



Locked rigid antegrade intramedullary nailing of adolescent femoral fractures using a lateral trochanteric entry point

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The purpose of this study is to present our experience of treating adolescent femoral fractures using a locked intramedullary nail with a lateral trochanteric entry point.

We retrospectively reviewed 15 femoral fractures in 13 adolescents who were treated in our unit between 2011 and 2014. Data collected included patient demographics, mechanism of injury, type of fracture, associated injuries, time to union and complications. A radiographic review was also undertaken.

The mean time to radiological union in 14 out of the 15 fractures was 13 weeks (range, 10-20 weeks). One patient had a delayed union that required bone grafting and united finally at 30 weeks post injury. The mean difference in the neck shaft angle between the operated and non-operated side was 1.5 degrees (range: -10 to 10 degrees). No patients had infection or avascular necrosis. Five nails were removed after the fractures had healed without complications. Locked rigid intramedullary nailing of adolescent femoral fractures is a safe and effective treatment option when the lateral aspect of the greater trochanter is used as an entry point.

INTRODUCTION

Femoral shaft fractures account for 1.4-1.7% (24,33) of all paediatric fractures and the peak incidence varies between 2-17 years (9,13).

The common modes of injury in the adolescent include road traffic accidents, sports injuries and fall from heights (4,13,15).

The treatment options have evolved over the last few decades and the operative options include open compression plating, sub muscular plating, external fixation, flexible and rigid intramedullary nailing (1, 2,3,5,7,8,9,10,16,23,27,36,39).

Flexible intramedullary nailing has been popularized over the years and appears to be the most common treatment mode for the uncomplicated fracture in children above 6 years of age (32).

Because of their flexible nature, these nails may not provide sufficient stability when used in the older or heavier child or those with an unstable fracture pattern resulting in an increased incidence of malunion and other complications (18,20,22,28,34).

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Rigid antegrade intramedullary nailing has been advocated in these children in a bid to provide greater fracture stability, reduce complications and facilitate early ambulation (8,14).

Unfortunately, disruption of the blood supply to the femoral head leading to the complication of avascular necrosis has been observed when the piriformis fossa has been used as the nail entry point as in adults (25,30).

Subsequent investigators have shown that insertion of rigid nails through the greater trochanter leads to good union rates and low complication rates (12, 23, 37).

Most reports have however reported on the use of the rigid antegrade intramedullary nail in both skeletally mature and immature patients weighing over 45 kilogram with a shaft fracture and used nails that were not designed to be used as trochanteric nails (11,12,16,31,37).

We present our results using a lateral trochanteric entry locked intramedullary nail to treat femoral fractures in adolescents irrespective of their weight but who were more than 10 years of age and skeletally immature.

MATERIAL AND METHOD

After seeking approval from the Audit and Research Department of the Sheffield Children's hospital, we undertook a retrospective review of patients who had a femoral fracture that was treated surgically.

All patients who were treated using a locked antegrade intramedullary nail between 2011 and 2014 were considered for inclusion in this study.

Criteria for exclusion from the study were : (1) Children aged less than 10 years, (2) pathological fractures, (3) fractures sustained following limb lengthening surgery and (4) fractures that had previously been treated using an alternate method to rigid intramedullary nails.

The patient's medical records were reviewed for demographic information, mechanism of injury, associated injuries, pre and peri-operative treatment details, post-operative course, length of hospital stay, weight bearing status, fracture healing and complications.

On discharge from hospital all patients were reviewed in the outpatient clinic at regular intervals where they were assessed clinically and radiologically.

Clinical evaluation included assessment of the range of motion of the hip and knee joints, any leg length discrepancy by block measurement and rotational mal-alignment.

Radiographic assessment included plain anteroposterior (AP) and lateral views of the affected femur and AP pelvic radiographs.

The final clinical and radiological assessment was undertaken by (MH and NM) and the radiographs were assessed for evidence of avascular necrosis of the femoral head.

The proximal femoral anatomy was also assessed in 11 patients with unilateral fractures by comparing the fractured with the contralateral non fractured side using radiographic measurements such as femoral neck diameter (FND) and neck-shaft angle (NSA).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 19 (IBM, Inc Armonk, New York, USA) software. Descriptive statistics are reported as numbers (percentage) or mean (absolute range) as appropriate. Parametric data were analysed using the Students t-test and the significance level was set at a p value of less than or equal to 0.05.

Of the 13 patients who qualified for inclusion in this study, 7 (54%) were males and 6 (46%) were females.

The mean age at the time of surgery was 12.2 years (range, 10 - 15.7 years) (Table 1) and all patients had open distal femoral physes. The mean weight was 46 kg (range, 25 - 70 kg). Seven (54%) patients weighed more than 45 kg.

The mechanism of injury was road traffic accidents (RTA) in 6 patients (46%) and falls (high energy related to sports activities) in 7 (54%). The right femur was fractured in 9 and the left in 2 patients. Two patients had bilateral fractures. The fracture location was within the proximal third of the femur (sub-trochanteric) in 7 (47%) fractures and the middle third in 8 (53%).

Table I — showing patient and fracture demographics

| Pt. | Age (Yrs) | Side | Weight (kg) | Mechanism | Associated Injuries | Site | Nail Size (mm) | Time to Unite (weeks) | Hospital stay (days) | Complications |
|-----|-----------|------|-------------|-----------|--|---------------------------------------|----------------|-----------------------|----------------------|-----------------------|
| 1 | 14 M | Rt | 45 | Fall | Nil | Proximal 3rd, Transverse | 8 x 300 | 12 | 3 | Nil |
| 2 | 11.5 F | Lt | 40 | Fall | Distal radius fracture | Mid shaft, oblique | 7 x 300 | 20 | 9 | Nil |
| 3 | 15.7 M | Rt | 60 | RTA | Tibia/Fibula, distal radius fracture | Mid shaft, comminuted | 8 x 340 | 12 | 15 | Nil |
| 4 | 14.5 M | Rt | 55 | RTA | Nil | Mid shaft, spiral | 9 x 360 | 10 | 5 | Broken proximal screw |
| 5 | 13.2 M | Rt | 58 | RTA | Nil | Proximal 3 rd , Tranverse | 9x360 | 16 | 11 | Nil |
| | | Lt | | | | Mid shaft, Transverse | 9x360 | 16 | | Nil |
| 6 | 15.6 M | Rt | 70 | RTA | Ipsilateral talus, calcaneus, open tibia and distal radius/ulna fracture | Mid shaft, comminuted | 9x380 | Delayed | 14 | Delayed union |
| 7 | 13 M | Rt | 46 | RTA | Distal radius fracture | Mid shaft, oblique | 8x320 | 12 | 15 | Nil |
| | | Lt | | | | Proximal 3 rd Transverse | 8x320 | 12 | | Nil |
| 8 | 11 F | Rt | 36 | Fall | Nil | Mid shaft comminuted | 9x260 | 14 | 8 | Distal femoral Valgus |
| 9 | 10.4 F | Rt | 32 | RTA | L4 fracture | Proximal 3 rd comminuted | 7x280 | 12 | 5 | Nil |
| 10 | 10 F | Rt | 25 | Fall | Nil | Proximal 3 rd , oblique | 7x260 | 14 | 8 | Nil |
| 11 | 10 M | Lt | 30 | Fall | Nil | Proximal 3 rd , oblique | 7x260 | 16 | 6 | Nil |
| 12 | 11 F | Rt | 46 | Fall | Nil | Proximal 3 rd , transverse | 7x280 | 14 | 7 | Nil |
| 13 | 13.2 F | Rt | 55 | Fall | Nil | Mid shaft, comminuted | 8x320 | 14 | 5 | Nil |

The fracture pattern was transverse in 5 (33%) fractures, spiral in 1 (7%), oblique in 4 (27%) and comminuted in 5 (33%).

Eight (62%) of the 13 patients had isolated femoral fractures with no associated injuries. Of the remaining 5 patients, 3 had closed unilateral distal radius fractures, however one of the 3 also had an ipsilateral tibia/fibula fracture.

The 4th patient had a compression fracture of the 4th lumbar vertebrae whilst the last patient who was involved in a road traffic accident had ipsilateral talus, calcaneus, open tibia and contralateral distal radius/ulna fractures.

Two (13%) of the 15 fractures were open (Gustilo type 3a fractures) and involved the middle third of the femur.

These fractures were in patients who were involved in Road traffic accidents and had associated injuries.

Operative technique

The operative procedure was carried out under general anesthesia with the patient supine on a traction table. Surgery was undertaken by the Consultants (SG, JF and SJ). Intravenous antibiotics was administered on induction of anaesthesia and 2 additional doses were given post-operatively.

A 3.2 mm threaded tipped guide wire was inserted percutaneously through the lateral aspect of the greater trochanter at a point half way between the tip of the trochanter and the trochanteric physis.

The guide wire was driven under power into the medullary canal up to but not through the medial cortex of the proximal femur. The position of the guide wire was verified under fluoroscopy. A 1.5 cm skin incision was made proximal to the guide wire.

A 9.5 mm cannulated entry reamer was advanced over the guide wire into the femoral canal. A flexible reamer was then used to prepare the intramedullary canal over a ball tipped guide wire. Reaming was done progressively till the largest possible reamer.

The nail length and diameter were determined by pre and intraoperative radiographic measurements. The mean nail length was 31 cm (range, 26-38 cm).

A PediNail™ (Orthopediatrics, Warsaw) (Lateral trochanteric entry nail) was used in all cases and the nails were locked proximally and distally.

The proximal locking screw(s) was inserted using an insertional jig whereas the distal screw(s) were placed freehand under fluoroscopic guidance.

The mean operating time for all fractures was 102 minutes (range, 80-130 minutes). No patient experienced significant intraoperative blood loss to require blood or blood product transfusion.

The length of hospital stay ranged from 3-15 days with a mean stay of 8.6 days. Longer stays were observed in patients with associated injuries.

Post operatively all patients were advised to touch weight bear on the operated limb for the first 2 weeks with progressive weight bearing beyond that. This advice was irrespective of the fracture site and pattern.

RESULTS

The mean length of follow up for all 13 patients was 26 months (range, 8-44 months) and the mean time to fracture union was 13 weeks (range, 10-20 weeks in 14 fractures).

One patient had a delayed union that required a secondary surgical procedure i.e. bone grafting to facilitate union. The fracture finally united at 30 weeks.

This patient had associated fractures of the distal radius/ulna, talus, calcaneum and ipsilateral open tibia fracture which required stabilization using an external fixator. He was non-compliant with instructions regarding rehabilitation and refused to weight bear for a prolonged period after the initial surgery. In addition he was a cigarette smoker.

Some patients experienced intermittent discomfort to the lateral aspect of the hip but none required analgesia 6 weeks after surgery.

The mean limb length discrepancy by block assessment at the final follow up was 8mm (range, -5 to 12mm). This difference was not statistically significant ($p=0.20$).

A valgus alignment of 10 degrees was observed in one patient. This patient required a distal femoral hemi-epiphysiodesis using an 8 plate. A sagittal plane mal-alignment of 3 degrees procurvatum was observed in one other patient but no treatment was required. No patient had clinically significant mal-rotation.

At final follow up the mean femoral neck diameter of the operated limb was 32mm (range, 26-41mm) while that of the non-operated limb was 31mm (range, 25-40mm). The mean difference between the operated and contralateral non operated side was 0.6mm and not statistically significant (p value = 0.08).

The mean neck shaft angle of the operated side was 132 degrees (range, 115 -148 degrees) while that of the non-operated side was 134 degrees (range, 118-150 degrees). The mean difference in NSA between the sides was 1.5 degrees (range, -10 to 10 degrees). There was no significant differences between the sides (p value = 0.7).

One patient had a broken proximal locking screw. This was not replaced and fracture healing was not delayed.

None of the patients in this study had a non-union, deep infection or avascular necrosis.

Five of the 13 patients have had the nails removed without complications as it is our unit policy to remove metalwork in children.

DISCUSSION

Intramedullary nailing of femoral fractures in children has been carried out for a number of decades (17,21). In early reports the piriform fossa was used as the entry point but due to the reported complication of avascular necrosis (AVN) of the femoral head this entry point is not now recommended (25,30).

This catastrophic complication of avascular necrosis is believed to be the result of injury to the ascending cervical artery, a branch of the medial circumflex artery which lies in close proximity to the piriform fossa (6,25,38).

It is known that the blood supply to the femoral head in skeletally immature patients is primarily from the medial circumflex femoral artery as the supply from the ligamentum teres is minimal and the open physis serves as a barrier to blood flow from the metaphysis to the femoral head (6,29,38).

To avoid this complication, alternative nail entry sites such as the tip and lateral aspect of the greater trochanter have been used (8,12,11,31).

Gonzalez-Herranz et al (11) and Raney et al (31) then raised concerns after reporting the complications of femoral neck narrowing and femoral neck valgus deformity when the tip of the trochanter was used as an entry point.

Early in the development of the proximal femur, the proximal femoral physis is a single continuous growth plate with the epiphysis consisting of a combined femoral head and greater trochanter (16,29). Siffert (35) believed that a remnant of this physis persisted along the lateral aspect of the femoral neck as a femoral neck isthmic physis. Keeler et al (16) also believed that damage to this proximal femoral physis remnant that produces lateral growth then produces the femoral neck valgus and narrowing observed by Gonzalez-Herranz et al.

This therefore suggests that using the lateral aspect of the greater trochanter as an entry point avoids

injury to the proximal femoral physis remnant and this permits continued growth of the femoral neck isthmus without producing femoral neck narrowing and valgus. In addition the risk of avascular necrosis is non-existent as reported by McNeil et al (23) in a meta-analysis. They reported AVN rates of 1.4% when the tip of the greater trochanter was used, 2% for the piriform fossa and 0% for the lateral aspect of the greater trochanter.

It is because of the reported advantages of the lateral trochanteric entry point (no AVN or femoral neck valgus) that we have used the PediNail (a lateral trochanteric entry nail) and compare our results with other reports.

The PediNail has a 15 degree bend proximally that enables the entry point to be approximately 1 finger breadth lateral to the tip of the greater trochanter thus avoiding tethering of the trochanteric growth plate hence decreasing the risk of femoral neck narrowing and valgus deformity.

In addition, the short skin incision (1.5 cm) and small diameter (9.5 mm) entry reamer recommended for implanting this nail may further decrease the risk of femoral neck deformity and avascular necrosis.

Gordon et al (12) reported on 15 femoral shaft fractures in patients aged between 8 and 17 years treated using a modified rigid humeral intramedullary nail inserted through the lateral aspect of the greater trochanter. They reported no complications and an average fracture healing time of 7 weeks.

Keeler et al (16) reviewed 80 femoral shaft fractures also treated using a modified locked humeral nail inserted via a lateral trochanteric entry point. The average fracture healing time was also 7 weeks. Although they reported no case of AVN or clinically significant femoral neck valgus they noted 2 deep infections. The age range of their patients was 8.2-18.4 years.

Keeler et al and Gordon et al reported better fracture healing times compared to our series and this we believe is due to the fact that a number of patients in their series were young (less than 10 years of age) and fracture healing times would be expected to be short. None of the patients in our series were less than 10 years of age.

Miller et al (26) reported on 18 femoral shaft fractures in skeletally immature patients with ages

ranging from 7.6 -11.9 years treated using a locked titanium pediatric femoral nail using a lateral trochanteric entry point. The average fracture healing time was 13 weeks and no complications were noted.

All 13 patients in our series were skeletally immature and the mean fracture healing time of 13 weeks compares favorably to the report by Miller et al.

Although we observed no cases of AVN in our series, we had a case of delayed union in an adolescent with multiple fractures. This we believe was because the patient was a cigarette smoker and he was not compliant with physiotherapy and other treatment post-surgery refusing to weight bear for a prolonged period.

In addition we did not observe any significant changes in the proximal femoral anatomy, leg length, sagittal plane alignment and rotational alignment.

Though the flexible intramedullary nail is a reasonable treatment option for treating femoral fractures in adolescents a report by Lee et al (19) has suggested that they can only withstand 40% of the body weight of young adolescents (approximately 45 kg) and hence various authors advocate rigid intramedullary nailing for the obese adolescent. In our series there was no significant difference in the fracture healing times and proximal femoral anatomy in the 7 patients that weighed more than 45 kg compared to the 6 that weighed less. We suggest that rigid intramedullary nailing is not only considered for the obese patient.

The limitations of this study include the retrospective nature and the small sample size. We are continuing to review these patients and will recruit further patients to increase the size of our cohort.

We believe there is an important place for locked intramedullary nails in the armamentarium of equipment to treat femoral fractures in the adolescent age group as it provides good fracture stability, facilitates early weight bearing and good healing times.

CONCLUSION

Locked rigid antegrade intramedullary nailing of adolescent femoral fractures is a safe and effective

tive treatment option when the lateral aspect of the greater trochanter is used as an entry point.

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