

Decreased Complications of Pediatric Femur Fractures With a Change in Management

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Background: Elastic intramedullary nails are commonly the preferred treatment option for operative stabilization of pediatric diaphyseal femur fractures. Increased complication rates have been reported in unstable fractures and older patients treated with TENs (titanium elastic nails). The reported complications have led to a change in management at our institution: limiting the use of TENs and using submuscular plating and trochanteric entry nails as alternatives. The purpose of this study is to analyze whether this change in management has improved outcomes defined by a decrease in complications between 2 time periods.

Methods: This retrospective study compared 2 cohorts of femur fractures: those treated from January 2001 to January 2003 versus those treated from January 2003 to December 2006. Patient's age, weight, fracture type (stable or unstable), operative fixation technique, and complications were compared. Outcomes were measured by major or minor complications that occurred after operative treatment.

Results: Period I consisted of 46 patients and Period II of 95 patients. There was a significant decrease in TEN use in unstable fractures in Period II versus Period I. Submuscular plating increased from 9% in Period I to 28% in Period II. All complications decreased from 52% in Period I to 23% in Period II. Major complications decreased from 22% to 5%, and minor complications decreased from 30% to 18%. Complications in unstable fractures decreased from 57% to 26% and in stable fractures from 48% to 22%.

Conclusions: Outcomes of pediatric femur fractures are improved with limiting the use of TENs to stable fractures. Complications resulting from unstable femur fracture management have decreased with other methods of stabilization such as submuscular plating or trochanteric entry nails.

Key Words: pediatric femur fractures, management of pediatric femur fractures, complications of pediatric femur fractures, intramedullary elastic nails, submuscular plating

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Operative management of pediatric femur fractures is recommended over traction or spica casting as it allows for early mobilization, more predictable healing, and allows patients a more rapid return to school.^{1,2} The common techniques are elastic intramedullary nails, submuscular plating, and lateral trochanteric entry nails. Which technique is chosen is dependent on situational factors of age, fracture type, and surgeon preference. At this time, there is no study that compares one technique over the other. The resurgence and success of flexible intramedullary nails is well documented and responsible for the preference of operative stabilization.^{1,3–5} Treatment with elastic nails allows early surgical stabilization without prolonged hospitalization or spica casting which reduces hospital costs and allows a more rapid return to school.^{1,2,6} Operative stabilization also theoretically decreases the risk of fracture shortening and malreduction.

With widespread use of elastic nails, reports of “complications” have followed and recommendations on which patients are better suited for elastic nails have emerged.^{7–11} Titanium Elastic Nails (TENs) seem to be implanted more commonly than stainless steel nails (Enders nail) because of surgeon's preference and instrumentation. Common reported complications of TENs are: knee pain at the insertion site, nail prominence, nail back-out or migration, fracture shortening, malunion, and delayed union.^{7,10} The conclusion of many of the retrospective case series is that complications are greater in patients who are above the age of 11 years, heavier than around 50 kg, or with unstable fracture patterns.^{7,8,10}

At our institution, we reported that complications of TENs were greater in length-unstable fractures.⁸ This was a retrospective case series of all femur fractures treated over a 2-year period from January 2001 to January 2003. During this period, TENs were used in most femur fractures regardless of fracture stability. The results of this study led to a change of practice at our institution. Applying what we learned, the same group of surgeons have limited the use of TENs in length-unstable fractures. Submuscular plating and rigid trochanteric nails have been the alternatives in the unstable fractures.

The purpose of this study is to analyze whether this change in practice has decreased the complications after operative management of pediatric diaphyseal femur fractures. We aim to compare 2 cohorts, those treated during the time period of the prior published series (January 2001 to January 2003) to those since January

2003, after we limited the use of TENs. Our hypothesis is that there has been a significant improvement in outcomes defined by a decrease in complications.

METHODS

This is a retrospective review comparing 2 cohorts that represent 2 different time periods of pediatric diaphyseal femur fractures treated with internal fixation. Period I includes pediatric femur fractures managed operatively from January 1, 2001 to December 31, 2002. Period II includes pediatric femur fractures managed operatively from January 1, 2003 to December 31, 2006. These periods were chosen as the dates and patients included Period I are the same as our prior publication. The information from this cohort led to an institutional change in operative management reflected in Period II. Therefore, we believe that the dates separating the 2 cohorts were not randomly chosen. Inclusion criteria are patients treated with operative management of diaphyseal femur fractures (subtrochanteric region to distal femoral metaphysis) until skeletal maturity. Patients with pathologic fractures and patients who did not have follow-up until complete fracture union were excluded.

The retrospective review included patient age, weight, and fracture type. Fractures were classified as either stable or unstable fracture. A stable fracture is defined as a fracture that is transverse or short oblique (the length of the fracture is less than the diameter at the level of the fracture). An unstable fracture is defined when the fracture is comminuted or long oblique (the length of the fracture is longer than the diameter of the femur at the level of the fracture). The technique of operative fixation was recorded. The techniques were titanium elastic nailing (Synthes; Paoli, PA), submuscular bridge plating, trochanteric entry nails, and external fixation.

Outcomes were defined by complications after operative treatment. Complications were classified as either minor or major. Minor complications were implant pain at the knee, implant prominence, knee pain, or infections. Major complications were an unplanned return to surgery, malunion (> 10 degrees of varus/valgus or recurvatum/procurvatum), or delayed union of greater than 6 months without 3/4 cortices healed.

Analysis was performed using SAS Version 9.2 (Cary, NC). The 2 periods were compared with respect to fracture stability, fracture management, and complications. Chi-squared and Fisher exact tests were used for the comparisons. All factors that could define a difference between the 2 periods were analyzed to allow a true historical comparison: distribution of fracture types, surgeons, patient demographics, and surgical technique. Technical factors considered relevant to TENs (cutting the nails short, using nails $> 80\%$ the diameter of the canal, and using the same diameter nails) were analyzed to address any differences in technique that may explain any differences in complication rates between the 2 cohorts.

Patient weight and age as a factor in implant choice were also considered in the sensitivity analysis for Period II. Receiver-operating characteristic curves were plotted for stable fractures in the TENs group using logistic regression models, with any complication as the outcome and weight and age as explanatory variables (both individually and in combination). Sensitivity and specificity were calculated for the range of ages and weights in the data.

RESULTS

Sixty-three children in Period I and 131 children in Period II had operative fixation of diaphyseal femur fractures. There were 46 patients in Period I and 95 patients in Period II who met the inclusion criteria and had follow-up until fracture union. The distribution of fracture types in Period I was 25 (54%) stable and 21 (46%) unstable. The distribution of fracture types in Period II was 60 (63%) stable and 35 (37%) unstable. There was no significant difference between the 2 cohorts with regard to fracture stability ($P = 0.32$).

TENs were used in 39 of 46 fractures (85%) for Period I and 58 of 95 fractures (61%) in Period II. There was statistically a significant decrease in their utilization between the 2 periods ($P = 0.004$). In Period I, TENs were used in 24 of 25 (96%) stable fractures and 15 of 21 (71%) unstable fractures. In Period II, TENs were used in 52 of 60 (87%) stable fractures and only 6 of 36 (17%) unstable fractures. There was a significant decrease in TENs' use in unstable fractures in Period I versus Period II ($P < 0.0001$).

Submuscular plating was used more in Period II (28%, 27 of 95) than in Period I (9%, 4 of 46) ($P = 0.008$). In Period II, the majority of unstable fractures, 71%, were treated with submuscular plates (25 of 35). This was significantly more than the 19% (4 of 21) treated with submuscular plates in Period I ($P < 0.001$). There was an increase in trochanteric nail use from 1 of 46 (2%) in Period I to 9 of 95 (9%) in Period II, although the numbers are too small to reach statistical significance ($P = 0.11$). These results indicate that there was a significant change in practice between the 2 cohort periods. (Figs. 1A, B).

The 2 cohorts were similar with regard to surgeons (the same), patient ages, and distribution of fracture stability. Technique differences in TENs between the 2 cohorts were not statistically significant except larger nails were used in Period II. Nail sizes of 3.5 or 4 mm were used in 53 of 58 (91%) patients in Period II compared with 25 of 39 (64%) patients in Period I ($P < 0.001$). Therefore, the recommendation of each nail at 40% of canal diameter (80% for both nails) was followed in 51% versus 59% of cases. In Period I, 36% of nails were cut short of the distal femoral physis so they would not be prominent and symptomatic versus 48% in Period II. This was not a statistically significant increase but suggests that more effort was made in Period II to cut the nails shorter.

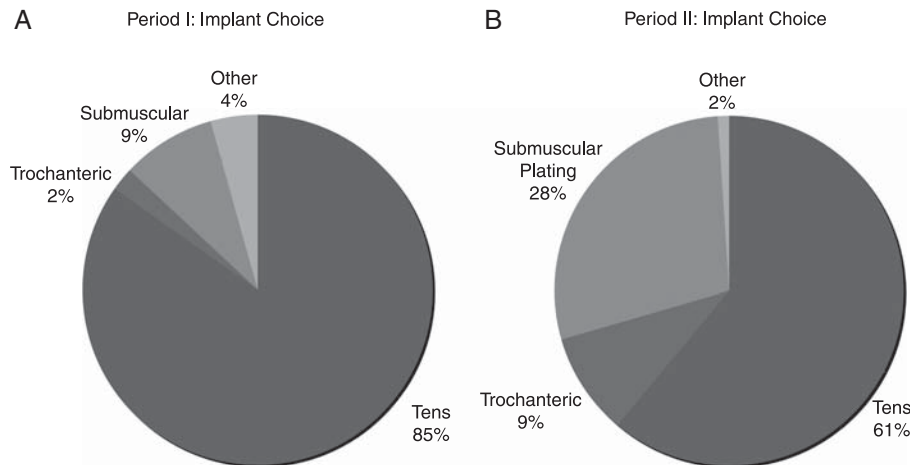


FIGURE 1. A, Implants chosen for operative stabilization in Period I. Notice the significant use of TENS. B, Implants chosen for operative stabilization in Period II. There was a significant increase in the choice of submuscular plating ($P=0.0001$) and a decrease in the choice of TENS ($P=0.004$). TENS indicates titanium elastic nails.

There was a decrease in all complications from 52% (24 of 46) in Period I to 23% (21 of 95) in Period II ($P < 0.001$). Major complications (nonunion, delayed union, and return to surgery) decreased from 22% (10 of 46) to 5% (5 of 95) ($P = 0.007$). Minor complications decreased from 30% (14 of 46) to 18% (17 of 95) ($P = 0.09$). The specific complications are listed in Table 1.

Complications in unstable fractures decreased from 57% (12 of 21) to 26% (9 of 35) ($P = 0.019$). There was a significant reduction of major complications in the unstable fractures (7 of 21, 33% to 1 of 35, 3%, $P = 0.003$). This pattern was clearly observed in the subgroup of patients treated with TENS, which showed a reduction in complications from 62% (24 of 39) to 31% (18 of 58) ($P = 0.003$). We also found a reduction in stable fractures that had complications from 48% (12 of 25) to 22% (13 of 60) ($P = 0.015$). The change in complications between the 2 periods is summarized in Figures 2A and B.

The complication rate in the group whose surgical procedure conformed to a proposed algorithm based on age (> 11 y and stable fractures as a cutoff for using TENS) was 12% (9 of 78) versus 76% (13 of 17) in those whose surgical procedure did not conform to age below 12 years and stable fractures for TENS use. When a cutoff

for weight greater than 50 kg was used instead of age, the complication rate in those who followed the algorithm was 15% (12 of 81) versus 71% (10 of 14) in those who did not follow the algorithm. Basing an algorithm on age improved sensitivity/specificity in predicting complications in patients with stable fractures treated with TENS compared with weight. Using both variables was no better than using age alone.

DISCUSSION

We compared 2 cohorts representing 2 consecutive time periods of operative treatment of pediatric diaphyseal femur fractures. There was a significant decrease in complications as a result of a “change in management” between the 2 different cohorts. Period I corresponds to pediatric femur fractures managed operatively from January 1, 2001 to December 31, 2002. Period II corresponds to pediatric femur fractures managed operatively from January 1, 2003 to December 31, 2006. These 2 cohorts were similar with respect to fracture stability, age, and treating surgeons. The significant difference between the cohorts was the change in method of operative fixation.

The most significant change between the 2 cohorts was limiting the use of TENS in unstable fractures. The benefits of TENS are early fixation, early patient mobilization, minimally invasive fixation, and improved alignment with good reported results.^{1–3,6} TENS were used in the majority of fractures in Period I regardless of fracture stability as there was a lot of enthusiasm for this technique over traction, followed by spica casting and external fixation. As with any surgical technique, there are limitations or situational factors that make TENS less appealing. When we studied the complications of TENS at our center, we concluded that the rate of complications was greater when used in length-unstable fractures. Major complications (unplanned return to surgery, delayed

TABLE 1. Description of the Specific Complications for Each Period

	Period I n = 24	Period II n = 21
Major		
Return to operation room	8 (33)	3 (14)
Malunion	1 (4)	1 (5)
Delayed union	1 (4)	1 (5)
Minor		
Nail prominence and knee pain	12 (50)	14 (66)
Infection	2 (8)	1 (5)
Other	0	1 (5)

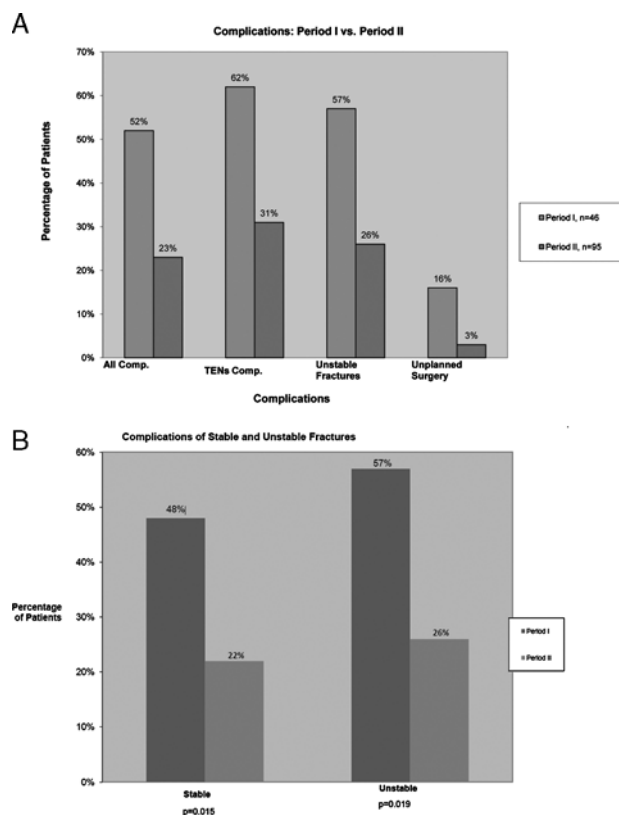


FIGURE 2. A, Complications in each period. B, Complications in each period by fracture type. TENs indicates titanium elastic nails.

union, and malunion) were greater in unstable fractures versus stable fractures ($P < 0.05$).⁸ There have been other studies on elastic nails that validate the efficacy or elastic nails but also highlight some limitations.^{5,7,9–11} In a multicenter study of 229 children treated with elastic nailing, Moroz et al⁷ concluded that an age ≥ 11 years and weight greater than 49 kg are more likely to have a complication. We found that using age (> 11 y) was a better predictor of complications than weight, and that using both age and weight was no better at predicting complications than age alone. Learning from these studies and our own experience led to a change in how we managed pediatric femur fractures in Period II. The dates chosen for the 2 cohorts was not random but based on analysis performed at the end of Period I.

There was a significant shift in Period II to submuscular plating in the unstable fracture patterns. Submuscular plating was used in only 19% of unstable fractures in Period I versus 71% in Period II. The effectiveness of submuscular plating for treatment of unstable pediatric femur fractures has been reported with minimal complications naturally leading to a shift to using this technique in unstable fractures.^{12,13} In Period I, the complication rate was 57% in the unstable fractures group compared with 26% in Period II. This change may be partially attributed to the increased use of submuscular plating in the unstable fractures and possibly to improved

technique with the elastic nails such as using larger diameter nails. In the unstable fractures treated with submuscular plates in Period II, there were only 3 complications in 25 patients; 1 rotational malunion of 15 degrees that had no clinical significance, and 2 cases of distal plate and screw irritation that resolved with plate removal.

Since there was a decrease in complications for both stable and unstable fractures with the same surgeons, there is a “learning curve” effect. Inherent in the learning curve is not only familiarity with the technique over time, but learning and applying the technical factors of the TEN techniques that would lead to a decrease in complications. Technical factors described to decrease complications when using elastic nails are: using the largest nail diameter possible, use the same diameter nails, and leave the nail ends short.^{7,9–11} Knowledge of these technical “tips” and greater experience with the elastic nail technique certainly played a role in the change in complications between the 2 cohorts. We evaluated the surgical technical factors that would effect the complications. The only significant difference between Period I and II with regard to TEN techniques was using larger diameter nails. This may explain the decreased incidence in the stable fracture complications. Nails were cut shorter in Period II (although not significantly) so there were less prominent nails that could cause symptoms around the knee. For example, surgeons would initially bend the nails away from the distal femur to facilitate later implant removal. This practice would increase the chance of implant prominence and knee pain as a complication reported in the early series. Another reason for improvement in the stable fractures may be that we increased the use of trochanteric entry rigid nails for the older and heavier patients with stable fractures, thus limiting delayed union and mild angular deformities with a rigid implant.

The limitations of this study are that it is a retrospective review therefore the data is only as good as the chart documentation. In addition, there are many patients who were treated that are not in either cohort as many patients treated at our institution are from out of state and lost to follow-up. This large percent of patients lost to follow-up was similar in both groups. At this time, there is no validated radiographic standard of malunion or shortening that may affect functional outcome and development of later osteoarthritis or pain. Therefore short-term and intermediate outcome variables are used in this study that highlight any change in the routine early postoperative course such as an unplanned return to surgery or implant prominence. Knee pain and implant prominence is considered a minor complication in this study and others that have reported this as a complication.^{9,10} In Period II, this complication may be under-reported as it becomes expected with elastic nails inserted around the knee, therefore this is resolved with implant removal and never documented.

The decreased incidence in complications in this study after a change in management is present in both unstable and stable fractures but most evident in unstable

fractures and in complications after elastic nail treatment. Many of the complications are minor and do not result in any long-term morbidity, therefore, we would still recommend operative management over spica casting or traction for the benefits of early mobilization, decreased hospital costs, and faster return to school.

Considering what we have learned in this analysis and from other authors, we propose the following algorithm for treatment of pediatric femur fractures. We recommend TENs for stable fractures (transverse or short oblique) with the age of 5 to 11 years. We would recommend adherence to earlier published technical factors such as using the largest diameter nails possible, leaving the nail ends short, and limiting use in older and heavier patients. In patients above 11 years of age, with stable fractures, we would recommend trochanteric entry nails (if the canal size is large enough) or submuscular plating as options for treatment. We recommend using methods other than TENs for unstable femur fractures (comminuted or long oblique). TENs or stainless steel elastic nails are still options for treatment for all pediatric femur fractures but adherence to proper technique such as using the largest diameter nails is recommended. In this study, submuscular bridge plating was a successful alternative in the unstable fractures yet trochanteric rigid nailing (in children > 11 y with a large enough canal to accept the nail) and stainless steel elastic nails are other alternatives.^{14,15} The proposed algorithm may benefit surgeons when deciding which option for treatment of pediatric femur fractures would limit complications depending on the situational factors of age, weight, and fracture stability.

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