Research Article

Increasing Rate of Surgical Fixation in Four- and Five-year-old Children With Femoral Shaft Fractures

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Abstract

Background: The purpose of this study was to identify temporal trends in the management of pediatric femoral shaft fractures in 4- and 5-year-old children.

Methods: The Kids' Inpatient Database was used to extract data on patients aged 4 and 5 years with closed femoral shaft fractures. The frequency of nonsurgical and surgical management was calculated, and temporal trends were evaluated.

Results: Between 1997 and 2012, the absolute increase in surgical fixation was 35% and 58% in 4- and 5-year-old patients, respectively. The surgical rate increased every 3 years by 13.8% in 4-year-old patients and 7.6% in 5-year-old patients. Significant associations were noted based on demographics, comorbidities, and hospital characteristics with management decisions.

Conclusions: A clear and significant increase was noted in internal fixation for pediatric femoral shaft fractures in 4- and 5-year-old children, and the lower age limit for surgical management of these fractures is decreasing.

Level of Evidence: Level III. Retrospective comparative study

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Pediatric femur fractures are among the most common injuries treated by orthopaedic surgeons.[1-3] Treatment of these fractures depends on factors such as age, size and weight of a patient, fracture pattern, soft-tissue integrity, comorbidities, concurrent injuries, family preference, and surgeon preference. Despite rare cases of significant morbidity, the overwhelming majority of pediatric patients with femoral shaft fractures are expected to heal with normal function and radiographic alignment.[4-6]

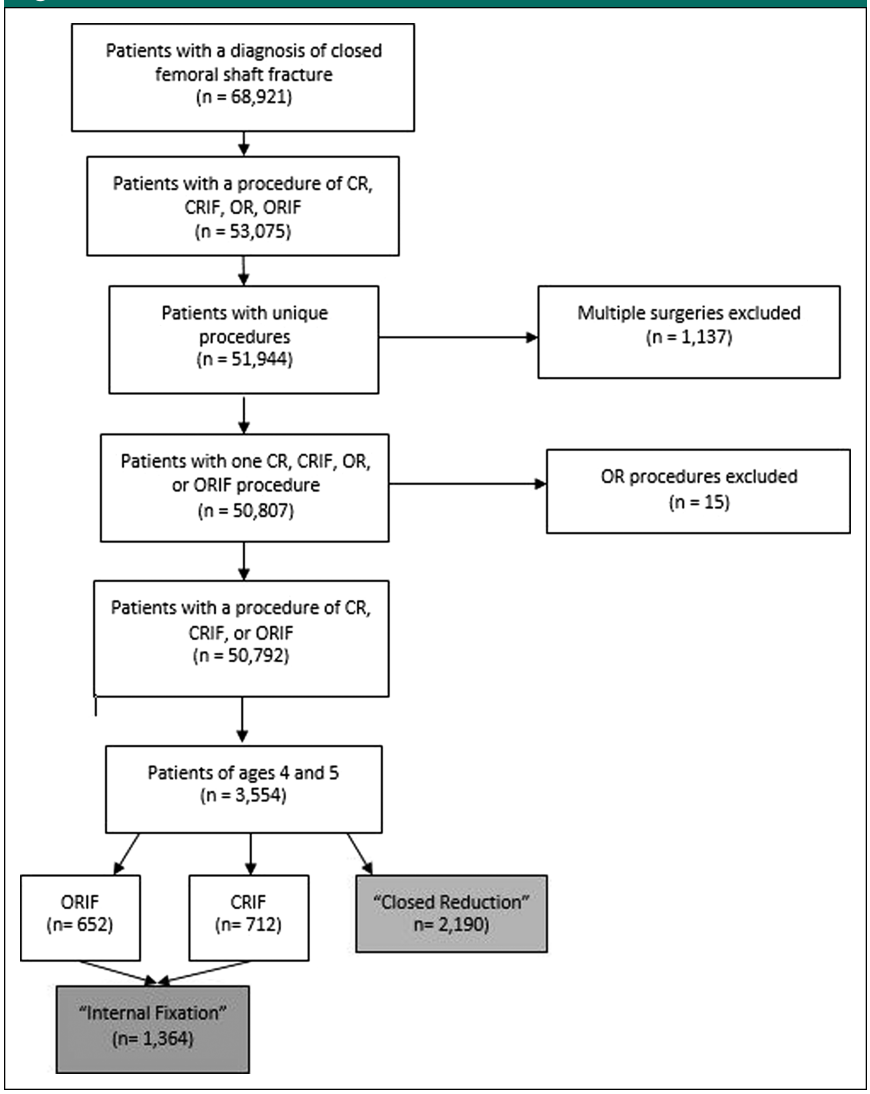
Treatment options for the management of pediatric femoral shaft fractures include Pavlik harness application, spica casting, external fixation, submuscular plating, and flexible or rigid intramedullary (IM) nailing.[7] Currently no consensus exists regarding the best treatment modality, and many surgeons follow an age-based algorithm where patients younger than 6 months are treated with a Pavlik harness and patients aged between 6 months to 6 years are treated with spica casting, typically without traction. Older children aged between 6 and 10 years are often treated with flexible IM nailing, whereas children in this age group with length unstable fracture patterns may be treated with submuscular plating. A lateral entry rigid IM nail may be used in children older than 10 years.[7,8] The American Academy of Orthopaedic Surgeons Clinical Practice Guideline recommends, with moderate strength, spica casting of most diaphyseal femur fractures in children aged

6 months to 5 years and, with limited strength, the use of flexible IM nails in patients aged 5 to 11 years.[9]

The success of flexible IM nailing of pediatric femur fractures has resulted in a general transition away from nonsurgical management toward surgical intervention.[10-12] Specifically in younger patient cohorts, the relative safety and efficacy of flexible IM nail placement along with greater ease of postoperative care compared with spica casting have resulted in a progressive trend toward surgical management.[13] The treatment of preschool children, aged 4 to 5 years, is of particular interest and remains controversial. A recent study demonstrated no difference in clinical or radiographic outcomes when comparing spica casting to flexible IM nailing in this age group.[4]

The purpose of this study was to identify nationwide temporal trends in the management of pediatric femoral shaft fractures in 4- and 5-year-old children while identifying potential demographic, surgical, and hospital characteristics that may predict surgical versus nonsurgical management. We hypothesized that the surgical management of femoral shaft fractures in patients between ages 4 and 5 years has progressively increased during the period examined in this study.

Figure 1



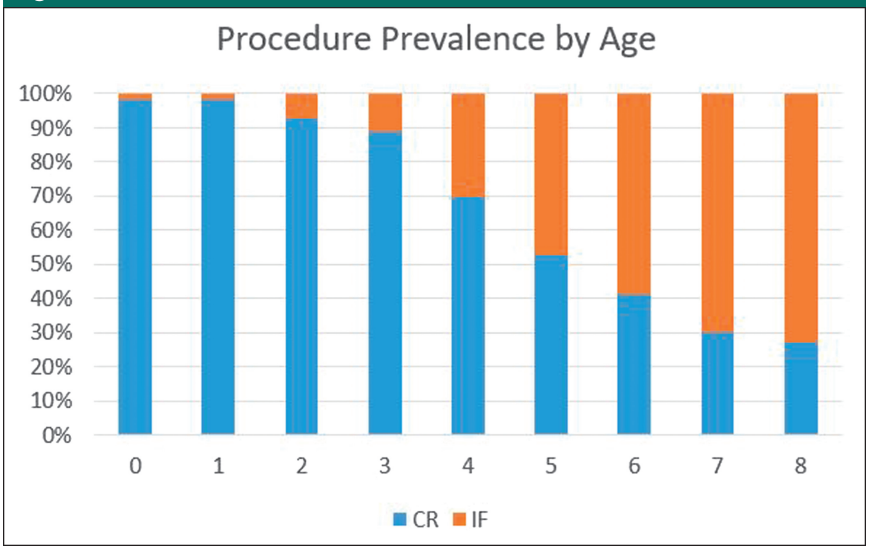
Flow diagram showing patient selection (CR = closed reduction, CRIF = closed reduction and internal fixation, OR = open reduction, ORIF = open reduction and internal fixation). The number of patients listed represents weighted numbers.

Methods

The Kids' Inpatient Database (KID) is a national hospital discharge database of patients younger than 21 years. It is maintained by the Healthcare Cost and Utilization Project and is the largest publicly available pediatric database of inpatient hospitalizations in the United States. The release of data sets on a triennial basis began in 1997, and these contain information on approximately 2 to 3 million pediatric inpatient discharges occurring in community, nonrehabilitation hospitals across participating states. The Healthcare Cost and Utilization Project defines a community hospital as a nonfederal, short-term (less than 30-day stay) hospital that is accessible to the public. The KID database uses a sample of pediatric discharges from all hospitals in the sampling frame, selecting 10% of "normal newborns" born in the hospital and 80% of other pediatric cases from each frame hospital.[14] The KID database provides sampling weights for obtaining national estimates, which are based on characteristics of the poststratified hospitals.[14] The weighting algorithm can allow for reliable estimates of national volumes for a given diagnosis or procedure, and this algorithm has been previously validated.[15]

Data from the 1997, 2000, 2003, 2006, 2009, and 2012 data sets were compiled and retrospectively reviewed. At the time of the study, the 2012 data set was the most recent data set. Patients aged between zero and eight years were identified using data filters. The primary purpose of

Figure 2



Graph showing the comparison of CR versus IF between 1997 and 2012 for ages zero to 8 years. CR = closed reduction, IF = internal fixation

this study was to identify trends between nonsurgical and surgical management of femoral shaft fractures in patients aged between 4 and 5 years. We included ages zero to 3 years and 6 to 8 years to serve as relative comparison groups because treatment in these age groups is less controversial with nonsurgical management almost always recommended for the zero to 3 years age group and generally surgical management for the 6 to 8 years age group.[3,16]

After identifying all patients aged between zero and 8 years, we used the International *Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnostic code 82101 to identify patients with a closed femoral shaft fracture. This subset of patients was again filtered using an *ICD-9-CM* procedure code of either 7905, 7915, 7925, or 7935 describing closed reduction (CR) of femur fracture without internal fixation (IF), CR of femur fracture with IF (CRIF), open reduction (OR) of femur fracture without IF, and OR of femur fracture with IF (ORIF), respectively. All patients with more than 1 of the designated *ICD-9-CM* procedure codes, a bilateral procedure or revision surgery, or having undergone an apparent OR without IF (*ICD-9-CM* procedure code 7925) were excluded. Patients who underwent CR without IF were designated as one group, "CR." Patients who underwent either CRIF or OR of femur fracture with IF ORIF were combined into a second group, "IF." Figure 1 illustrates our patient selection process.

Closed femoral shaft fractures in pediatric inpatients of ages 4 and 5 years were analyzed in detail in terms of demographic, surgical, and hospital/institutional characteristics provided by the KID database. Inpatient variables such as "risk of mortality" and "severity of illness" were also analyzed. The "severity of illness" variable is based on a numeric value ranging from 1 to 4, with 1 representing minor loss of function and 4 representing extreme loss of function. The KID database assigns a numeric severity of illness value at the time of admission using an algorithm that factors in the underlying comorbidities and primary and secondary diagnoses.

The counts of inpatient admissions were weighted using provided weights from the KID database to generate national estimates for the "CR" and "IF" groups. All reported numbers are national estimates based on the weights provided by the KID database. Statistical analysis comparing demographic, surgical, and hospital-level variables between the two groups was performed using STATA 13.0 (StataCorp LP). Fisher exact and chi-square analyses were performed to compare categoric data between treatment groups and populations treated at different hospital types. For continuous or discrete variables, a Student *t*-test was used. Surgical trends over time were analyzed using linear regression, and the *P* value of the slope from the line of best fit was calculated. Categoric variables included a prevalence percentage, whereas continuous/discrete variables included an SD. $P \leq 0.05$ was considered statistically significant.

Results

Between 1997 and 2012, 15,583 pediatric femoral shaft fractures (71%) were treated with closed management and 6,417 (29%) were treated with IF in children aged <8 years. In patients aged less than 1 year, 1,356 femoral shaft fractures (98%) were treated with closed management, whereas in 8-year-old children, 1,234 (73%) were treated with IF (Figure 2). Linear regression demonstrated that surgical fixation increased by 9.1% ($P < 0.0001$) for every integral increase in age up to 8 years.

Over the 15-year period that this study examined, in 4-year-old patients, a total of 1,285 femoral shaft fractures (70%) were treated with closed management and 554 (30%) were treated with IF. In 1997, 300 (87%) were treated with closed management and 44 (13%) were treated

with IF (Figure 3). In 2012, 149 (52%) were treated with closed management and 136 (48%) were treated with IF (Figure 3). The absolute increase in IF over the 15-year period was 35%. Linear regression demonstrated that surgical fixation increased by 14% ($P = 0.0003$) every three years from 1997 to 2012.

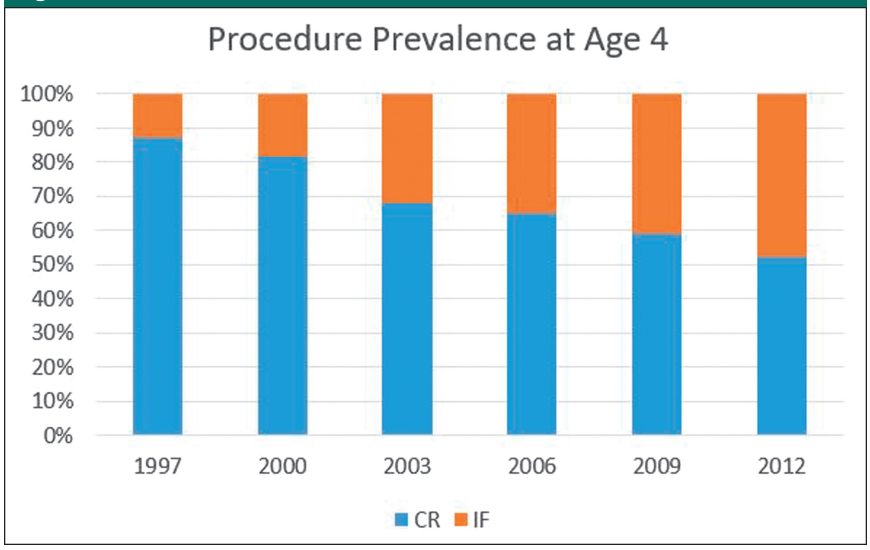
For the same 15-year period, in 5-year-old patients, a total of 904 femoral shaft fractures (53%) were treated with closed management and 810 (47%) were treated with IF. In 1997, 334 (84%) were treated with closed management and 64 (16%) were treated with IF (Figure 4). In 2012, 62 (26%) were treated with closed management and 178 (74%) were treated with IF (Figure 4). The absolute increase in IF over the 15-year period was 58%. Linear regression demonstrated that surgical fixation increased by 8% ($P = 0.003$) every 3 years from 1997 to 2012.

Combined analysis of demographic variables from patients aged both 4 and 5 years demonstrated no differences in closed management versus IF based on sex, race, or payment method (Table 1). Patients from families with higher median household incomes were more likely to undergo closed management ($P = 0.048$) (Table 1).

In both the 4- and 5-year-old patient groups, patients with higher loss of function were more likely to undergo IF than receive closed management ($P < 0.001$) (Table 2). No significant difference was noted in the mortality risk between the two treatment groups ($P = 0.517$) (Table 2). Discharge disposition was also similar ($P = 0.182$), and more than 90% of children were routinely discharged after closed management or IF. The length of stay was approximately 4 days regardless of treatment modality ($P = 0.559$) (Table 2); however, total hospital charge was significantly higher for patients receiving IF compared with closed management ($P < 0.0001$) at $28,200 and $17,400, respectively (Table 2).

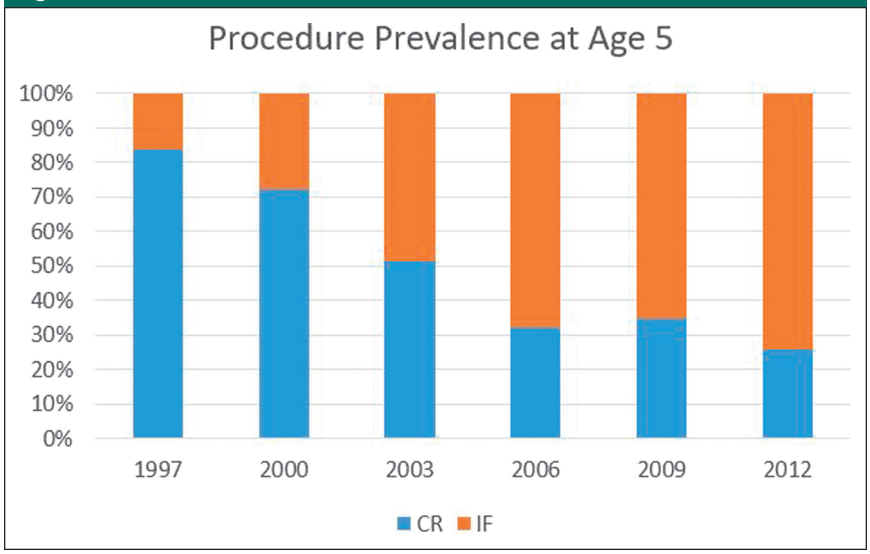
Analysis of hospital variables demonstrated no differences in closed management or IF for 4 and 5 year olds based on the percentage of pediatric discharges ($P = 0.083$), hospital bed size ($P = 0.249$), or hospital ownership ($P = 0.101$) (Table 3). Both the region and teaching status of the hospital demonstrated significant differences. Teaching hospitals were more likely than nonteaching hospitals to use IF ($P = 0.034$) (Table 3). Last, significant differences were noted between geographic regions

Figure 3



Graph showing the comparison of CR versus IF between 1997 and 2012 for patients of age 4 years. CR = closed reduction, IF = internal fixation

Figure 4



Graph showing the comparison of CR versus IF between 1997 and 2012 for patients of age 5 years. CR = closed reduction, IF = internal fixation

Table 1

Comparison of Demographic Variables in Patients of Ages 4 and 5 Years Undergoing Closed Reduction Versus Internal Fixation

Demographics	Closed Reduction	Internal Fixation	*P* Value
Sex (female)	559 (25.51%)	357 (26.16%)	0.759
Race			0.104
White	1,070 (65.05%)	674 (63.67%)	—
Black	237 (14.42%)	159 (15.02%)	—
Hispanic	222 (13.46%)	143 (13.54%)	—
Asian or Pacific Islander	37 (2.22%)	9 (0.85%)	—
Native American	15 (0.91%)	11 (1.06%)	—
Other	65 (3.93%)	62 (5.87%)	—
Primary payment method			0.074
Medicare	1 (0.06%)	3 (0.20%)	—
Medicaid	742 (33.96%)	540 (39.72%)	—
Private, including HMO	1,217 (55.67%)	691 (50.88%)	—
Self-pay	125 (5.73%)	62 (4.59%)	—
No charge	0 (0.00%)	0 (0.00%)	—
Other payment	100 (4.58%)	63 (4.61%)	—
Median household income			0.048
0–25th percentile	579 (27.20%)	379 (28.43%)	—
26–50th percentile	531 (24.96%)	349 (26.16%)	—
51–75th percentile	449 (21.10%)	331 (24.77%)	—
76–100th percentile	569 (26.74%)	275 (20.64%)	—

HMO = health maintenance organization

Table 2

Comparison of Inpatient Variables in Patients of Ages 4 and 5 Years Undergoing Closed Reduction Versus Internal Fixation

Inpatient Variables	Closed Reduction	Internal Fixation	*P* Value
Severity of illness			<0.001
Minor loss of function	5 (0.44%)	0 (0.00%)	—
Moderate loss of function	1,038 (92.76%)	897 (79.37%)	—
Major loss of function	60 (5.33%)	202 (17.92%)	—
Extreme loss of function	16 (1.46%)	31 (2.71%)	—
Risk of mortality			0.517
Minor likelihood of dying	1,063 (94.98%)	1,070 (94.69%)	—
Moderate likelihood of dying	30 (2.68%)	34 (3.01%)	—
Major likelihood of dying	25 (2.21%)	20 (1.78%)	—
Extreme likelihood of dying	1 (0.13%)	6 (0.52%)	—
Length of stay	4.19 ± 5.96	4.04 ± 5.45	0.559
Total charge (dollars)	17,400 ± 26,600	28,200 ± 31,500	<0.001

with respect to management: the South and Midwest more frequently using IF compared with the West and Northeast ($P < 0.0001$) (Table 3).

Conclusions

This study using a national pediatric database demonstrated a significant increase in IF compared with nonsurgical management among 4 -and 5-year-old children with closed femoral shaft fractures between 1997 and 2012. Several demographic, surgical, and hospital variables were associated with variations in management. Although previous studies have evaluated trends in pediatric femoral shaft fracture management, this is the first study to specifically assess 4- and 5-year-old children, for which management is controversial.[1,4,10,16-19]

The increased use of IF in 4- and 5-year-old children with closed femoral shaft fractures is likely due to increased utilization of flexible IM nails in lieu of spica casting. Although the database used for this study does not allow for assessment of the type of IF used, it can reasonably be assumed that most of the 4 -and 5-year-old patients receiving IF for a femoral shaft fracture were treated with flexible IM nails.

Some studies have demonstrated that spica casting can result in higher rates of malunion, delayed hip and knee range of motion, slower mobilization, and poorer functional outcomes compared with flexible IM nails.[13,20,21] Aside from clinical and radiographic outcomes, certain socioeconomic factors may affect femur fracture management decisions. Outcome surveys have revealed that flexible nails may decrease the burden of care on family members because spica casts can be difficult to take care of.[22] Furthermore, spica casting may force parents to take increased time off work to care for their child who may not be allowed to return to school until the cast is off.[20,23] Although several reported benefits of flexible nailing exist, surgery carries a risk of general anesthesia complications, infection, blood loss, and damage to surrounding neurovascular structures along with surgical scarring and postoperative skin irritation. In addition, a second surgery is usually required or

recommended to remove the flexible nails.[4,24] Although the data from this study show a clear increasing trend toward the use of IF, the management of closed femoral shaft fractures in 4- and 5-year-old children still remains without consensus.

The lack of consensus can be attributed to limitations of studies assessing this age group, along with numerous patient characteristics, radiographic parameters, socioeconomic variables, and surgeon preferences influencing management decisions.[4,6,13] A recent retrospective cohort study by Ramo et al[4] demonstrated similar clinical and radiographic outcomes in 4- and 5-year-old patients treated with spica casting or flexible nails, but average follow-up was less than 1 year for both groups. A similar retrospective study by Heffernan et al[13] comparing spica casting with flexible nails in children aged 2 to 6 years demonstrated similar time to union between the two groups, but the flexible nail group had shorter times to independent ambulation and returned to full activity earlier than the spica casting group. Average follow-up in this study was 1.2 ± 1.5 years for the spica group and 3.7 ± 2.7 years for the flexible nail group, which was a point of concern brought up in the commentary by Price.[25] Price validly argues that a minimum of 2-year follow-up should be obtained to adequately assess for radiographic overgrowth of the femur, which can occur for up to 3.5 years after treatment.[26] The less than 2-year follow-up in the spica casting group and some patients in the flexible nail group in the study by Heffernan et al[13] and the less than 1-year follow-up of all patients in the study by Ramo et al[4] likely inadequately assess femoral overgrowth. At the time of treatment, overgrowth can be mitigated with spica casting by intentionally implementing a 1-cm overlap of the fracture, but this is not possible with an elastic IM nail. Ultimately, no clear conclusion can be drawn about the superiority of either spica casting or flexible nailing of closed pediatric femoral shaft fractures in 4- and 5-year-old children in the absence of well-defined prospective studies with clinical and radiographic outcomes and adequate midterm follow-up.

Table 3

Comparison of Hospital-Level Variables in Patients of Ages 4 and 5 Years Undergoing Closed Reduction Versus Internal Fixation

Hospital Variables[a]	Closed Reduction	Internal Fixation	*P* Value
% Of pediatric discharges	38.9% ± 30.8%	42.0% ± 33.2%	0.083
Bed size of hospital			0.249
Small	202 (13.36%)	183 (15.28%)	—
Medium	387 (25.57%)	273 (22.78%)	—
Large	924 (61.07%)	743 (61.94%)	—
Ownership of hospital			0.101
Government/private collapsed category	977 (75.06%)	711 (80.31%)	—
Government, nonfederal, public	54 (4.12%)	43 (4.85%)	—
Private, nonprofit, voluntary	148 (11.41%)	79 (8.87%)	—
Private, invest-own	58 (4.44%)	20 (2.25%)	—
Private, collapsed category	65 (4.97%)	33 (3.71%)	—
Region of hospital			<0.001
Northeast	319 (20.54%)	169 (13.45%)	—
Midwest	374 (24.02%)	399 (31.74%)	—
South	449 (28.85%)	395 (31.43%)	—
West	414 (26.59%)	294 (23.38%)	—
Teaching status of hospital			0.034
Nonteaching	404 (31.05%)	224 (25.33%)	—
Teaching	897 (68.95%)	661 (74.67%)	—

[a] The percent of pediatric discharges is defined as the number of total pediatric patients discharged divided by the total number of patients discharged from a given hospital.

Our analysis of demographic variables for patients aged 4 and 5 years demonstrated no differences in race, sex, or insurance status between children receiving closed treatment versus IF. This is consistent with similar studies in older children.[18] However, we demonstrated that patients from families with higher median household income were more likely to undergo closed treatment. The greatest difference was seen in median household incomes from the 75th to 100th percentile, where a 7% higher rate of CR was noted. Although this was statistically significant, the clinical significance is unknown. It is possible that patients from families with more economic resources would prefer nonsurgical treatment to avoid a first and possibly second surgery while having more means to care for a potentially burdensome spica cast. On average, families may require up to three weeks off to care for these patients which can have a significant financial impact, particularly in single-provider homes.[23]

With respect to surgical variables and patient selection criteria, our study demonstrated that 4- and 5-year-old children with higher preoperative loss of function were more

likely to receive IF, whereas those with lower loss of function were more likely to undergo closed management. This difference in treatment may be due to surgeons electing for IF in patients with greater loss of function, such as polytrauma patients, to facilitate postoperative rehabilitation or because spica casting in a patient with multiple injuries can be technically challenging. This finding is consistent with previous studies in which patients in this age group with greater mechanisms of injury or polytrauma were more likely to be treated with flexible nailing.[4,13]

From a financial standpoint, inpatient charges were $10,800 higher in the IF group. This was an expected finding presumably due to implant and operating room cost; many hip spica casts can be applied in a procedure room or emergency department and do not require consumption of operating room resources.[27] In addition, the actual final cost of flexible nailing may be higher because our study does not account for costs associated with removal of the nail, which can occur in greater than half of patients.[13] Conversely, the final cost of spica casting could be higher because of costs associated with adjusting the cast, replacing the cast, or having to covert to surgical management; these costs would not be captured by the KID database. Previous studies have demonstrated no difference in cost between the two treatment options.[21]

Length of inpatient stay can also significantly influence hospital charges. In our study, the length of stay was similar, 4 days, for both treatment groups. The literature reports mixed results when comparing length of stay between these two treatment modalities. Jauquier et al[6] reported that median hospital stay was 1 day for spica casting and 4 days for patients receiving a flexible nail in patients aged 1 to 4 years. The longer length of stay with surgical treatment was due to postoperative pain control. Other studies examining older children treated with spica casting have reported longer lengths of stay with spica casting, but this was mostly due to the use of traction.[21,28] A secondary analysis of our data demonstrated that 4 and 5 year olds undergoing CR received traction less than 10% of the time (see Appendix I, Supplemental Digital Content 1, http://links.lww.com/JAAOS/A124). Overall, the reported 4-day length of stay for spica casting is higher than to be expected. This is likely due to the sampling process of the KID database, which captures only inpatient admissions. It is not uncommon for a spica cast to be placed in the emergency department, followed by discharge after a brief period of observation; therefore, our data may be overestimating the true length of stay for spica casting.

Last, out study demonstrated several differences based on hospital characteristics. Teaching hospitals were more likely to use IF in 4- and 5-year-old children. This may be secondary to teaching hospitals having pediatric orthopaedic surgeons on staff who may be more comfortable placing flexible nails in younger children and managing them postoperatively. There may also be financial motive partially contributing to the trend for surgical management in younger patients; flexible IM nailing has a reimbursement rate more than three times higher than placement of a spica cast.

There are several limitations of this study. First, we used a national database that is dependent on analyzing *ICD-9* codes to isolate procedures and diagnosis. This lends our data subject to coding error and also prevents us from differentiating between various forms of IF. Perhaps the most significant limitation of this study is that we could not assess fracture pattern, which is a critical factor when deciding to elect for nonsurgical or surgical management. It is a valid assumption; however, that the distribution of fracture patterns remained relatively constant over the 15-year period studied, and therefore, our results demonstrating increased rates of IF for femoral shaft fractures in 4- and 5-year-old patients hold true. Similarly, this study categorized patients primarily on chronological age, which may not account for variability in patient weight, body mass index, skeletal maturity, or other patient factors that could affect treatment decisions. The use of current procedural codes or *ICD-10* codes may offset this limitation in the future, but are currently not available in any national pediatric database.

Further limitations of the KID data set include its utilization of only discharge records to analyze patient data, and therefore, analysis of surgical or other clinically relevant variables is not feasible. In addition, this database analysis may have underreported the rates for CR because some institutions may perform CR and spica casting in an emergency department setting without inpatient admission; these instances would not be captured by the KID. Moreover, this study categorized patients as either having undergone CR or IF, but data were not available regarding the type of IF used; the authors of this study chose to refer to the IF group as primarily being flexible IM nailing. There is likely a smaller percentage of the IF group that underwent another form of IF, such as submuscular plating. In addition, it is possible that patients in the CR group actually received external fixation and not a spica cast, but analysis demonstrated that this was less than 2% of patients (data not presented). For the purposes of this analysis, the authors did not feel that this potential heterogeneity of fixation choices changed the conclusions of the study.

Over a 15-year period, the management of pediatric femoral shaft

fractures in 4- and 5-year-old children has progressively shifted. Recently, more surgeons are electing for surgical management with IF, and correspondingly less are using closed management with spica casting as demonstrated by our study. The cause of this shift in management is outside the scope of this study but warrants further investigation. The select studies comparing spica casting versus flexible nailing in children aged 4 to 5 years are limited by their retrospective design and inadequate follow-up. Both spica casting and flexible nailing are adequate treatment options, each with relative advantages and disadvantages. Currently, treatment decisions are made based on surgeon preference, family preference, radiographic parameters, and potential socioeconomic variables. The results of this study demonstrate a clear national paradigm shift in the management of closed femoral shaft fractures in 4- and 5-year-old patients, but additional prospective studies with adequate follow-up and appropriate clinical and radiographic outcomes are needed to investigate whether this shift toward more surgical management may actually lead to better patient outcomes.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 5, 21, and 22 are level II studies. References 1, 2, 4, 6, 12, 13, 16-20, and 26-28 are level III studies. References 23 and 24 are level IV studies.

References printed in **bold type** are those published within the past 5 years.

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