison and Fahey (1940) in experiments on dogs. Their findings have been applied clinically in the management of patients with relative overgrowth of the greater trochanter secondary to necrosis of the head of the femur in CDH or Legg-Calvé-Perthes disease (Langenskiöld and Salenius 1967; Gage and Cary 1980).

There are few reports in the English literature of changes in the proximal end of the femur after IM nailing (Ziv et al 1984; Raney et al 1993), but they have been described by German authors (Vontobel et al 1961; Merki 1968; von Ansorg and Graner 1976; Herzog et al 1976). The latter group found arrest of trochanteric growth and coxa valga in 21% to 50% of cases, and Herzog et al (1976) also reported necrosis of the head of the femur resulting from damage to the blood supply from the posterior circumflex artery. These changes are due to direct damage to the cartilage and possibly also to injury to the ascending lateral branches of the posterior circumflex artery (Chung 1976).

We found that the point of entry of the nail and the age of the child are significant factors. Discussion arises as to whether the nail should enter through the tip of the trochanter as suggested by Weber (1966) and Oelsnitz (1972) or through the piriform fossa (Vinz 1972; Herndon et al 1989; Maruenda-Paulino et al 1993) to avoid the trochanteric growth plate. Studies on growing and developing hips (Ogden 1983; Siffert 1983; Raney et al 1993) and the observations of Herzog et al (1976) suggest that the greater trochanter does not have an isolated growth plate, and that the direction of growth of the neck of the femur is determined by the activity of a continuous growth plate which extends from the longitudinal growth plate to that of the greater trochanter. In children this makes it almost impossible to avoid the continuous proximal physal system. We found no statistical difference between entry by the trochanter or the piriform fossa, but the incidence of abnormality doubled when entry was through the latter.

Radiological changes were more common in patients under 13 years of age and the difference was statistically significant when compared with those in older children. In

the nine children over 13 years of age no changes were seen in the CDA.

von Ansorg and Graner (1976) suggested that the valgus deformity seen in 21% of their patients should be considered as a prearthritic lesion likely to develop into osteoarthritis of the hip, with no chance of a reduction in the angle by remodelling. For this reason they advised a varus osteotomy in the more severe cases. They also advised entry via the tip of the greater trochanter, using a careful technique, and recommended early removal of the implant. We have not seen any difference in our results when the nail had been removed. Herzog et al (1976) recorded that 50% of their patients had a valgus deformity of over 5°. They considered that coxa valga, necrosis of the femoral head and trochanteric disorders were a direct result of treatment. They did not relate coxa valga to age, placement of the nail, site of the fracture, discharge time or the time which had elapsed before removal of the implant. They considered that a compression screw plate was the best method of osteosynthesis in these children. Ziv et al (1984) experienced trochanteric epiphysiodesis in only 23.5% of cases. They attributed the incidences of avascular necrosis and coxa valga to interruption of the blood supply to the neck of the femur and felt that this could be avoided by the retrograde insertion of a smaller nail. They advised that a Rush nail be used, sometimes supplemented by a plaster cast, and considered that the use of a screw plate required an extensive exposure and increased the risk of infection.

We have observed shortening only in fractures which had considerable comminution and do not consider it to be due to lesions of the trochanteric growth plate.

IM nailing is a useful method of managing fractures of the femur in children with polytrauma since it facilitates nursing and intensive care. The changes which occur in the medium to long term due to injury of the proximal growth plate, however, mean that this technique should be avoided during the growth period and replaced by procedures such as external fixation (González-Herranz et al 1993), stable elastic centromedullary nailing (Ligier et al 1988), the insertion of a tibial Küntscher nail through the external subtrochanteric zone, or a screw plate (Saxer 1980). IM nailing may be necessary in limb-preserving operations for sarcoma since the other procedures do not provide sufficient rigidity (Campanacci et al 1990). Secondary coxa valga may occur, however, and influence limb-length discrepancy (González-Herranz et al 1995).

The insertion of IM nails through the greater trochanter should be avoided in children because of the high risk of secondary lesions. These iatrogenic lesions should be considered to be prearthritic and a varus osteotomy may be needed where there are gross changes (Fig. 3). We therefore recommend that IM nailing should not be used for fractured femur in children under 13 years of age.

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