

Operative Treatment Versus Spica Casting for Treatment of Pediatric Femoral Shaft Fractures in Children Aged 4 to 6 Years: A Large Multi-Institutional Age-Stratified Comparative Analysis

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Background: Femoral shaft fractures in children aged 4 to 6 years represent a clinical gray zone between closed reduction with casting and operative treatment. Traditional guidance favors closed treatment under age 6, yet recent reports suggest increasing use of operative treatment despite limited evidence. This study characterized national treatment rates from 2013 to 2024 and compared health care utilization outcomes.

Methods: This retrospective cohort study used the TriNetX Research Network, a federated platform containing nationwide de-identified health records. Patients from 2013 to 2024 with femoral shaft fractures were identified through ICD codes. Data on closed versus operative treatment (defined by CPT codes), sex, race, and ethnicity were extracted. Annual treatment rates, both total and age-stratified, were calculated. Logistic regression and Rao & Scott adjusted χ^2 testing with Bonferroni correction were performed. Propensity score matching was performed for the combined 4- to 6-year cohort; age-stratified analyses were unmatched.

Results: A total of 2486 children aged 4 to 6 years with femoral shaft fractures were identified; 47.3% underwent operative treatment. The proportion treated with closed reduction and spica casting decreased overall, most notably among children aged 5 years (64.3% to 30.6%) and 6 years (51.4% to 23.7%), while rates remained stable at age 4 (67.4% to 77.8%). In the matched combined cohort, operative treatment was associated

with fewer early emergency department visits (RR: 0.64; 95% CI: 0.42-0.97), more late postreduction procedures (RR: 4.20; 95% CI: 2.77-6.37), and more routine healing visits (RR: 1.76; 95% CI: 1.45-2.13). Differences were most pronounced at age 6 in unmatched analyses (early ED visits—OR: 0.32; 95% CI: 0.19-0.51; early postreduction procedures—OR: 0.23; 95% CI: 0.12-0.42).

Conclusions: The rate of operative management of femoral shaft fractures increased by 94% at age 5 and by 61% at age 6 during the study period, despite limited age-specific evidence supporting this shift. This change likely reflects multiple factors, including growing surgeon familiarity with minimally invasive fixation, family-centered considerations, and age-dependent challenges of spica casting, rather than evidence of clinical superiority.

Level of Evidence: Level III—therapeutic study (retrospective comparative study).

Key Words: pediatric femur fracture, femoral shaft fracture, hip spica casting, operative fixation, treatment trends, emergency department utilization, implant removal, TriNetX

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Femoral shaft fractures are uncommon in young children but impose substantial burdens, including prolonged immobilization and caregiver strain.^{1,2} Management is classically age-dependent: nonoperative closed reduction with spica casting has been recommended for children younger than 6 years, whereas older children are typically managed operatively.³ The 4- to 6-year age range sits at the margin of these categories and remains a clinical gray zone. Both the original and updated AAOS guidelines acknowledge the limited high-quality evidence to guide decision-making for this transitional group.⁴

Contemporary reports suggest a shift toward operative fixation even among children younger than 6 years,^{5,6} raising concern that practice may be outpacing the evidence base in this cohort. Complication profiles also appear to differ across techniques in multicenter

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series,⁷ yet age-resolved, decision-informing data for 4 to 6-year-olds remain limited. Each approach carries distinct trade-offs: spica casting avoids surgery and implant-related risks but can be associated with loss of alignment and cast-related morbidity in older or heavier preschoolers,^{8,9} whereas internal fixation may offer more reliable alignment and earlier mobilization at the cost of operative risks and potential later procedures for hardware management.^{10,11}

High-quality comparative evidence specific to 4 to 6-year-olds is sparse; prior studies often focus on younger children or aggregate broad pediatric age ranges, limiting applicability to this decision point.^{12,13} Moreover, adverse events may cluster at different times, as cast-related issues often arise earlier, while implant-related reinterventions tend to occur later, suggesting value in distinguishing early from late outcomes when comparing treatments. Age-related differences within the 4 to 6 range (eg, remodeling potential, body size) may further modify treatment effects.^{14,15}

Accordingly, the purpose of this study is to quantify treatment selection rates over time (closed reduction vs. operative treatment) for femoral shaft fractures in children aged 4, 5, and 6 years. The secondary goal of this study is to compare health care utilization between operative treatment and closed reduction within early and late post-treatment periods and determine whether these associations differ across ages 4, 5, and 6 years.

METHODS

This is a retrospective cohort study performed using the TriNetX Research Network (TriNetX LLC, Cambridge, MA), a federated platform containing deidentified electronic health record (EHR) data from academic and nonacademic health care organizations across the United States (80+ health care organizations across all 9 US Census Bureau divisions). This study was exempt from institutional review board approval because it uses only deidentified data.

Children with femoral shaft fractures were identified using International Classification of Diseases (ICD) and Current Procedural Terminology (CPT) codes. Patients treated with operative treatment or closed reduction were identified using the relevant procedure codes. Outcomes included postfracture emergency department visits, post-reduction procedures, and routine healing visits. Post-reduction procedures were defined as subsequent procedural interventions following the index treatment, identified using procedure codes; anesthesia billing codes were used as a surrogate marker to identify interventions requiring procedural sedation or operative-level care. The early postreduction period was defined as 0 to 3 months, while the late postreduction period was defined as 3 to 12 months.

Annual treatment rates, both total and age-stratified, were calculated. Logistic regression ($\alpha < 0.05$) was used to evaluate temporal changes in treatment selection over the study period, with odds ratios per year and 95%

CI reported. Rao & Scott adjusted χ^2 testing with Bonferroni correction was used to compare treatment proportions across age groups.

For the combined 4- to 6-year cohort, propensity score matching (PSM) was performed to address potential confounding from baseline imbalances, balancing on age, sex, body mass index category, and fracture pattern (oblique, spiral, transverse, comminuted, unspecified). Covariate balance was assessed using standardized mean differences, with values < 0.1 considered balanced. Combined-cohort outcomes after matching are reported as risk ratios (RRs) with 95% CIs. Outcomes during the 3- to 12-month period were assessed in patients with sufficient post-treatment follow-up, yielding 448 patients per group.

Age-stratified outcomes at ages 4, 5, and 6 were analyzed as unmatched comparisons because matched sample sizes at each individual age were insufficient and outcome data following matching were therefore unavailable; odds ratios (ORs) and 95% CIs were reported. Analyses were performed in the TriNetX platform and RStudio (version 4.3.1; R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was set at $P < 0.05$.

RESULTS

Cohort

This study included 2486 children aged 4 to 6 years who underwent treatment for femoral shaft fractures; 1176 children were treated with operative treatment and 1310 with closed reduction and casting. Children aged 4 years underwent 245 operative treatments and 725 closed reductions. Children aged 5 years underwent 419 operative treatments and 368 closed reductions. Children aged 6 years underwent 512 operative treatments and 217 closed reductions.

Treatment Selection Over Time

For the aggregate 4- to 6-year cohort, the proportion managed with closed reduction declined from 62.3% in 2013 to 46.5% in 2024, corresponding to a 2.6% lower odds of closed reduction per year (OR/year, 0.974; $P = 0.032$). When stratified by a single year of age, there was no significant temporal change at age 4 (closed reduction 67.4% $\rightarrow$ 77.8%; OR/year, 1.040; $P = 0.091$). In contrast, closed reduction decreased by 52.4% at age 5 and 53.9% at age 6 (age 5: 64.3% $\rightarrow$ 30.6%; OR/year, 0.921; $P = 0.00017$; age 6: 51.4% $\rightarrow$ 23.7%; OR/year, 0.923; $P = 0.00165$). Incidence data and annual treatment rates are presented in Table 1.

Early (0 to 3 mo) and Late (3 to 12 mo) Outcomes: Ages 4 to 6 Combined

After propensity score matching, baseline balance was achieved across age, sex, BMI category, and fracture pattern (all standardized mean differences < 0.1 ; Table 2). Mean follow-up was 298.5 ± 111.3 days in the operative cohort and 293.4 ± 123.5 days in the closed reduction

TABLE 1. Treatment Selection for Femoral Shaft Fractures, Ages 4 to 6 Combined (2013 to 2024)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Closed reduction, n (%)	76 (62.0)	103 (54.3)	113 (56.6)	126 (52.2)	123 (53.4)	96 (44.8)	128 (57.2)	120 (54.6)	123 (48.8)	115 (55.5)	88 (51.2)	99 (46.4)
Operative treatment, n (%)	46 (38.0)	87 (45.7)	87 (43.4)	115 (47.8)	107 (46.6)	118 (55.2)	96 (42.8)	100 (45.4)	129 (51.2)	93 (44.5)	84 (48.8)	114 (53.6)
Total, n	122	190	200	241	230	214	224	220	252	208	172	213

cohort; median follow-up was 365 days in both groups (IQR: 112 and 110, respectively). Among the 1176 children aged 4- to 6-year-olds who underwent operative treatment in the matched cohort, 74 (6.3%) had an emergency department (ED) visit within the first 0 to 3 months, 74 (6.3%) underwent a postreduction procedure, and 656 (55.8%) had a routine healing visit. In the late postoperative period (n = 448), 33 (7.4%) had an ED visit, 105 (23.4%) underwent a postreduction procedure, and 197 (44.0%) had a routine healing visit.

Among the 1310 children aged 4- to 6-year-olds who underwent closed reduction in the matched cohort, 130 (9.9%) of them had an ED visit within the first 0 to 3 months, 115 (8.8%) underwent a postreduction procedure, and 714 (54.5%) had a routine healing visit. In the late postoperative period (n = 448), 47 (10.5%) had an ED visit, 25 (5.6%) underwent a postreduction procedure, and 112 (25.0%) had a routine healing visit.

In the early postoperative period, operative treatment was associated with fewer ED visits (RR: 0.64; 95% CI: 0.42-0.97; $P=0.04$) compared with closed reduction. Postreduction procedures (RR: 0.72; 95% CI: 0.47-1.10; $P=0.13$) and routine healing visits (RR: 1.02; 95% CI: 0.92-1.14; $P=0.72$) did not differ significantly between groups. From 3 to 12 months, ED visits did not differ (RR: 0.70; 95% CI: 0.46-1.07; $P=0.10$), but operative treatment was associated with a substantially higher rate of postreduction procedures (RR: 4.20; 95% CI: 2.77-6.37; $P<0.001$) and routine healing visits (RR: 1.76; 95% CI: 1.45-2.13; $P<0.001$). Full outcome data are presented in Table 3.

Age-Stratified Outcomes

Age 4: in the first 3 months, there were no significant differences between operative treatment and closed reduction for ED visits (OR: 0.74; 95% CI: 0.38-1.42; $P=0.367$) or post-reduction procedures (OR: 1.01; 95% CI: 0.58-1.75; $P=0.984$). Between 3 and 12 months, ED utilization did not differ (OR: 0.89; 95% CI: 0.49-1.61; $P=0.715$); postreduction procedures were more frequent after operative treatment (OR: 5.90; 95% CI: 3.53-9.87; $P<0.001$). Full counts and outcome data are presented in Table 4.

Age 5: during the first 3 months, differences were not significant for ED visits (OR: 0.63; 95% CI: 0.34-1.18; $P=0.145$) or postreduction procedures (OR: 0.68; 95% CI: 0.41-1.12; $P=0.127$). From 3 to 12 months, operative treatment was associated with fewer ED visits (OR: 0.50; 95% CI: 0.31-0.81; $P=0.004$) and more postreduction procedures (OR: 2.42; 95% CI: 1.48-3.98; $P<0.001$).

Age 6: in the early period, operative treatment was associated with fewer ED visits (OR: 0.32; 95% CI: 0.19-0.51; $P<0.001$) and fewer postreduction procedures (OR: 0.23; 95% CI: 0.12-0.42; $P<0.001$). In the late period, operative treatment remained associated with fewer ED visits (OR: 0.37; 95% CI: 0.21-0.65; $P<0.001$) and more postreduction procedures (OR: 3.45; 95% CI: 1.79-6.63; $P<0.001$). Age-stratified odds ratios are summarized in Figure 1.

DISCUSSION

This study clarifies a persistent gray zone in pediatric femoral shaft fracture care by pairing age-specific treatment rates with time-segmented utilization data in children 4 to 6 years old. Operative management in-

TABLE 2. Baseline Characteristics of the Operative and Closed Reduction Cohorts Before and After Propensity Score Matching

Variable	Operative (before), n (%)	Closed reduction (before), n (%)	Standard difference	Operative (after), n (%)	Closed reduction (after), n (%)	Standard difference
N	1176	1310	—	1176	1310	—
Age, mean $\pm$ SD, (y)	5.16 $\pm$ 0.79	4.60 $\pm$ 0.75	0.733	4.94 $\pm$ 0.78	4.94 $\pm$ 0.80	0.007
Male	785 (66.8)	876 (66.9)	0.001	773 (65.7)	863 (65.9)	0.004
BMI: 10-15 kg/m ²	69 (5.9)	105 (8.0)	0.083	81 (6.9)	90 (6.9)	<0.001
BMI: 15-20 kg/m ²	140 (11.9)	183 (14.0)	0.062	141 (12.0)	168 (12.8)	0.023
BMI $\geq$ 20 kg/m ²	32 (2.7)	35 (2.7)	0.003	27 (2.3)	35 (2.7)	0.025
Fracture pattern						
Unspecified	514 (43.7)	326 (24.9)	0.403	352 (29.9)	405 (30.9)	0.021
Oblique	167 (14.2)	126 (9.6)	0.142	128 (10.9)	143 (10.9)	<0.001
Spiral	119 (10.1)	136 (10.4)	0.011	126 (10.7)	119 (9.1)	0.051
Transverse	214 (18.2)	75 (5.7)	0.393	107 (9.1)	130 (9.9)	0.026
Comminuted	135 (11.5)	51 (3.9)	0.291	81 (6.9)	75 (5.7)	0.047

TABLE 3. Health Care Utilization Outcomes in the Propensity-Matched 4- to 6-Year Combined Cohort

Outcome	Period	Operative, n (%)	Closed reduction, n (%)	RR (95% CI)	P
Emergency department visit	1-3 mo	74/1176 (6.3)	130/1310 (9.9)	0.64 (0.42-0.97)	0.04
Postreduction procedure	1-3 mo	74/1176 (6.3)	115/1310 (8.8)	0.72 (0.47-1.10)	0.13
Routine healing visits	1-3 mo	656/1176 (55.8)	714/1310 (54.5)	1.02 (0.92-1.14)	0.72
Emergency department visit	3-12 mo	33/448 (7.4)	47/448 (10.5)	0.70 (0.46-1.07)	0.10
Postreduction procedure	3-12 mo	105/448 (23.4)	25/448 (5.6)	4.20 (2.77-6.37)	<0.001
Routine healing visits	3-12 mo	197/448 (44.0)	112/448 (25.0)	1.76 (1.45-2.13)	<0.001

RR indicates relative risk for operative treatment compared with closed reduction (reference).

creased by 93.9% at age 5 and 60.7% at age 6 (age 5: 36.0%→69.8%; age 6: 47.6%→76.5%), while there was no significant change at age 4 (33.4%→23.1%).

The observations made in this study should be considered alongside longstanding guidance that favors nonoperative management in children younger than 6, while acknowledging low-certainty evidence in the transition years.^{3,4} Contemporary series nevertheless describe increasing operative use in younger children.^{5,6} Our incidence analysis confirms that this shift is occurring specifically at the older end of the 4 to 6 range. The gap between evolving practice and age-resolved evidence remains the central issue this study addresses.⁴⁻⁶

Although this data set cannot identify the reasons underlying individual treatment decisions, several factors likely contribute to the observed shift. Growing surgeon familiarity with minimally invasive fixation techniques, particularly titanium elastic nailing, is supported by meta-analytic data confirming lower malunion and unplanned intervention rates compared with spica casting in preschool-aged children.^{12,16} Caregiver and family considerations also play a role: spica casting imposes well-documented challenges, including skin complications, transportation difficulties, and prolonged caregiver demands.⁹ Prospective data further suggest that flexible nailing may reduce overall family burden.¹⁷ In addition, age-dependent spica failure rates may further lower the threshold for operative intervention, as older preschoolers treated with casting have higher odds of unplanned revision than younger children.¹⁸ The interplay of these factors, rather than any single driver, likely explains the observed shift, particularly at ages 5 and 6.

The pattern of lower early ED utilization after operative treatment has plausible clinical explanations. Internal fixation confers immediate stability, reduces caretaker burden during recovery, and may reduce cast-related loss of alignment or skin problems that disproportionately affect older or heavier preschoolers.⁸⁻¹¹ These factors align with the observed reduction in early ED visits after operative treatment, particularly at age 6, where body size and activity level challenge spica management.^{14,15}

By contrast, the higher rates of later postreduction procedures and routine healing visits after operative treatment in the matched combined cohort are consistent with downstream implant removal and postfixation follow-up; although this data set cannot distinguish planned from unplanned procedures, hardware removal after pediatric femoral fixation is commonly performed electively.¹⁹ Casting avoids hardware entirely and consequently any future hardware complications, an important consideration for families weighing lower early utilization against the expectation of a second procedure months later. The age-stratified patterns suggest that this trade-off is not uniform: early utilization differences favoring operative treatment become more pronounced as children approach age 6, whereas at age 4, early differences are minimal, yet later implant care is just as much of a concern.

Prior comparative studies often pooled broad pediatric age ranges or emphasized younger patients, limiting applicability at this decision point.^{12,13,15} By disaggregating 4, 5, and 6 years and separating early from

TABLE 4. Health Care Utilization Outcomes by Age (Unmatched Comparisons)

Age	Outcome	Period	Operative, n (%)	Closed reduction, n (%)	OR (95% CI)	P
4	Emergency department visit	1-3 mo	11/245 (4.7)	46/725 (6.3)	0.74 (0.38-1.42)	0.367
4	Postreduction procedure	1-3 mo	17/245 (6.8)	49/725 (6.8)	1.01 (0.58-1.75)	0.984
4	Emergency department visit	3-12 mo	15/245 (5.9)	69/725 (9.6)	0.89 (0.49-1.61)	0.715
4	Postreduction procedure	3-12 mo	48/245 (19.5)	29/725 (3.9)	5.90 (3.53-9.87)	<0.001
5	Emergency department visit	1-3 mo	18/419 (4.4)	26/368 (7.0)	0.63 (0.34-1.18)	0.145
5	Postreduction procedure	1-3 mo	28/419 (6.8)	37/368 (10.0)	0.68 (0.41-1.12)	0.127
5	Emergency department visit	3-12 mo	29/419 (6.9)	48/368 (13.0)	0.50 (0.31-0.81)	0.004
5	Postreduction procedure	3-12 mo	64/419 (15.3)	23/368 (6.3)	2.42 (1.48-3.98)	<0.001
6	Emergency department visit	1-3 mo	29/512 (5.7)	39/217 (18.0)	0.32 (0.19-0.51)	<0.001
6	Postreduction procedure	1-3 mo	16/512 (3.1)	29/217 (13.5)	0.23 (0.12-0.42)	<0.001
6	Emergency department visit	3-12 mo	25/512 (4.8)	28/217 (12.9)	0.37 (0.21-0.65)	<0.001
6	Postreduction procedure	3-12 mo	95/512 (18.5)	13/217 (6.2)	3.45 (1.79-6.63)	<0.001

OR indicates odds ratio for operative treatment compared with closed reduction (reference).

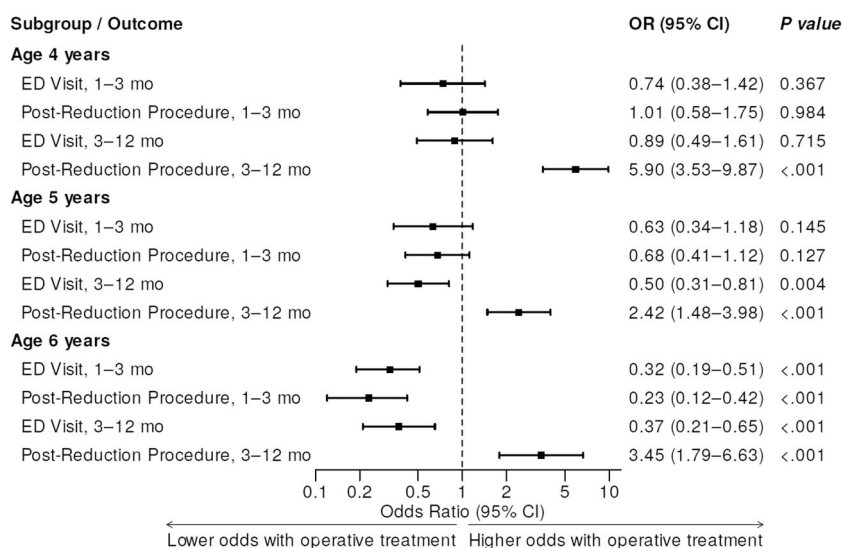


FIGURE 1. Comparison of ED visits and procedures in each age group.

late outcomes, the present work provides age-specific utilization data that complement existing recommendations. At age 6, operative treatment was associated with significantly fewer emergency department visits and postreduction procedures; later procedures were more common after operative treatment across all ages. Whether these utilization patterns reflect meaningful clinical differences requires further investigation with radiographic and functional outcomes. These patterns may inform family counseling and resource planning while reinforcing the need for evidence-based guidelines in this transitional age group.

Clinical applications should emphasize shared decision-making. Counseling ought to address the distinct recovery trajectories and procedure timelines associated with each treatment, incorporate family preferences regarding anesthesia exposure, cast management, mobility, and time away from work, and account for fracture pattern, fracture stability, patient body weight, and surgeon experience.

This study has limitations inherent to retrospective observational designs. Selection bias and residual confounding are possible, including surgeon preference, institutional pathways, and fracture-specific details not fully captured. Age-stratified analyses could not be propensity-matched and remain subject to baseline imbalances between treatment groups within each age, unlike the matched combined-cohort results. Administrative coding may misclassify exposures or outcomes, and the data set structure precludes a clean distinction between planned and unplanned implant procedures. Due to database limitations, we are unable to distinguish specific postreduction procedure subtypes, such as cast wedging versus repeat casting. The data set also did not capture whether closed reductions and cast applications were performed in the emergency department or operat-

ing room. Because operative procedures were analyzed as a single cohort, this study does not address variation in utilization patterns or outcomes among specific fixation techniques. Patient-reported outcomes and cost or time-burden measures were not available. Importantly, core clinical outcomes, including fracture healing time, radiographic alignment, and functional recovery, are not captured in this data set; the findings therefore reflect differences in health care utilization and should not be interpreted as evidence of clinical superiority of either treatment. Finally, we were unable to obtain the reason for any emergency department visits, so they may not have all been related to the femoral shaft fracture. These constraints temper causal inference but do not diminish the clinical relevance of the age-specific patterns observed.

In 4- to 6-year-olds with femoral shaft fractures, practice has moved toward surgery, especially at ages 5 (36.0% to 69.8%) and 6 (47.6% to 76.5%), despite limited age-specific evidence to guide that shift. In the matched combined cohort, operative treatment was associated with fewer early ED visits, more late postreduction procedures, and more routine healing visits; the magnitude and significance of these differences varied by age in the unmatched analyses. These data argue for age-specific shared decision-making and prospective studies that integrate radiographic, functional, caregiver, and cost outcomes to determine when increased surgical use is truly justified in this gray-zone population.

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