

Twenty-Year Experience with Rigid Intramedullary Nailing of Femoral Shaft Fractures in Skeletally Immature Patients

Samuel N. Crosby Jr., MD, Elliott J. Kim, MD, Daniel M. Koehler, MD, Michael T. Rohmiller, MD, Gregory A. Mencio, MD, Neil E. Green, MD, Steven A. Lovejoy, MD, Jonathan G. Schoenecker, MD, PhD, and Jeffrey E. Martus, MD, MS

Investigation performed at the Department of Orthopaedic Surgery, Vanderbilt University Medical Center, Monroe Carell Jr. Children's Hospital, Nashville, Tennessee

Background: Debate exists over the safety of rigid intramedullary nailing of femoral shaft fractures in skeletally immature patients. The goal of this study was to describe functional outcomes and complication rates of rigid intramedullary nailing in pediatric patients.

Methods: A retrospective review was performed of femoral shaft fractures in skeletally immature patients treated with trochanteric rigid intramedullary nailing from 1987 to 2009. Radiographs made at initial injury, immediately postoperatively, and at the latest follow-up were reviewed. Patients were administered the Nonarthritic Hip Score and a survey.

Results: The study population of 241 patients with 246 fractures was primarily male (75%) with a mean age of 12.9 years (range, eight to seventeen years). The majority of fractures were closed (92%) and associated injuries were common (45%). The mean operative time was 119 minutes, and the mean estimated blood loss was 202 mL. The mean clinical follow-up time was 16.2 months (range, three to seventy-nine months), and there were ninety-three patients with a minimum two-year clinical and radiographic follow-up. An increase of articulo-trochanteric distance of >5 mm was noted in 15.1% (fourteen of ninety-three patients) at a minimum two-year follow-up; however, clinically relevant growth disturbance was only observed in two patients (2.2%) with the development of asymptomatic coxa valga. There was no femoral head osteonecrosis. Among the 246 fractures, twenty-four complications (9.8%) occurred. At the time of the latest follow-up, 1.7% (four of 241 patients) reported pain. The average Nonarthritic Hip Score was 92.4 points (range, 51 to 100 points), and 100% of patients reported satisfaction with their treatment.

Conclusions: Rigid intramedullary nailing is an effective technique for treatment of femoral shaft fractures in pediatric patients with an acceptable rate of complications.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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A commentary by Mark C. Lee, MD, is linked to the online version of this article at jbjs.org.

Femoral shaft fractures are a common injury in children and adolescents. In patients older than four years of age, the majority of fractures are treated operatively. Rigid intramedullary nailing is the standard treatment of femoral shaft fractures in adults and in older children and adolescents with good results¹⁻⁶. Rigid intramedullary nailing provides stable internal fixation allowing for early mobilization of the patient with immediate weight-bearing. Other treatment options include traction with spica casting, flexible nailing, external fixation, and plate fixation; however, there are disadvantages with each of these alternatives. The disadvantages of traction and casting for femoral shaft fractures include prolonged hospitalization and immobilization with risks of malunion and joint stiffness⁷⁻¹⁰. Due to a lack of rigid fixation, flexible nailing has an increased rate of malunion in older and larger patients¹¹. External fixation has a higher rate of complications, including malunion, when compared with flexible nailing¹². Plate fixation does not allow immediate weight-bearing and may require greater use of intraoperative fluoroscopy when compared with rigid intramedullary nailing^{13,14}.

A major concern with rigid intramedullary nailing in skeletally immature patients is the association of piriformis entry rigid intramedullary nailing with resultant osteonecrosis¹⁵⁻²¹. This complication is believed to be related to injury to the ascending branch of the medial femoral circumflex artery, which is in close proximity to the piriformis fossa¹⁹. The rate of osteonecrosis with piriformis entry nailing may be as high as 1% to 5% in a skeletally immature patient^{15,16,22}. Trochanteric entry has been utilized as an alternative for rigid intramedullary nailing in children and adolescents as it is relatively distant from the pericapsular vasculature⁵, with only two reported cases of osteonecrosis with this technique^{23,24}.

Although trochanteric rigid intramedullary nailing of femoral shaft fractures in skeletally immature patients has gained acceptance, concern remains related to the potential for proximal femoral growth disturbance secondary to the implant crossing the trochanteric apophysis. Alterations of proximal femoral anatomy have been described following trochanteric rigid intramedullary nailing in this population, but these radiographic findings may not be clinically important^{1,2,25}.

The current literature on skeletally immature patients with femoral shaft fractures treated with rigid intramedullary nailing consists of relatively small studies ranging in size from twenty to eighty patients²². Furthermore, there are four clinical series showing functional outcomes after femoral rigid intramedullary nailing in adults²⁶⁻²⁹; however, to our knowledge, there have been no similar studies for skeletally immature patients.

The objective of this study was to present a large cohort of skeletally immature patients with femoral shaft fractures treated with rigid intramedullary nailing and a subcohort with a minimum two-year follow-up. We sought to determine the rate of complications and to describe functional outcomes using a validated measure.

Materials and Methods

Following institutional review board approval, a retrospective review was performed of femoral shaft fractures treated with rigid intramedullary nailing at a single institution from 1987 to 2009. Inclusion criteria were skeletal immaturity with an open proximal femoral physis, distal femoral physis, or iliac apophysis at the time of injury, treatment with trochanteric entry rigid intramedullary nailing, and minimum clinical follow-up of three months. Complication rates were determined within this overall cohort. Clinical and radiographic outcomes were assessed in subcohorts with a minimum two-year follow-up. Exclusion criteria were inadequate medical records or radiographs, an underlying bone disorder, or ipsilateral proximal femoral or acetabular injury.

TABLE I Radiographic Measurement Reliability Analysis

	Intraclass Correlation Coefficient*	95% Prediction Limit†
Conventional radiographs (manual measurement)		
Femoral neck-shaft angle		
Intra-rater	0.772 (0.679 to 0.840)	1.5° (0.2° to 2.8°)
Inter-rater	0.871 (0.809 to 0.913)	1.9° (0.9° to 2.9°)
Articulotrochanteric distance		
Intra-rater	0.987 (0.981 to 0.991)	0.3 mm (0 to 1.1 mm)
Inter-rater	0.993 (0.990 to 0.996)	0.5 mm (0 to 1.4 mm)
Digital radiographs (PACS measurement)		
Femoral neck-shaft angle		
Intra-rater	0.831 (0.759 to 0.883)	1.5° (0.4° to 2.6°)
Inter-rater	0.908 (0.863 to 0.938)	1.8° (1.0° to 2.6°)
Articulotrochanteric distance		
Intra-rater	0.993 (0.986 to 0.996)	0.3 mm (0 to 0.7 mm)
Inter-rater	0.997 (0.993 to 0.998)	0.4 mm (0 to 1.0 mm)

*The values are given as the mean, with the 95% confidence interval in parentheses; these values were significant at $p < 0.001$. †The values are given as the mean, with the range in parentheses.



Fig. 1-A



Fig. 1-B

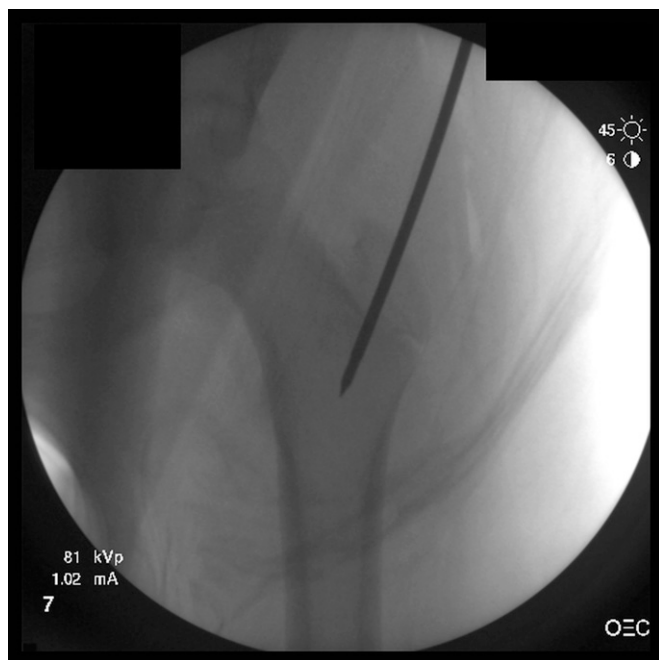


Fig. 1-C

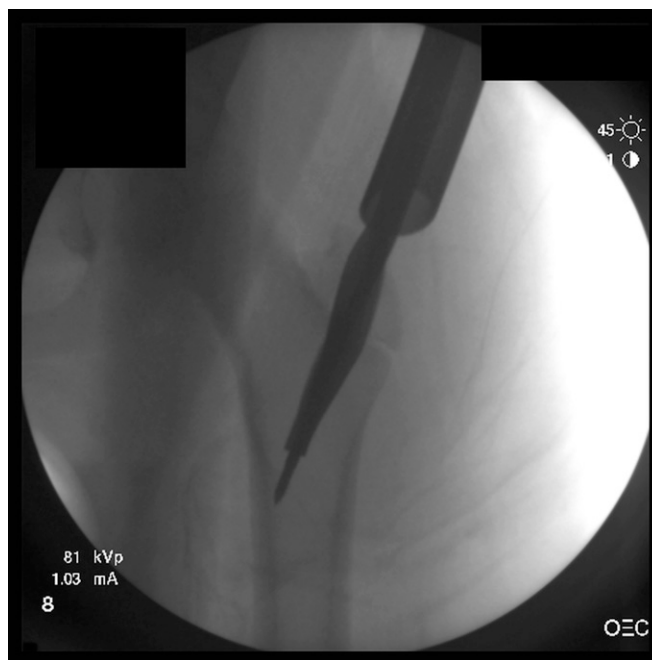


Fig. 1-D

Figs. 1-A through 1-F Images showing trochanteric entry rigid intramedullary nailing for an eleven-year-old boy with a type-II open fracture. **Fig. 1-A** Preoperative lateral radiograph. **Fig. 1-B** Preoperative anteroposterior radiograph. **Fig. 1-C** Intraoperative fluoroscopic image of guidewire insertion. **Fig. 1-D** Intraoperative fluoroscopic image of proximal reaming.

In general, our algorithm for treatment of femoral shaft fractures in skeletally immature patients is as follows. Patients who are under five years of age are managed with closed reduction and application of a one-and-one-half-leg

spica cast or a single-leg spica cast. Patients who are five to nine years of age are managed with flexible nailing for stable fractures and submuscular plating or flexible nailing supplemented with casting for unstable fractures. Patients who are

ten years of age and older are managed with rigid intramedullary nailing considered on the basis of patient and fracture characteristics that favor rigid fixation, including greater physiologic maturity, larger size (weight of >45 kg), length unstable fractures (oblique, segmental, or comminuted), or fracture locations that would preclude other types of fixation (proximal or distal fractures). Early in the experience described in this article, younger children (7.5 to nine years of age) were treated with trochanteric rigid intramedullary nailing. Currently, we do not use this technique in this younger age range because of concerns of potential growth disturbance and the proven reliability of alternative fixation methods.

Operative Technique

All patients were treated with trochanteric rigid intramedullary nailing on a radiolucent table or a fracture table. In the early years of the study, a straight nail was utilized (Russell-Taylor Delta II, Smith & Nephew, Memphis, Tennessee). Later in the study, a nail with proximal angulation was utilized (Trigen, Smith & Nephew). The trochanteric entry point is in the lateral portion of the trochanter, inserting the guide pin in a location to avoid disruption of the lateral wall of the piriformis fossa when reaming. Nail diameters were based upon preoperative assessment of canal diameter and intraoperative determination of appropriate fit during reaming. Complete fill of the canal was not attempted or desired. Reaming was completed at 1.0 to 1.5 mm above the intended nail diameter. Proximal reaming was performed to accommodate the proximal nail geometry (Fig. 1).

Postoperative Care

Patients were mobilized weight-bearing as tolerated without a specific physical therapy regimen unless there was difficulty regaining strength or range of motion of the hip or knee. Patients were followed until radiographic union. Early in the study, routine implant removal (nail and screws) was recommended irrespective of age. Over more recent years, we discouraged routine implant removal because

of the extent of dissection required. When necessary, symptomatic interlocking screws were removed. Medical records were reviewed for demographic characteristics, injury mechanism, associated injuries, operative details, and complications. Radiographs made at initial injury, immediately postoperatively, and at the latest follow-up were reviewed. Radiographic outcomes were assessed in patients with a minimum two-year follow-up by evaluating for evidence of osteonecrosis or proximal femoral growth disturbance. Growth disturbance was noted with a change in the articulo-trochanteric distance of >5 mm or the presence of coxa valga, defined as a 10° increase in the femoral neck-shaft angle or a femoral neck-shaft angle of $>145^\circ$ at the time of the latest follow-up. Radiographs prior to 2000 and after 2000 were examined. A standardized positioning protocol was utilized during both time periods where the lower extremities are internally rotated 15° to 20° for anteroposterior images of the pelvis and proximal femur. Prior to 2000, anteroposterior pelvis and standing bone length radiographs at the time of the latest follow-up were made for all patients, and comparisons for growth disturbance were determined with the contralateral hip. After 2000, our postoperative protocol was altered to minimize radiation and cost, and radiographs of the anteroposterior pelvis and bone length were not routinely available at the time of the latest follow-up; thus, comparisons for growth disturbance were conducted between radiographs that were made immediately postoperatively and those that were made at the time of the latest follow-up. Limb-length discrepancy after 2000 was determined by clinical examination of the iliac wings and posterior superior iliac spines, leveling the pelvis with graduated blocks. Conventional radiographs prior to 2002 were measured manually. Digital radiographs after 2002 were measured on our picture archiving and communication system (PACS).

Clinical outcomes were determined by attempting to contact and to interview all patients with a minimum two-year follow-up. First, the patients were administered the Nonarthritic Hip Score³⁰. Next, they were asked four additional questions: (1) had they seen another orthopaedic surgeon for their



Fig. 1-E



Fig. 1-F

Fig. 1-E Proximal anteroposterior radiograph showing healing fracture at four weeks postoperatively. **Fig. 1-F** Distal anteroposterior radiograph showing healing fracture at four weeks postoperatively.

TABLE II Demographic Characteristics of Total Study Population and Phone Survey Cohort

	Total Study Population (N = 241)	Phone Survey Cohort (N = 39)	P Value
Injury mechanism			
Motor vehicle collision	50%	38%	0.23
All-terrain vehicle or motorcycle accident	18%	14%	0.64
Sports	23%	21%	0.84
Other	9%	17%	0.15
Sex			
Male	75%	74%	1.0
Female	25%	26%	1.0
Mean age (yr)	12.9	13.5	0.34
Open fracture	8.1%	0%	0.09
Associated injury	45%	46%	1.0
Postoperative complication	10%	5%	0.55
Elective implant removal (interlocking screws and/or nail)	50%	56%	0.49
Mean duration of follow-up (mo)	16	83	NA*
*NA = not applicable.			

leg or hip, (2) were they able to run or to participate in sports, (3) were they employed or in school, and (4) were they satisfied with their treatment?

Demographic characteristics of the total study population and the phone survey cohort were statistically compared utilizing a two-tailed Fisher exact test for categorical values and an unpaired t test for continuous variables. Inter-rater and intra-rater reliability of the radiographic measurements were determined. Randomization charts were created and ten patients' radiographs were selected from both before and after the PACS time periods. Individual radiographs were then randomly selected ten times and measurements of the femoral neck-shaft angle and articulothoracic distance were completed by two observers (S.N.C. and E.J.K.). Intraclass correlation coefficients were calculated. Agreement was determined by intraclass correlation coefficient: <0.40 indicated poor agreement, 0.40 to 0.59 indicated fair agreement, 0.60 to 0.74 indicated good agreement, and 0.75 to 1.0 indicated excellent agreement. Analysis of variance calculations were used to determine 95% prediction limits for error in the measurements.

Source of Funding

No external funding was received for this study.

Results

A total of 411 patients were identified. Patients were excluded for inadequate follow-up or records ($n = 147$), underlying bone disorder ($n = 19$), or ipsilateral proximal femoral or acetabular injury ($n = 4$). A total of 241 patients with 246 femoral shaft fractures were included. Of these patients, fifty-four were able to be located via administrative information in the medical record and were contacted by telephone. Thirty-nine (72.2%) of the fifty-four patients agreed to participate in the survey portion of the study; the total response rate as compared with the overall study population was 16.2% (thirty-nine of 241 patients).

Demographic Characteristics

The overall study population of 241 patients was primarily male (75%) with a mean age of 12.9 years (range, eight to seventeen

years). Common injury mechanisms were motor vehicle collisions (50%), sports (23%), and all-terrain vehicle or motorcycle accidents (18%). Associated injuries were common (45%), and the majority of fractures were closed (92%). Of the open fractures, according to the Gustilo and Anderson classification system, fourteen were type I, three were type II, and three were type IIIa³¹. The mean operative time was 119 minutes (range, sixty to 325 minutes), and the estimated blood loss was 202 mL (range, 50 to 600 mL). The nail diameters were ≤ 8.5 mm (34%), 9 mm (21%), 10 mm (44%), or ≥ 11 mm (<1%). The Russell-Taylor Delta II nail was implanted in 113 fractures (46%) and the Trigen nail was implanted in 133 fractures (54%). Overall, the mean clinical and radiographic follow-up time was 16.2 months (range, three to seventy-nine months). The minimum two-year clinical and radiographic follow-up subcohort of ninety-three patients (ninety-four fractures) had a mean follow-up of 37.4 months (range, twenty-four to seventy-nine months).

Radiographic Measurement Reliability Analysis

The reliability of the femoral neck-shaft angle and articulothoracic distance measurements were determined for conventional and digital radiographs. All intraclass correlation coefficients were in the excellent range with values of >0.75 ($p < 0.001$). The mean 95% prediction limits were 1.5° to 1.9° for the femoral neck-shaft angle and 0.3 to 0.5 mm for the articulothoracic distance (Table I).

Radiographic Analysis

Radiographs of all 246 fractures included in the study were reviewed at a mean follow-up of 16.2 months and no osteonecrosis was observed. Radiographs were analyzed for growth disturbance in two separate groups with a minimum two-year follow-up. The



Fig. 2-A



Fig. 2-B



Fig. 2-C

Figs. 2-A, 2-B, and 2-C Radiographs showing asymptomatic coxa valga following rigid intramedullary nailing. **Fig. 2-A** Initial postoperative radiograph of a type-I open fracture treated with rigid intramedullary nailing at the patient age of 10.4 years. The postoperative course was complicated by chronic osteomyelitis and the necessity of multiple operative interventions. **Fig. 2-B** Radiograph after refracture at twenty-two months post-initial injury. **Fig. 2-C** The latest radiograph at the patient age of 14.2 years with minimal limb-length discrepancy and a femoral neck-shaft angle of 150°.

first group consisted of sixty-nine patients (sixty-nine fractures) treated from 1987 to 1999 with a mean follow-up duration of 37.3 months (range, twenty-four to sixty-four months). In this group, radiographs of the injured femur at the time of the latest follow-up were compared with those of the contralateral side. The mean difference in the articulothoracic distance was 4.1 mm (range, -20 to +24 mm). The mean limb-length discrepancy was 1.3 mm (range, -25 to +26 mm). Eleven patients (15.9%) had a >5-mm increase in the articulothoracic distance; none of the patients were symptomatic. One of these patients, the youngest child in the study overall, developed coxa valga with the femoral neck-shaft angle increasing from 137° immediately postoperatively to 149° at 6.5 years postoperatively. She was asymptomatic, and no further treatment was required.

The second group consisted of twenty-four patients (twenty-five fractures) treated from 2000 to 2009 with a mean follow-up of 37.5 months (range, twenty-four to seventy-nine months). In this group, radiographs of the injured femur at the time of the latest follow-up were compared with the injury radiographs. At the time of the latest follow-up, the mean difference in the articulothoracic distance was 0.2 mm (range, -7 to +19 mm). A >5-mm increase in articulothoracic distance was noted in 12.5% (three of twenty-four patients) at the twenty-four-month follow-up; none of the patients were symptomatic. A limb-length discrepancy of

1 to 2 cm was noted in five patients (20.8%), and a limb-length discrepancy of >2 cm was noted in one patient (4.2%). One patient developed coxa valga after sustaining a Gustilo and Anderson type-I open femoral shaft fracture and a contralateral tibial spine fracture at the age of 10.4 years (Fig. 2). He was treated with serial debridement, rigid intramedullary nailing, and internal fixation of the tibial spine. A deep infection was recognized at seven months post-injury and he underwent nail removal, sequestrectomy, and prophylactic external fixation. At twenty-one months post-injury, he sustained a pathologic femoral shaft fracture and was treated

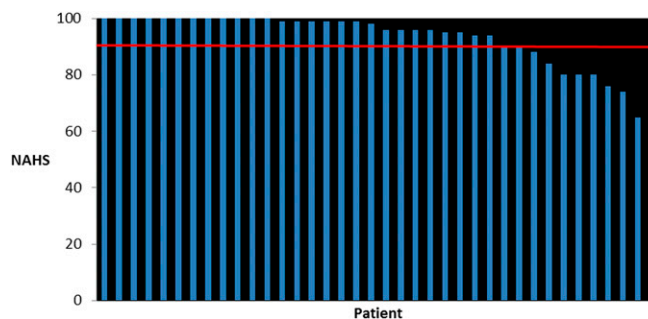


Fig. 3
Distribution of the Nonarthritic Hip Score (NAHS).

TABLE III Complications After Fractures for Total Study Population and Cohort with a Minimum Two-Year Follow-up

Complication	Total Study Population*	Cohort with a Minimum Two-Year Follow-up†
Heterotopic ossification (asymptomatic)	11 (4.5%)	4 (4.3%)
Delayed union requiring dynamization	3 (1.2%)	3 (3.2%)
Malunion (>10°)	3 (1.2%)	3 (3.2%)
Malrotation requiring reoperation	1 (0.4%)	1 (1.1%)
Interlocking screw migration requiring removal	3 (1.2%)	3 (3.2%)
Proximal femoral growth disturbance (coxa valga)	2 (0.8%)	2 (2.1%)
Deep infection	1 (0.4%)	1 (1.1%)
Osteonecrosis	0 (0.0%)	0 (0.0%)
No. of thromboembolic events	0 (0.0%)	0 (0.0%)
Total no. of complications	24 (9.8%)	17 (18.1%)

*The values are given as the number of complications, with the percentage, based on 246 fractures, in parentheses. The mean duration of follow-up for the total study population was sixteen months. †The values are given as the number of complications, with the percentage, based on ninety-four fractures, in parentheses. The mean duration of follow-up for the cohort with a minimum of two-year follow-up was thirty-seven months.

with rigid intramedullary nailing. The refracture healed and, at the time of the latest follow-up, 3.8 years after his initial injury, he was asymptomatic, and the femoral neck-shaft angle had increased to 150° from 140° immediately postoperatively. No further treatment was needed.

Outcomes

Of the 241 patients included in the study, four (1.7%) had substantial pain recorded in the latest follow-up progress note. Thirty-nine patients completed the Nonarthritic Hip Score and phone questionnaire. The mean age at the time of survey was 20.4 years (range, 14.8 to 25.1 years) and the mean time from injury to the interview was 6.9 years (range, 2.8 to 12.4 years). There were no significant differences in the demographic characteristics of the total study population as compared with those of the phone survey cohort (Table II). The mean Non-

arthritic Hip Score was 92.4 points (range, 51 to 100 points), and 74% of patients had a Nonarthritic Hip Score of ≥90 points. The distributions of the Nonarthritic Hip Score and the pain responses are presented in Figures 3 and 4. In this cohort of thirty-nine patients, twenty-six (67%) reported being active in sports or running, thirty-eight (97%) were either employed or in school, one (3%) had seen an outside orthopaedic surgeon, and thirty-nine (100%) stated that they were satisfied with their treatment. A lower Nonarthritic Hip Score or residual pain was not correlated with complications, including heterotopic ossification.

Complications

Twenty-four complications (9.8%) occurred in the treatment of the 246 fractures: eleven complications were asymptomatic Brooker class-I heterotopic ossifications³², three were delayed

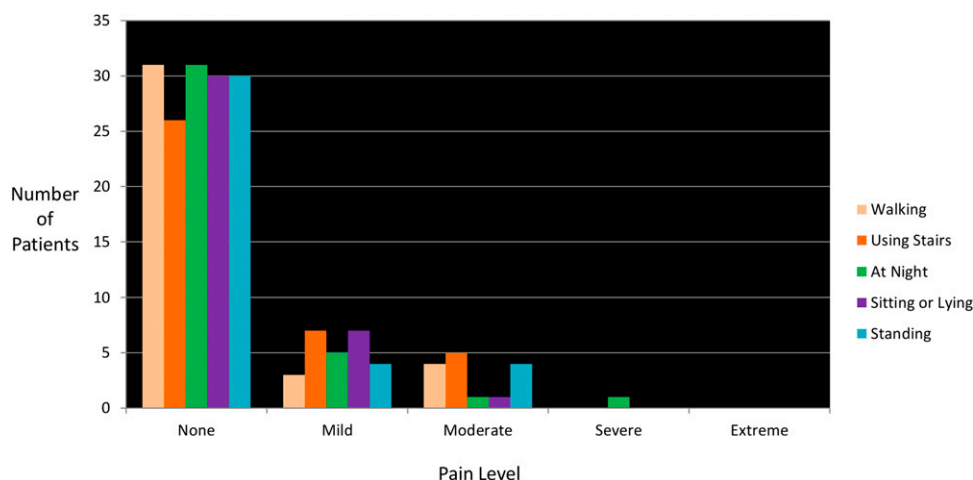


Fig. 4

A bar graph showing the distribution of the pain responses within the Nonarthritic Hip Score.

union requiring dynamization, three were malunion with $>10^\circ$ of deformity, three were interlocking screw migration requiring removal, two were asymptomatic coxa valga, one was a deep infection requiring reoperation, and one was a malrotation requiring reoperation. No thromboembolic complications or implant-related fractures were noted. Osteonecrosis was not clinically suspected within the study population (Table III) or in those patients who did not meet the inclusion criteria. Additional surgical procedures were performed in 50.4% of the overall study population for the following indications: implant removal, including symptomatic implants or removal recommended by the surgeon (47%); deep infection (0.4%); delayed union requiring nail dynamization (1.2%); malrotation (0.4%); and interlocking screw migration (1.2%). An association of complications with age, sex, fracture pattern, or injury mechanism was not identified.

Discussion

Rigid intramedullary nailing is a safe and effective technique for the treatment of femoral shaft fractures in skeletally immature patients. The advantages include a high union rate, early mobilization, and good outcomes¹⁻⁶. The risks of proximal femoral growth disturbance and femoral head osteonecrosis are low when a lateral trochanteric entry point is utilized^{22,33-35}. These advantages are further reinforced by our study with a 99% union rate, a 2.2% incidence of proximal femoral growth disturbance, and no cases of femoral head osteonecrosis.

The existing publications on the use of trochanteric entry rigid intramedullary nailing in skeletally immature patients have all included relatively low numbers of patients. A recent systematic review of the literature by MacNeil and colleagues identified nineteen studies of trochanteric rigid intramedullary nailing with a combined total of 219 patients²². Our study included 241 patients managed with this technique over the course of more than two decades.

A >5 -mm increase of articulo-trochanteric distance was noted in 15.1% (fourteen of ninety-three patients) at a minimum two-year follow-up; however, there were only two cases of proximal femoral growth disturbance (2.2%), manifested as asymptomatic coxa valga. In both of these cases, trochanteric physeal arrest was not suspected radiographically. The coxa valga may have resulted from growth stimulation of the proximal femoral physis or growth retardation of the trochanteric apophysis. In addition, secondary procedures such as intramedullary nail removal may also contribute to the development of a growth disturbance. Other studies have shown cases of proximal femoral valgus deformity after intramedullary nailing through the trochanteric apophysis^{2,25}. These studies imply that the disruption of the growth plate contributes to the valgus deformity, and some recommend alternative fixation that does not cross the trochanteric apophysis. However, Gage and Cary reported that trochanteric epiphyseodesis in patients with osteonecrosis of the proximal femoral epiphysis who were eight years of age or older has minimal effects on trochanteric growth and suggested that, after this age, trochanteric growth is mostly appositional³⁶. Gordon et al. hy-

pothesized that the valgus deformity may occur because of disruption of the medial greater trochanteric physis where it extends to the lateral side of the femoral neck³⁴. They concluded that placement of an intramedullary nail through the lateral aspect of the greater trochanter avoids the medial physis and will not produce clinically important valgus deformity in children who are nine years of age or older.

The risk of proximal femoral osteonecrosis is well documented in piriformis entry rigid intramedullary nailing^{15-21,37}, whereas trochanteric entry rigid intramedullary nailing is believed to be safer because it avoids the pericapsular vasculature. However, skepticism remains with regard to the safety of trochanteric rigid intramedullary nailing in skeletally immature patients. In a 1998 survey of Pediatric Orthopaedic Society of North America (POSNA) members on their experience with femoral fracture treatment, fourteen specific cases of osteonecrosis were noted, of which at least three were likely treated with trochanteric entry rigid intramedullary nailing; the nail entry site was not specified for the other cases³⁸. Two case reports of osteonecrosis after trochanteric rigid intramedullary nailing have been published^{23,24}. One case involved insertion of a relatively large nail adjacent to the medial aspect of the greater trochanter, and the other was a suspected case at almost the twenty-year follow-up.

Although functional outcomes after rigid intramedullary nailing have been reported in the adult population²⁶⁻²⁹, data on functional outcome in pediatric femoral shaft fractures treated with rigid intramedullary nailing are limited. The patients in this study returned to relatively good function after treatment. The survey cohort demonstrated that 67% continued to participate in sports or jogging and 97% were either employed or in school. The relatively low rate of participation in athletic activity at a mean follow-up of 6.9 years after injury may be related to the transition to adulthood with a sedentary lifestyle. The Nonarthritic Hip Score is a reliable and validated outcome measure for young patients without hip arthritis³⁰. The Nonarthritic Hip Score was designed with the maximum score of 100 points to be considered as normal hip function. The mean Nonarthritic Hip Score of the patients in the current study was 92.4 points, and 74% had a Nonarthritic Hip Score of ≥ 90 points, which correlates with excellent function and very low disability. It was unclear why 26% of patients had lower scores; this issue deserves further investigation. Outcomes have been described with the Nonarthritic Hip Score in other conditions, including Legg-Calvé-Perthes disease, in which the mean Nonarthritic Hip Score was 79 points in a long-term study after nonoperative treatment³⁹.

In the medical records of the overall study population, at the time of the latest follow-up, residual pain was documented in only 1.7% of patients, and no pain was documented in the remaining 98.3% of patients. However, the survey data indicate a higher rate of residual pain in the activities assessed by the Nonarthritic Hip Score (Fig. 4). This finding suggests the need for longitudinal studies of this population to determine factors associated with residual pain and potential disability.

The major limitation of this study was the retrospective design over an extended time period. A large number of patients were excluded because of inadequate follow-up, common in a posttraumatic population. None of the patients who were excluded because of inadequate follow-up are known to have had complications. It is conceivable that longer follow-up of those excluded patients could alter the conclusions of this study. Another limitation was the use of two different radiographic comparisons for proximal femoral growth disturbance because of differences in clinical practice over the time period of the study. The functional outcome data were also limited as this cohort represents only 16% of the study population; however, 72% of those patients who could be contacted agreed to participate, and their demographic characteristics, including age, injury mechanism, frequency of associated injuries, and rate of complications were similar in comparison with those of the overall study population.

In summary, trochanteric entry rigid intramedullary nailing of femoral shaft fractures in skeletally immature patients is an effective treatment with an acceptable rate of complications. The rate of union is high, and many patients return to normal function after treatment. However, some patients have long-term residual pain in the injured extremity, which may be underestimated at the time of the latest follow-up. Despite this, rigid intramedullary nailing is recommended as the standard treatment for management of diaphyseal femoral fractures in the adolescent population. ■

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Samuel N. Crosby Jr., MD
Elliott J. Kim, MD
Gregory A. Mencia, MD
Neil E. Green, MD
Steven A. Lovejoy, MD
Jonathan G. Schoenecker, MD, PhD
Jeffrey E. Martus, MD, MS
Department of Orthopaedic Surgery,
Vanderbilt University Medical Center,
Monroe Carell Jr. Children's Hospital,
4202 DOT, 2200 Children's Way,
Nashville, TN 37232-9565.
E-mail address for J.E. Martus: jeff.martus@vanderbilt.edu

Daniel M. Koehler, MD
Department of Orthopaedics and Rehabilitation,
University of Iowa Hospitals and Clinics,
200 Hawkins Drive, 01008 JPP,
Iowa City, IA 52242

Michael T. Rohmiller, MD
Beacon Orthopedics and Sports Medicine,
500 E-business Way,
Sharonville, OH 45241

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