

# Increasing rates of surgical treatment for paediatric tibial shaft fractures: a national database study from between 2000 and 2012

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## Abstract

**Purpose** Tibia fractures are the third most common long bone fracture in children. Because of the remodelling potential of the tibial diaphysis, nonoperative treatment has historically been advocated for most tibial shaft fractures in children. The purpose of this study was to estimate the rate of surgical treatment of tibial shaft fractures over time and identify demographic factors associated with surgical treatment, utilizing a large, publicly available, national database.

**Methods** The Healthcare Cost and Utilization Project Kids' Inpatient Database was evaluated for the years between 2000 and 2012. Tibial shaft fractures and surgically treated patients were identified using International Classification of Diseases, 9th Revision, Clinical Modification codes. Univariable and multivariable logistic regression were used to determine variables associated with a greater proportion of surgical treatment. Statistical analyses were performed utilizing SAS statistical software v.9.4. Statistical significance was set at  $p < 0.05$ .

**Results** In all, 24 166 tibial shaft fracture admissions were identified, with 15 621 (64.7%) treated surgically. The percentage of patients receiving surgery to treat tibial shaft fractures increased from 57.3% in 2000 to 74.3% in 2012 ( $p < 0.001$ ). Multivariable regression showed that increasing age was associated with increased rate of surgical treatment ( $p < 0.001$ ). The greatest increase in surgical treatment was seen in children aged five to nine years, increasing from 23.0% in 2000 to 46.2% in 2012.

**Conclusion** The rate of operative treatment of paediatric tibial shaft fractures increased over time. The largest increase was seen in children aged five to nine years. Increased proportion of surgical treatment was associated with older age, concurrent femur fracture and non-Medicaid insurance status.

**Level of Evidence** Level III - Retrospective comparative study

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**Keywords:** tibia; fracture; paediatric surgical treatment

## Introduction

Tibia fractures are the third most common long bone fracture in children, with approximately 39% occurring in the tibial diaphysis.<sup>1</sup> The majority of paediatric tibial shaft fractures can be managed nonoperatively, however, surgical intervention is indicated for open fractures as well as those that are irreducible, have failed nonoperative management, are associated with compartment syndrome or in the multiply injured patient. The numerous surgical options for treatment include flexible intramedullary nailing, plate osteosynthesis, external fixation and rigid intramedullary nailing. In the past, as few as 4.5% of paediatric tibial shaft fractures underwent operative intervention.<sup>1</sup> However, more recent literature has shown that as many as 40% of adolescents fail nonoperative intervention and require surgery.<sup>2</sup> A recent Finnish retrospective cohort study showed that almost one-third of children with tibial shaft fractures underwent operative intervention in their series.<sup>3</sup> To our knowledge, there has not been a recent survey of paediatric tibial shaft fracture management practices in the United States. We sought to elucidate management trends for paediatric tibial shaft fractures by utilizing a large, publicly available, nationally representative inpatient hospital database. We hypothesized that there would be a significant increase over time in the rates of operative intervention for paediatric tibial shaft fractures treated in the United States. We also sought to examine factors associated with increased rates of surgical treatment.

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## Materials and methods

The Healthcare Cost and Utilization Project (HCUP) Kids' Inpatient Database (KID) is the largest publicly-available all-payer paediatric inpatient database that is compiled based on two to three million annual hospital stays. The database is a result of data collected in the 46 states that have partnered with the Agency for Healthcare Research and Quality and maintain statewide data collection efforts. The database is a sample of all discharges at all hospitals in participating states. The large sample size generates data that is generalizable to the national paediatric population.

Paediatric tibial shaft fractures were identified using International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9 CM) diagnosis codes.<sup>4</sup> ICD-9 CM procedure codes were used to identify patients who received surgical treatment for the years between 2000 and 2012. The demographic characteristics collected included sex, age (stratified into age groups of 0 to four, five to nine, ten to 14 and 15 to 20 years old to correspond with preschool-, elementary school-, middle school- and high school-aged children, respectively), insurance status (Medicaid, private, self-pay, other), hospital type (children's, general) and ICD-9 derived injury severity score (ICISS). ICISS was calculated for each admission as described by Clark et al<sup>4</sup> and rescaled to a range of 0 to 100. ICD-9 CM diagnosis codes were used to identify patients with concurrent femur fracture. Standard error and 95% confidence limits were calculated for all variables.

Multivariable logistic regression was used to determine variables associated with greater proportion of surgical treatment. All statistical analyses were performed utilizing SAS statistical software v.9.4 (SAS Institute Inc., Cary, North Carolina). Statistical significance was set at  $p < 0.05$ .

## Results

Table 1 represents the demographic characteristics of patients who were identified as having sustained a tibial shaft fracture. In all, 24 166 tibial shaft fracture admissions were identified (average 4833 per year queried), with 15 621 (64.7%) of these patients treated surgically (Table 2). The percentage of patients receiving surgery to treat tibial shaft fractures increased from 57.3% in 2000 to 74.3% in 2012 ( $p < 0.001$ ), with the percentage increasing each year (Fig. 1, Table 2). Of admitted patients with tibial shaft fractures, 75.8% were male and 24.2% were female. Management of tibial shaft fracture was similar between sexes, with 65.5% of male patients managed surgically, compared with 62.1% of female patients ( $p = 0.350$ ). Patients with concurrent femur fracture had increased rate of surgical management, with 76.3% of patients managed surgically, compared with 63.8% of patients who did not have concurrent femur fracture ( $p < 0.001$ ).

Surgical management of tibial shaft fractures was performed in 22.1% of 0- to four-year-old children, 35.3% of five- to nine-year-old children, 51.9% of ten- to 14-year-old children and 82.2% of 15- to 20-year-old children. The rate of increase in surgical management varied between age groups ( $p = 0.05$ ). In children 0 to four years old the rate increased from a rate of 10.4% to a peak of 23.84% in 2006 but has decreased slightly to 15.98% in 2012. Patients aged five to nine and ten to 14 years old increased from 23.03% to 46.23% and from 40.51% to 61.11%, respectively. The rate of surgical fixation in the 15 to 20 years bracket increased from 75.01% to 84.37% over the study period (Fig. 2, Table 3).

Multivariable regression showed that increasing age was associated with increased rate of surgical treatment ( $p < 0.001$ ) (Fig. 3, Table 2). Patients insured with Medicaid were managed surgically 61.3% of the time, while 67.5% of patients with private, self-pay or other insurance were

**Table 1** Demographics of paediatric tibial shaft fractures

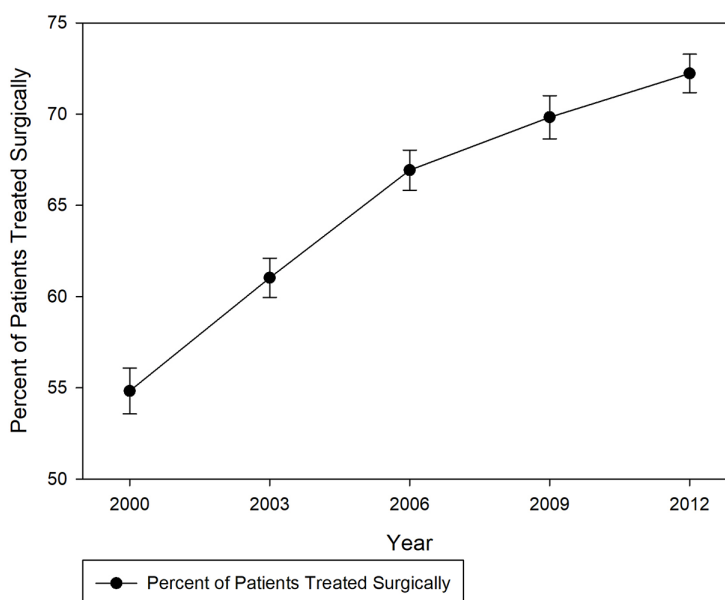
Variable	Category	National estimate of patients	Patients (%)	Standard error (%)	95% CI lower (%)	95% CI higher (%)
Sex	Male	18315	75.79	0.38	75.04	76.53
	Female	5852	24.21	0.38	23.47	24.96
Age	0 to 4	891	3.69	0.20	3.30	4.08
	5 to 9	2708	11.21	0.39	10.43	11.98
	10 to 14	6831	28.27	0.47	27.35	29.18
	15 to 20	13736	56.84	0.74	55.39	58.29
Hospital type	General hospital	21761	90.05	0.97	88.15	91.94
	Children's hospital	2405	9.95	0.97	8.06	11.85
Insurance status	Medicaid	5618	23.25	0.57	22.13	24.36
	Private/self-pay/other	18549	76.75	0.57	75.64	77.87
Concurrent injury	Isolated tibia fracture	22520	93.19	0.30	92.60	93.78
	Concurrent femur fracture	1646	6.81	0.30	6.22	7.40
Year	2000	5163	21.36	0.74	19.90	22.82
	2003	4987	20.64	0.57	19.53	21.75
	2006	5024	20.79	0.54	19.72	21.85
	2009	4636	19.18	0.53	18.15	20.22
	2012	4357	18.03	0.70	16.65	19.41
Total		24166				

**Table 2** Treatment of paediatric tibial shaft fractures

Variable	Category	Treated surgically (%)	Standard error (%)	95% CI lower (%)	95% CI higher (%)
Sex	Male	65.45	0.67	64.14	66.76
	Female	62.11	1.04	60.08	64.14
Age	0 to 4	18.70	1.71	15.35	22.05
	5 to 9	32.55	1.39	29.83	35.28
	10 to 14	50.02	0.95	48.15	51.88
	15 to 20	81.22	0.49	80.25	82.18
Hospital type	General hospital	65.92	0.56	64.83	67.01
	Children's hospital	53.03	2.921	47.31	58.76
Insurance status	Medicaid	59.20	1.07	57.09	61.30
	Private/self-pay/other	66.29	0.63	65.05	67.53
Concurrent injury	Isolated tibia fracture	63.79	0.64	62.53	65.05
	Concurrent femur fracture	76.27	1.46	73.41	79.13
Year	2000	54.82	1.26	52.35	57.30
	2003	61.03	1.08	58.92	63.15
	2006	66.93	1.10	64.78	69.09
	2009	69.83	1.19	67.51	72.16
	2012	72.24	1.06	70.16	74.31
Total		64.64	0.62	63.42	65.86

CI, confidence interval

Percent of Tibial Shaft Fractures Treated Surgically, 2000-2012

**Fig. 1** Percentage of admitted patients treated surgically between 2000 and 2012.

managed surgically ( $p = 0.044$ ) (Fig. 4). Surgical treatment was not associated with increased injury severity, with a mean ICISS of 98.3, compared with a mean ICISS of 98.7 in non-surgically managed patients ( $p = 0.215$ ; Fig. 3). In all, 53% of patients admitted to a children's hospital were managed surgically, while 65.9% of patients receiving care at a general hospital were managed surgically. After adjustment for patient demographics, there was no significant difference in surgical management between children's and general hospitals ( $p = 0.166$ ).

## Discussion

In general, the rate of surgical fixation for all paediatric fractures has been increasing in recent years. This is particularly true for less invasive methods. Cheng et al<sup>6</sup> analyzed 6493 paediatric patients with upper extremity fractures from 1985 to 1995, showing an increase in the rates of closed reduction and percutaneous pinning amongst supracondylar humerus fractures (4.3% to 40%), distal radius fractures (9.5% to 38.7%) and forearm shaft frac-

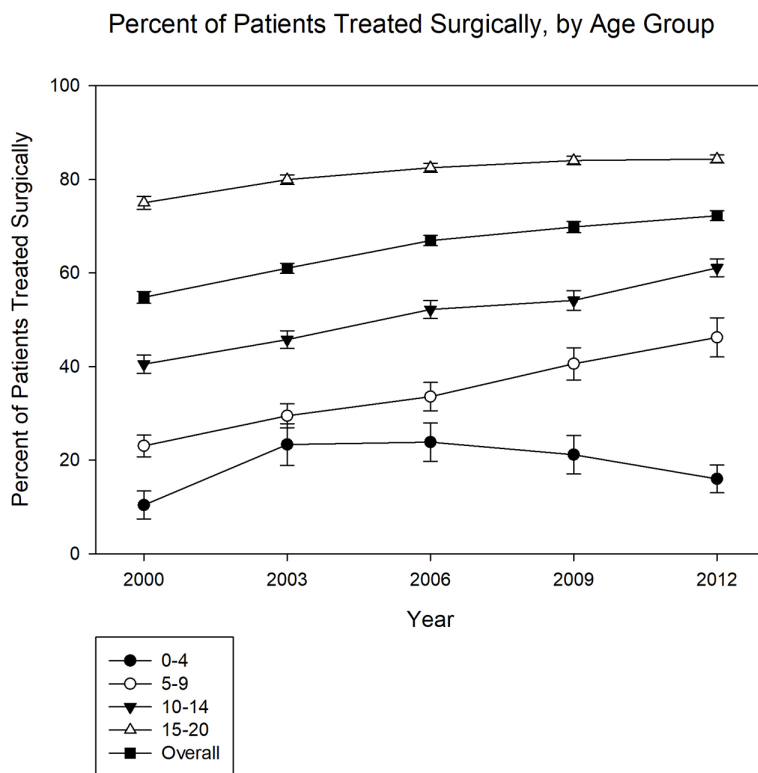


Fig. 2 Percentage of admitted patients treated surgically over time by age group.

Table 3 Percentage of patients surgically treated by age group over time

Year	Age 0 to 4 yrs	SE	Age 5 to 9 yrs	SE	Age 10 to 14 yrs	SE	Age 15 to 20 yrs	SE	Total	SE
2000	10.40	2.97	23.03	2.30	40.51	1.94	75.01	1.39	54.82	1.26
2003	23.32	4.45	29.48	2.57	45.77	1.90	79.97	1.03	61.03	1.08
2006	23.84	4.09	33.56	3.03	52.22	1.93	82.50	0.98	66.93	1.10
2009	21.15	4.11	40.59	3.45	54.16	2.09	84.05	0.90	69.83	1.19
2012	15.98	2.98	46.25	4.21	61.11	1.90	84.37	0.84	72.24	1.06
Increase	1.54-times		2.01-times		1.51-times		1.12-times		1.32-times	

SE, standard error

tures (1.8% to 22%), with declining rates of open reduction internal fixation. Other studies over more recent years have shown stable rates of operative intervention for forearm shaft fractures (20% to 44%) but an increase in the percentage of elastic intramedullary nail fixation performed.<sup>7,8</sup> The treatment of femoral shaft fractures is highly age- and weight-dependent but there has also been a high rate of fixation recently (44.2%) with a trend towards increasing operative intervention in children less than five years old.<sup>9</sup> Additionally, an analysis of the KID database showed increasing nationwide utilization of surgical treatment for paediatric femoral fracture.<sup>10</sup> The stimulus for increasing rates of surgical intervention are likely to be multi-factorial, however, technological advances, particularly with regards to intramedullary fixation techniques, may play a large role. There is also an emphasis on

stable internal fixation to allow earlier rehabilitation and return to activity.<sup>11</sup> Patient and family expectations as well as surgeon preferences may also influence these developing trends.

The current study analyzed treatment trends for paediatric tibial shaft fracture across the United States. Our findings show an increase in the frequency of operative management of tibial shaft fractures over time, from 57.3% to 74.3% over the 13 years examined (2000 to 2012). This trend is consistent with findings from a prior study by Stenroos et al<sup>3</sup> which examined a population of children from Finland. The authors reported an operative rate of 30.4% for paediatric tibial fractures which itself was higher than older studies showing operative rates as low as 4.5%.<sup>1</sup> The operative rate reported in the current study was considerably higher, however, it is

important to highlight that the population examined in the Stenroos et al<sup>3</sup> study was less than 16 years old, while our study included patients up to 20 years old. Patients older than the age of 16 are typically skeletally mature and treated as adults, who have a higher rate of operative treatment. However, the rates of surgical fixation in children aged five to nine years and ten to 14 years also increased to greater rates than those seen in the Finnish study; 46.25% and 61.11%, respectively. The oldest patients (15 to 20 years old) showed relatively stable rates of surgical fixation (1.12-times increase), while the youngest age bracket (0 to four years old) showed a downtrend in surgical fixation rates over recent years. Patients in the

five- to nine-year-old group showed the greatest increase in operative treatment over time (2.01-times increase). This could be due to the technological advances in minimally invasive surgical methods, such as flexible nailing, as is the trend with other fractures. Flexible nailing offers earlier stability and rehabilitation, with low complication rates in an age group that would have traditionally been treated with casting.<sup>11-14</sup>

We also found a statistically significant increase the rates of surgical fixation in older patients, which is likely due to the more stringent radiographic criteria used when assessing tibial shaft fractures in older patients.<sup>15,16</sup> With less remaining skeletal growth, there is less potential for fracture remodelling. The study by Stenroos et al<sup>3</sup> also showed an increase in the rate of operative intervention as patients age, along with an increased rate of surgical fixation in combined tibia and fibula fractures and in fractures with larger amounts of initial angulation; the latter two factors may be indicative of a higher-energy mechanism of injury. We could not examine specific fracture characteristics or initial displacement in our analysis, given the limitations of the HCUP-KID database. We did, however, examine overall patient injury severity, using ICISS as a marker, and found no difference in ICISS between operative- and nonoperatively-treated patients. We also examined whether the presence of a femur fracture influenced rates of surgical fixation and found that patients with a concurrent femur fracture did indeed have higher rates of surgery compared with those with isolated tibia fractures. This suggests that patients with higher energy injury mechanisms and/or polytrauma are more likely to undergo surgical fixation of tibia fractures.

Percent of Tibial Shaft Fractures Treated Surgically, by Age

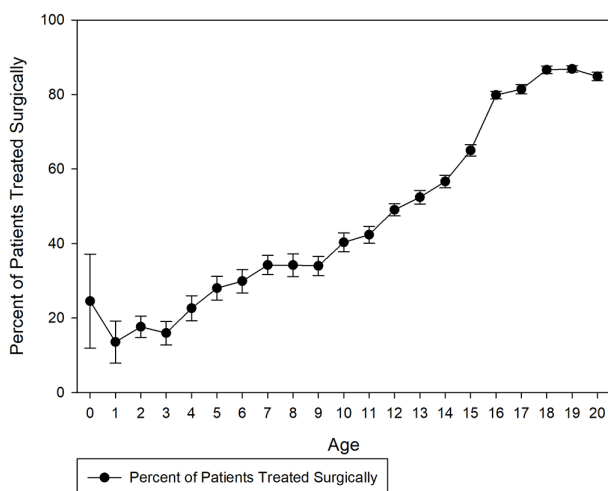


Fig. 3 Percentage of admitted patients treated surgically by age.

Demographic Predictors of Surgical Treatment Odds Ratio and 95% CL

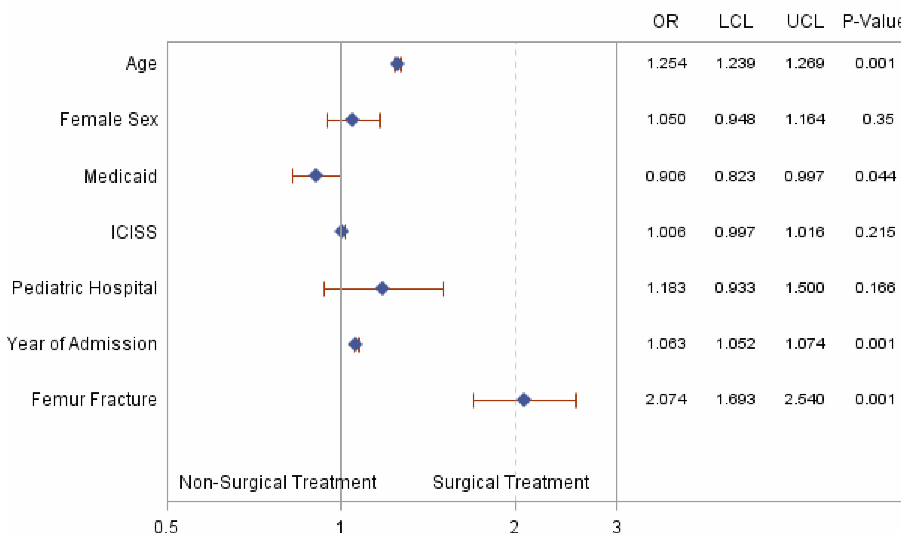


Fig. 4 Demographic predictors of surgical treatment; multivariable regression (ICISS, International Classification of Diseases-9 derived injury severity score; CL, confidence level; OR, odds ratio; LCL, lower confidence level; UCL, upper confidence level).

This study also evaluated the relationship between surgical treatment of tibia fractures and hospital and insurance type. While we found a gross difference between children's and general hospitals in the rate of operative treatment (53% versus 65.9%, respectively), that difference was not statistically significant after adjustment for hospital specific patient demographics. With regards to insurance type, we found no significant difference in management between patients with Medicaid versus private insurance. While other studies in the orthopaedic literature have found disparities in treatment based on insurance type,<sup>17-19</sup> it is reassuring that insurance type was not associated with differences in rates of surgical treatment in the current study.

Our study has inherent limitations. First, because it is a retrospective, database analysis, we are limited by the data available to use within the database and were not able to collect information on more specific variables, such as fracture pattern, fracture displacement or type of surgical fixation used. It would have been interesting to see the type of surgical fixation used as surgery rates increased between 2000 and 2012; specifically, whether the use of elastic intramedullary nailing has increased, as its popularity in the literature has increased over recent years.<sup>14,20,21</sup> Second, the oldest age bracket from the database extends from 15 to 20 years old. Including patients up to 20 years of age may skew our data towards increased surgical intervention since adult tibia fractures are rarely managed non-operatively as surgical fixation has been shown to provide more rapid union with less rates of malunion and shortening in this age group.<sup>22</sup> Prior studies have also shown that adolescent patients are more likely to fail nonoperative management,<sup>2</sup> which may further skew our findings. Third, our multivariable logistic regression model was limited by the variables recorded and available for analysis. Finally, the database used in this study only accounts for hospital admissions/discharges. Patients with injuries that did not necessitate admission would not have been captured in this sample.

We used the HCUP KID to analyze trends in the hospital-based inpatient management of paediatric tibial shaft fractures across the United States. We found that an average of 64.7% of hospital inpatients underwent surgical fixation over the years between 2000 and 2012, with the percentage of patients receiving surgery to treat tibial shaft fractures increasing from 57.3% in 2000 to 74.3% in 2012 ( $p < 0.001$ ). We also found that while older patients were more likely to undergo surgical treatment, it was the five- to nine-year-old age group that showed the greatest increase in surgical fixation rates over this time period. We did not find a difference in the rate of operative intervention based on hospital type, insurance type, patient gender or injury severity score. Overall, rates of surgical intervention for paediatric tibial shaft fractures

in the United States are increasing, with older patients more likely to undergo surgery. This may reflect a general trend within paediatric orthopaedics for increased surgical management of extremity fractures that have traditionally been treated by nonoperative methods.<sup>2,3,6,8,9</sup>

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### ETHICAL STATEMENT

**Ethical approval:** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent:** Not required for this work.

### ICMJE CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflicts of interests.

### AUTHOR CONTRIBUTIONS

All authors contributed to the experimental design and data interpretation and wrote and edited the manuscript.

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