Original Article

Pediatric femoral shaft fractures: the American Academy of Orthopaedic Surgeons clinical practice guidelines versus actual management in a teaching hospital

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Background: In 2009, the clinical practice guidelines (CPG) were released by the American Academy of Orthopaedic Surgeons (AAOS), which outline an age-based approach for treating pediatric femoral shaft fractures (PFSF), both nonoperatively and operatively. The aim of the current study was to investigate potential disparities between the recommended treatments for PFSF based on the AAOS-CPG and the actual treatments administered in The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University.

Methods: A retrospective review was conducted on the medical charts and radiographs of all PFSF treated at The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University from January 2014 to January 2022. We identified 445 children who met our inclusion criteria and evaluated their treatments according to the AAOS-CPG. Actual treatments were then compared with the treatments recommended by the AAOS-CPG. Binomial and multivariate logistic regression was used to examine whether different factors could predict the choice between operative and nonoperative management.

Results: Operative treatments were undertaken in 102 of 215 (47.4%) fractures in children younger than 6 years, in 102 of 122 (83.6%) fractures in those between 6 and 12 years of age, and in 107 of 108 (99.1%) fractures in those older than 12 years. Nonoperative management was conducted in 113 of 215 (52.6%) fractures in children younger than 6 years, in 20 of 122 (16.4%) fractures in those between 6 and 12 years of age, and in 1 of 108 (0.9%) fractures in those older than 12 years of age. Surgeon decisions for non-surgery were in agreement with the CPG 52.6% of the time, whereas agreement reached 90.9% for surgical choices. Predictors of actual operative management were age (P=0.01), patient weight (P<0.001), fracture pattern (P<0.001), presence of other orthopedic injuries requiring surgery (P=0.002), and polytrauma (P=0.02).

Conclusions: There was limited concordance between actual treatments and CPG recommendations, particularly for the nonoperative management of fractures in children under 6 years old. Age, patient weight, fracture pattern, presence of other orthopedic injuries requiring surgery, and polytrauma were the main predictors of our operative decision-making process.

Keywords: Children; femoral shaft fracture (FSF); Academy of Orthopaedic Surgeons (AAOS); clinical practice guidelines (CPG)

Submitted May 07, 2024. Accepted for publication Jun 07, 2024. Published online Jun 20, 2024.
doi: 10.21037/tp-24-175
View this article at: https://dx.doi.org/10.21037/tp-24-175

Introduction

In 2009, the American Academy of Orthopaedic Surgeons (AAOS) released clinical practice guidelines (CPG) outlining an age-based approach for the nonoperative and operative treatment of pediatric femoral shaft fractures (PFSF) (1). In children younger than 6 years, the CPG recommend various nonsurgical treatments for femoral shaft fractures, such as using the Pavlik harness, applying an early spica cast, employing skeletal traction, and considering delayed spica casting. For children between ages 6 and 12 years, operative treatments are suggested, including external fixation, flexible nailing, and plating, among others. For skeletally mature children or those older than 12 years, the AAOS-CPG recommend rigid locked intramedullary nailing (1). The results of previous studies have suggested that choosing the therapeutic method recommended by the CPG on the basis of the age could obtain satisfactory clinical effects (2-6). However, some research points to drawbacks in the CPG, such as lack of higher-level evidence to support the guidelines, little change in the clinical practice, and no new literature to update the original recommendations (7-9).

In real clinical practice, management strategies for PFSFs may diverge from the official recommendations provided by the CPG (7,10). This study thus aimed to investigate the potential disparities between the theoretical treatment approaches for PFSF as outlined by the AAOS-CPG and the treatments actually received at The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University. Furthermore, we examined predictive factors for actual surgical intervention to determine their alignment with the operative recommendations of the CPG. We present this article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-24-175/rc).

Highlight box

Key findings

- The actual clinical treatment plan for pediatric femoral shaft fractures was outlined, highlighting the disparities with the American Academy of Orthopaedic Surgeons clinical practice guidelines (AAOS-CPG). Additionally, predictive factors for surgical intervention were provided.

What is known and what is new?

- The AAOS-CPG recommends conservative treatment for femoral shaft fractures in children under 6 years old and surgical treatment for children aged 6 and above with femoral shaft fractures.
- The decision to undergo surgery should not be based solely on the simplistic age threshold of 6 years, which contradicts the guidelines. Furthermore, our analysis identifies age, weight of patient, fracture pattern, with other orthopaedic injuries requiring surgery and polytrauma as predictive factors for surgery.

What is the implication, and what should change now?

- For the treatment plan of pediatric femoral shaft fractures (PFSF), we should consider factors such as age, weight, fracture pattern, with other orthopaedic injuries requiring surgery and polytrauma. We should not simply adhere to the guideline-recommended age threshold of 6 years as a dividing line. Sometimes, surgical treatment may be appropriate for PFSF patients under the age of 6 years.

Methods

We conducted a retrospective review of medical records for pediatric patients diagnosed with femoral shaft fractures at our institution from January 2014 to January 2022. The criteria for inclusion were (I) age from 0 to 14 years; (II) unilateral femoral shaft fracture; (III) closed fractures; (IV) no vascular or neurological injury; (V) available pretreatment and posttreatment radiographs; and (VI) no history of lower limbs injury or related operations. Meanwhile, the exclusion criteria were as follows: (I) >14 years old; (II) pathological fractures; (III) presence of older fractures; and (IV) inadequate or absent follow-up. Finally, 445 patients meeting our inclusion and exclusion criteria were identified for this study. All surgical and treatment plans we implemented were devised by specialized pediatric orthopedic surgeons. The surgical approach for treating patients in our hospital involved fixation with titanium elastic nails (TEN). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Ethics Committee of The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University (No. 2024LYYJ076). In our research, the consent statement is not required because our research is a retrospective study which retrieves existing data

Table 1 Baseline characteristics of 445 patients with femoral shaft fractures

Characteristics	Actual treatment		P value
	Nonoperative (n=134)	Operative (n=311)	
Age (years)	3.94±2.5	8.8±4.7	<0.001***
Sex			0.90
Male	47	110	
Female	87	201	
Weight of patient (kg)	16.7±3.8	24.8±5.0	<0.001***
Mechanism of injury			0.90
Fall	70	162	
Traffic injuries	52	131	
Sports injuries	6	12	
Others	6	6	
Fracture side			0.60
Left	57	140	
Right	77	171	
Fracture pattern			<0.001***
Transverse/oblique	114	145	
Spiral/comminuted	20	166	
Fracture location			0.20
Proximal 1/3	44	85	
Middle 1/3	60	153	
Distal 1/3	30	73	
Associated orthopaedic injury			0.002**
No	88	239	
Other injuries not requiring surgery	41	37	
Other injuries requiring surgery	5	35	
Polytrauma			<0.001***
Yes	10	74	
No	124	237	
Subspecialty of treating surgeon			0.30
Pediatric orthopedists	70	147	
Non-pediatric orthopedists	64	164	

Data are presented as n, or mean ± standard deviation. **, P<0.01; ***, P<0.001.

from Electronic Medical Record System of our hospital.

The patients' clinical documents and imaging were systematically collected, and information on patient age, sex, patient weight, mechanism of injury, fracture side, fracture pattern, fracture location, associated orthopedic injury, polytrauma, the time from injury to surgery, and subspecialty of treating surgeon was extracted. Mechanism of injury included ground fall, traffic injuries, sports injuries, and others. Fracture pattern was divided into transverse, oblique, spiral, and comminuted fractures. Fracture location included proximal third, middle third, and distal third fractures. Associated orthopedic injury was categorized as no associated orthopedic injury, with other orthopedic injuries not requiring surgery, and with other orthopedic injuries requiring surgery. The subspecialty of treating surgeon could include pediatric orthopedist or non-pediatric orthopedist. We recorded the number of patients who were actually treated with surgery and non-surgery, in addition to the number of surgical and nonsurgical patients recommended by the CPG. Furthermore, we used binomial and multivariate logistic regression to determine the clinical and radiographic factors that could best predict the choice between operative and nonoperative management.

Statistical analysis

Distributions of data were checked. We employed the Student *t*-test to compare continuous variables and the Chi-squared test to compare categorical variables. Additionally, a multivariate logistic model was employed to predict the choice between operative and nonoperative management. All potential predictors were included in the analysis, and a final model was derived using stepwise elimination. All statistical analyses were conducted using SPSS software version 22.0 (IBM Corp.). Statistical significance was defined as P<0.05.

Results

There were 452 patients who met our inclusion criteria, but 7 patients were excluded due to loss to follow-up. Ultimately, 445 children were included in our study. The average follow-up time of our group was 24.0±10.2 months (14–36 months). Each variable, including age, sex, patient weight, mechanism of injury, fracture side, fracture pattern, fracture location, associated orthopedic injury, polytrauma, the time from injury to surgery, and subspecialty of treating surgeon, is described in detail in *Table 1*.

Table 2 Treatment recommended by the CPG versus actual treatment

Age (years)	CPG, n		Actual treatment, n	
	Non-operative	Operative	Non-operative	Operative
<6	215	0	113	102
6–12	0	122	20	102
>12	0	108	1	107

CPG, clinical practice guideline.

Table 3 Multivariate logistic regression analysis of predictors of received operative treatment for children femoral shaft fractures

Risk factors	B	Wald	df	P value	Exp(B)
Age	0.136	6.22	1	0.01*	1.146
Weight of patient	−0.504	60.75	1	<0.001***	0.604
Fracture pattern	1.850	32.68	1	<0.001***	6.360
Associated orthopaedic injury	−1.171	12.79	1	0.002**	0.310
Polytrauma	1.221	4.93	1	0.02*	3.391

*, P<0.05; **, P<0.01; ***, P<0.001. B, correlation coefficient; Wald, Chi-Square; df, degree of freedom; Exp(B), odds ratio.

The number of patients was divided into two major categories: actual surgery and actual non-surgery. Operative treatments were undertaken in 102 of 215 (47.4%) fractures in children younger than 6 years, in 102 of 122 (83.6%) fractures in children between 6 and 12 years of age, and in 107 of 108 (99.1%) fractures in children older than 12 years. Nonoperative treatments were undertaken in 113 of 215 (52.6%) fractures in children younger than 6 years, in 20 of 122 (16.4%) fractures in children between 6 and 12 years of age, and in 1 of 108 (0.9%) fractures in children older than 12 years of age. The CPG recommend nonoperative treatment for children younger than 6 years and operative management for children over 6 years. Surgeon decisions for non-surgery were in agreement with the CPG 52.6% of the time, whereas agreement reached 90.9% for surgical choices. Notably, there was limited concordance between actual treatments and CPG recommendations, particularly for nonoperative management of fractures in children younger than 6 years old (*Table 2*).

Logistic regression analysis was employed to further investigate the determinants influencing the selection of operative intervention for femoral shaft fractures in pediatric patients. Factors included age (P=0.01), patient weight (P<0.001), fracture pattern (P<0.001), presence of other orthopedic injuries requiring surgery (P=0.002), and polytrauma (P=0.02) (*Table 3*).

Discussion

For the treatment of PFSF, the AAOS-CPG mainly recommended treatments based on age and has established a unified standard. The most significant recommendations include nonoperative treatment for children younger than 6 years and operative management for children over 6 years (1). In our study, we observed limited concordance between the treatment approaches implemented in practice and those advocated by the CPG, particularly concerning fractures occurring in children younger than 6 years old.

Surgical treatment options for PFSF encompass submuscular plating, elastic nails, rigid nails, as well as internal and external fixation (11). The management of PFSF can be broadly categorized into two groups: the treatment of closed isolated fractures and the treatment of open fractures and fractures associated with polytrauma (12). All our patients presented with closed femoral shaft fractures. Among closed PFSF, the use of stainless-steel or titanium nails, specifically ESIN, is becoming increasingly popular, particularly for transverse or short oblique fractures (13). ESIN offers advantages over other surgical methods. Compared to methods involving plates, ESIN requires minimal surgical exposure, carries lower infection risks, has fewer complications, and results in faster wound healing (11,14). Compared to external fixation, ESIN

fixation is safer, leads to faster healing, and has fewer complications (11,15). There are mainly two types of ESIN: TEN and stainless-steel nails. A study has shown that titanium nails are more elastic and more suitable for pediatric patients (16). The surgical approach for treating patients in our hospital involves fixation with TEN, aligning with the guiding principles outlined in the literature.

In our institution, operative treatments were undertaken in 47.4% fractures (102/215) in children younger than 6 years. Among them, those aged 3 to 5 years accounted for 95% of the total. The cause of this variation might be associated with surgeon preference, the heightened expectations for patients' fracture treatment results, potential socioeconomic variables, and the impact of the concept of accelerated rehabilitation, etc. In the literature, an ongoing discussion persists regarding the relative merits and drawbacks of nonoperative versus operative approaches in treating femoral shaft fractures in children younger than 6 years (3,7,17).

In recent years, an increasing number of studies on the surgical treatment of PFSF no longer adhere to the AAOS-CPG. Al-Doori's study, which compared the prognostic outcomes of elastic intramedullary nailing and plating for PFSF, involved the collection of patient cases aged 5 to 10 years (14). Heffernan *et al.* (18) reported that titanium elastic nailing is a viable choice for managing femur fractures in young children aged 2 to 6 years, as it demonstrated advantages over spica casting by facilitating earlier independent ambulation and full activity. According to Cintean *et al.* (7) and Rapp *et al.* (19), titanium elastic nailing is the preferred treatment for femoral shaft fractures in children aged over 3 years and has sufficient clinical rationale and safety. It has also been found that plaster fixation in PFSF can lead to issues such as limb shortening and slow healing (17).

However, Ramo *et al.* (20) discovered that titanium elastic nailing for isolated femoral fractures in preschool-aged children (aged 4 to 6 years) was linked to an increased likelihood of complications and markedly elevated rates of reoperation.

We also believe that children aged 3 to 5 years might be more suitable for elastic nailing surgery while those younger than 3 years might be more suitable for spica casting. Elastic nailing may be a more cost-effective method compared with spica casting. In the United States, Alluri *et al.* (21) reported that between 1997 and 2012, there was a notable and statistically significant increase in the use of internal fixation for treating femoral shaft fractures in 4- to 5-year-old children, along with a decreasing threshold for surgical intervention in managing these fractures. A study by van Cruchten *et al.* (22) also indicated that surgeons in the Netherlands recommended early surgical intervention for younger children with PFSF, which is in line with our views.

The CPG are gaining prominence in the field of clinical medicine, serving as a valuable resource for physicians to enhance the quality and efficiency of patient care by informing surgical decision-making and decreasing the variability in clinical of care, ultimately improving outcomes for a particular orthopedic injury or condition (23). Despite the endorsement of the CPG by medical societies, there is limited data available regarding the tangible clinical effects resulting from their creation and dissemination within the field of orthopedic surgery. Oetgen *et al.* (8) performed a retrospective review of the treatment of PFSF from 2007 to 2012 with the aim of evaluating the practical implications of the CPG. They observed minimal immediate clinical influence from the newly issued CPG regarding the management of PFSFs, and it resulted in limited adjustments in the treatment protocols for these fractures. Another study also showed that considerable variation existed among the participating centers regarding adherence to the 2009 AAOS-CPG for PFSF treatment (9). The actual treatments of our series also had great inconsistency in applying the recommendations of the CPG. The results underscored the necessity of meticulously planned prospective investigations aimed at delineating the most suitable treatment approaches for femoral shaft fractures across different pediatric age categories.

We also needed to further assess the national and/or regional variations in treatment practices. In our study, binomial and multivariate logistic regression analyses revealed that factors of age, patient weight, fracture pattern, presence of orthopedic injuries requiring surgery, and polytrauma significantly influenced our decision-making process regarding operative intervention. In pediatric surgical decision-making, age and fracture pattern have consistently been significant determinants (24). Similarly, for children with femoral shaft fractures, patient weight also plays a significant role in determining the surgical approach (22,25,26). van Cruchten *et al.* (22) suggested that surgical treatment be considered for children with closed femoral shaft fractures who are older than 4 years and weigh more than 15 kg. If the child's weight is relatively large (>50 kg), a stronger surgical fixation is needed (27). Dodd *et al.* (28) and Baker *et al.* (29) suggested that the choice of treatment for PFSFs also depends on concomitant injuries. Additionally,

we observed that patients with associated orthopedic injuries requiring surgery or polytrauma tended to undergo operative intervention for their femoral shaft fractures. This inclination stemmed from the need for surgical management of these fractures to aid in patient mobilization and facilitate rehabilitation of their concomitant injuries. This also facilitates nurse care for these patients. Furthermore, in situations where patients were already in the operating suite and anesthesia risks had been addressed, surgeons tended to opt for operative intervention for femoral shaft fractures. In current practice, doctors have the ability to compare the surgical efficacy of plate fixation versus that of flexible intramedullary nails (30). A study has shown that flexible intramedullary nails can better reduce complications of fractures (31), which is also warrants further exploration.

Our study had several limitations that should be mentioned. First, the study design involved a retrospective collection of injury and results data, and thus the final outcomes relied on the precision of documentation. Second, while we considered numerous factors for predicting the choice between operative and nonoperative management in our study, some factors remained outside our scope, such as the initial displacement of the fracture, preferences of the surgeon or patient, insurance coverage, and the socioeconomic status of the family. Finally, we only divided patients into two major categories—surgical or conservative treatment—and did not further subdivide the above two categories.

Conclusions

There was a discrepancy between the actual treatments and those recommended by the CPG in our institution, particularly regarding fractures in children younger than 6 years old. More children aged 3 to 5 years were treated with titanium elastic nailing. Age, weight of patient, fracture pattern, presence of other orthopedic injuries requiring surgery, and polytrauma were main predictors of our operative decision-making process. The AAOS-CPG should be gradually updated over time as new findings emerge.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-24-175/rc

Data Sharing Statement: Available at https://tp.amegroups.com/article/view/10.21037/tp-24-175/dss

Peer Review File: Available at https://tp.amegroups.com/article/view/10.21037/tp-24-175/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-24-175/coif). The authors have no conflicts of interest to declare.

Ethics Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Ethics Committee of The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University (No. 2024LYYJ076). In our research, the consent statement is not required because our research is a retrospective study which retrieves existing data from Electronic Medical Record System of our hospital.

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Cite this article as: Sun J, Wang T, Zhao N, Chen H, Chen C. Pediatric femoral shaft fractures: the American Academy of Orthopaedic Surgeons clinical practice guidelines versus actual management in a teaching hospital. Transl Pediatr 2024;13(6):938-945. doi: 10.21037/tp-24-175