Does Shorter Time to Treatment of Pediatric Femur Shaft Fractures Impact Clinical Outcomes?

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Background: Annual rankings by *US News and World Report* are a widely utilized metric by both health care leaders and patients. One longstanding measure is time to treatment of femur shaft fractures. Hospitals able to provide at least 80% of pediatric patients with an operating room start time within 18 hours of admission to the emergency department score better as part of the overall pediatric orthopaedic ranking. Therefore, it is important to determine whether the 18-hour treatment time for pediatric femur shaft fractures is a clinically meaningful metric.

Methods: A retrospective review of clinical outcomes of 174 pediatric patients (aged below 16 y) with isolated femur shaft fractures (Injury Severity Score = 9) was conducted from 1997 to 2017 at a single level I pediatric trauma center. The 2 comparison groups were patients receiving fracture reduction within 18 hours of emergency department admission (N = 87) or > 18 hours (N = 87).

Results: Patient, injury, and surgical characteristics were similar between the 2 groups. Both groups had a similar mean age (treatment <18 h = 7.5 y; treatment > 18 h = 8.1 y). Patients who received treatment within 18 hours were more often immobilized postoperatively (70.1% vs. 53.5%; $P = 0.0362$) and had a shorter median hospital length of stay (2 vs. 3 d; $P = 0.0047$). There were no statistically significant differences in any outcomes including surgical site infection, time to weight-bearing (treatment <18 h mean = 48.1 d vs. 52.5 d), time to complete radiographic fracture healing (treatment <18 h mean = 258.9 d vs. 232.0 d), decreased range of motion, genu varus/valgus, limb length discrepancy, loss of reduction, or persistent pain.

Conclusions: Treatment of pediatric femur shaft fractures within 18 hours does not impact clinical outcomes. National quality measures should therefore use evidence-based metrics to help improve the standard of care.

Level of Evidence: Therapeutic level III.

Key Words: femur fracture, time to treatment, US News and World Report

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Annual rankings by the *US News & World Report* (USNWR) are a widely recognized metric utilized by both hospital leaders and patients. This ranking is based on a series of questions about the practice including patient volumes for specific diagnoses and availability of services. Many of these inquiries, however, are arbitrary and may not be based on evidence-based clinical care. For example, when determining "America's Best Hospitals," hospital reputation has been used as a proxy for high-quality care rather than clinical outcomes. Looking at specialty specific rankings, some studies have shown that top-ranked cardiology departments perform better in certain patient outcomes, such as 30-day mortality rates for acute myocardial infarction,[1,2] heart failure, and coronary artery bypass, but fall short on other metrics such as 30-day hospital readmission rate[2] and may not have any association with decreased mortality when adjusting for hospital volume.[3] The lack of consistent, rigorous evidence-based inquiries has been attributed to limited data availability and homogeneity when comparing hospitals and methodological weaknesses when choosing key elements in rank scoring.[1,4]

According to the 2017-2018 US News and World Report Best Children's Hospitals methodology report, survey results based on "expert opinion" are currently utilized in determining outcomes of interest.[5] One specific USNWR metric used is the speed with which pediatric orthopaedic departments treat complex fractures, including femur shaft fractures. Hospitals that are able to provide more pediatric patients (at least 80%) with an operating room (OR) start time within 18 hours of admission to the emergency department (ED) received more points toward a better score for the overall pediatric orthopaedic departmental ranking. Therefore, it is important to determine whether the 18-hour cut-off time to treatment of pediatric femur shaft fractures has any meaningful impact on clinical outcomes. We hypothesize that there are no differences in both short-term and long-term outcomes and complication rates for patients who receive treatment within 18 hours compared with those who receive treatment after 18 hours.

This study was not designed to assess the adequacy of compliance with national guidelines for the treatment of pediatric femur fractures. The focus of this study is on the timing of femur fracture treatment rather than on the specific availability of an emergent OR or cast room. Additional studies determining the impact of resource

allocation for pediatric orthopaedic trauma would be interesting and informative.

METHODS

Cohort Selection

After IRB approval, the pediatric trauma database at a level I pediatric trauma center was queried for all femur fractures from January 1, 1997 to December 31, 2017. Only patients with an age below 16 years with an injury severity score of 9 and no additional injuries (ie, isolated traumatic diaphyseal femur fractures) were included in this retrospective study. Considering the complexity of timing femur fracture treatment in patients who sustained polytrauma and would require other more emergent/urgent treatments, only isolated diaphyseal femur fractures were included. Patients were excluded if they had neuromuscular diseases, syndromic conditions or were nonambulatory. Patients were also excluded if they had a pathologic fracture, slipped capital femoral epiphysis, or had a follow-up of <8 weeks. A total of 174 patients met inclusion criteria for this study.

Data Collection and Statistical Analysis

The electronic medical record was reviewed to retrospectively collect patient demographics, injury and surgical characteristics, and short-term and long-term clinical outcomes data. Sequential radiographs at clinical follow-up were evaluated to determine limb length discrepancies, degrees of angulation, loss of reduction, and when complete radiographic healing occurred (fracture no longer visible). Time to weight-bearing, gait disturbance, gait disturbance, and decreased range of motion were ascertained from clinical notes by the treating orthopaedic surgeon.

Statistical analyses were completed using R Statistical Software (Foundation for Statistical Computing, Vienna, Austria). Univariate analyses were conducted using the nonparametric tests Wilcoxon rank sum and Fisher exact test when appropriate. The log rank test was used to compare the cumulative complication incidence whereas Cox proportional hazard regression modeling was used for determining time to weight-bearing and radiographic fracture healing for both univariable and multivariable analyses.

RESULTS

Patient Demographics

Patient demographics are summarized for the 2 groups (Table 1). Eighty-seven patients (50%) were treated within 18 hours of ED admission (tx < 18 h) and 87 were treated later than 18 hours after ED admission (tx > 18 h). No statistically significant differences in patient demographics were found.

Injury and Transport Characteristics

The most common mechanism of injury for both groups was a fall, either from the ground or a height (tx < 18 h = 36.8%; tx > 18 h = 35.6%) More patients receiving treatment in the later treatment group had an injury playing recreational sports (20.7%) compared with those with treatment in the earlier group (13.8%) whereas those who received treatment in less time had higher rates of femur fractures caused by an impact (20.7% vs. 5.7%). Both groups had similar fracture severities (simple vs. comminuted, tx < 18 h simple—79.3%, tx > 18 h—69.0%; $P = 0.1656$) and transverse versus oblique/spiral fracture patterns (tx < 18 h transverse—41.4%; tx > 18 h—43.7%; $P = 0.8782$). There was no significant difference in the median time between injury and presentation to the ED (tx < 18 h, 150.0 min; tx > 18 h, 158.5 min; $P = 0.7919$). The majority of patients treated within 18 hours presented during the daytime hours of 8 AM to 5 PM (65.5%) whereas most patients in the later treatment group presented during night-time hours of 5 PM to 8 AM (83.9%, $P < 0.0001$). A similar percentage of patients in both groups were transferred from an outside hospital for treatment (tx < 18 h = 48.3%; tx > 18 h = 60.9%; $P = 0.1278$). The only significant difference between groups was the time of day at which patients presented to our institution (Table 2).

TABLE 1. Patient Demographics

	n (%)			
	Tx < 18 h, n = 87	Tx > 18 h, n = 87	All Patients, N = 174	*P*
Demographics				
Age, mean (SD) (y)	7.53 (4.70)	8.12 (4.70)	7.87 (4.70)	0.4096
Age (cat)				0.7326
<4	28 (32.2)	22 (25.3)	50 (28.7)	
4-9	27 (31.0)	29 (33.3)	56 (32.2)	
10-13	24 (27.6)	25 (28.7)	49 (28.2)	
14+	8 (9.2)	11 (12.6)	19 (10.9)	
Sex				1.0000
Male	63 (72.4)	64 (73.6)	127 (73.0)	
Female	24 (27.6)	23 (26.4)	47 (27.0)	
Race				0.1382
White	84 (96.6)	79 (90.8)	163 (93.7)	
African American	0 (0.0)	4 (4.6)	4 (2.3)	
Hispanic/ Latino	1 (1.1)	2 (2.3)	3 (1.7)	
Unknown	2 (2.3)	2 (2.3)	4 (3.0)	

Surgical Characteristics

Table 3 summarizes the surgical characteristics for both treatment time groups. Significantly more patients in the later treatment group were likely to be treated in the OR compared with the cast room (tx <18 h = 67.8% treated in the OR; tx > 18 h = 92.0% treated in the OR; $P = 0.0001$). The cast room is an area that is adjacent to the surgical suite and can be used as a minor procedure room with sedation availability. The average procedure length was ~4 hours for both groups in both the cast room and OR (tx <18 h = 4.0 h, tx > 18 h = 4.2 h) with no statistically significant difference.

The most common surgical procedures for those in the early treatment group were a closed reduction with no hardware placed (44.8%) and flexible intramedullary nail placement (35.6%). For those in the later treatment group,

TABLE 2. Injury Characteristics

	n (%)			
	Tx < 18 h, n = 87	Tx > 18 h, n = 87	All Patients, N = 174	*P*
Mechanism of injury				0.1402
Fall	32 (36.8)	31 (35.6)	63 (36.2)	
ATV/dirtbike/ snowmobile	15 (17.2)	15 (17.2)	30 (17.2)	
Recreational sports	12 (13.8)	18 (20.7)	30 (17.2)	
Impact	18 (20.7)	5 (5.7)	23 (13.2)	
Bike	5 (5.7)	9 (10.3)	14 (8.0)	
MVA noncollision	2 (2.3)	3 (3.4)	5 (2.9)	
Pedestrian	1 (1.1)	3 (3.4)	4 (2.3)	
MVA collision	1 (1.1)	1 (1.1)	2 (1.1)	
Abuse	1 (1.1)	1 (1.1)	2 (1.1)	
Other	0 (0.0)	1 (1.1)	1 (0.6)	
Fracture severity				0.1656
Simple	69 (79.3)	60 (69.0)	129 (74.1)	
Multifragmentary	18 (20.7)	27 (31.0)	45 (25.9)	
Fracture pattern				0.8782
Transverse	36 (41.4)	38 (43.7)	74 (42.5)	
Oblique/spiral	51 (58.6)	49 (56.3)	100 (57.5)	
Time from injury to institution (min)*	150.0 (60.0-250.0), Na = 27	158.5 (72.5-214.0), Na = 21	151.0 (64.2-245.0), Na = 48	0.7919
Time of presentation to institution				< 0.0001
Daytime (8 AM-5 PM)	57 (65.5)	14 (16.1)	71 (40.8)	
Nighttime (5 PM-8 AM)	30 (34.5)	73 (83.9)	103 (59.2)	
Transferred to institution	42 (48.3)	53 (60.9)	95 (54.6)	0.1278
Ground EMS	55 (63.2)	64 (73.6)	119 (68.4)	
Private vehicle	30 (34.5)	19 (21.8)	49 (28.2)	
Air EMS	2 (2.3)	4 (4.6)	6 (3.4)	

*Median (interquartile range).
ATV indicates all terrain vehicle; MVA, motor vehicle accident.

more patients had flexible intramedullary nails placed (39.1%) and fewer had a closed reduction with no hardware placed (31.0%) ($P = 0.2494$ for overall surgical procedure type). Rigid intramedullary nails, plating, and external fixation were relatively uncommon in both groups.

Postoperative Course

Seventy percent of patients in the tx <18 hours group were immobilized postoperatively compared with 53.5% of patients in the tx > 18 hours group ($P = 0.0362$). Although the median total length of stay in the hospital was shorter for those who received treatment within 18 hours (2 days) than those who received treatment in > 18 hours (3 days; $P = 0.0047$), the median postoperative length of stay was the same for both groups (2 days; $P = 0.2209$). Median follow-up was 311 days and 305 days for early and late treatment groups, respectively (Table 4).

Clinical Outcomes

There were no statistically significant differences in any clinical outcomes between those who were treated within 18 hours and those treated after 18 hours (Table 4). The average time to weight-bearing was similar between the 2 groups (tx < 18 h = 48.1 d; tx > 18 h = 52.5 d; $P = 0.3696$). The average time to complete radiographic fracture healing was also similar: 258.9 days for those in the early treatment group versus 232.0 days for those in the late treatment group ($P = 0.4970$). After adjusting for patient age categorically (< 4, 4 to 9, 10 to 13, 14+ yrs), there was no difference in mean time to weight-bearing for those with a fracture treated after 18 hours compared with those treated within 18 hours [hazard ratio = 1.05 (0.76-1.45); $P = 0.7787$)] or time to radiographic fracture healing [hazard ratio = 1.22 (0.85-1.75); $P = 0.2284$].

Overall complication incidence for both groups was statistically similar ($P = 0.1385$). Five patients (5.7%) in the early treatment group and 2 patients (2.3%) in the late treatment group had a loss of fracture reduction that required intervention. Three reduction losses were due to repetitive trauma and 4 were due to angulation/varus deformity postoperatively. Surgical site infections occurred in 6 patients (6.9%) in the early treatment group and 1 patient (1.1%) in the late treatment group.

Long-term, persistent complications occurred in <10% of patients of each cohort and overall. Only 1 patient, in the tx <18 hours group, had persistent limb length discrepancy > 2 cm (1.2%). Three patients (3.5% and 3.8%) in each treatment group sustained an on-going gait disturbance (limping) at last clinical follow-up, but these did not result in impairment in completing daily tasks or physical activity. In the early treatment group, 2 patients (2.3%) had a clinically significant persistent angular deformity of either genu varus or valgus versus 4 patients (4.6%) in the late treatment group. Seven patients (8.0%) in the early treatment group and 5 patients (5.8%) in the late treatment group complained of persistent pain or tenderness due to symptomatic hardware except for a single patient with presumed patellofemoral syndrome 2 years postoperatively.

DISCUSSION

Although femoral shaft fractures only account for ~2% of all pediatric fractures,[5] they are still among the most common diaphyseal fractures in children and constitute over 20% of all pediatric orthopaedic trauma.[6–10] They are also the most common pediatric orthopaedic injury that requires hospitalization,[9,10] representing a significant socioeconomic cost for patients and their families. In 2009, the American Academy of Orthopaedic Surgeons set out to provide clinical guidelines for the optimal treatment of pediatric femur fractures.[11] Guidelines based on fair-quality or good-quality evidence (level I or II) include evaluating all children under 36 months of age for child abuse and using early spica casting or traction with delayed spica casting for children between 6 months and 5 years of age with <2 cm of femur shortening. However,

TABLE 3. Surgical Characteristics

	n (%)			
	Tx <18 h, n = 87	**Tx > 18 h, n = 87**	**All Patients, N = 174**	***P***
Surgery				
ED time (min)*	157.5 (61.4)	182.6 (85.4)	170.0 (75.1)	**0.0277**
OR vs. cast room				
Cast room	28 (32.2)	7 (8.0)	35 (20.1)	**0.0001**
OR	59 (67.8)	80 (92.0)	139 (79.9)	
Time to treatment (h)†	7.5 (5.4-10.0)	36.3 (29.5-43.0)	17.5 (7.5-36.0)	—
Procedure length (h)*	4.0 (2.1) Na = 24	4.2 (2.0) Na = 6	4.1 (2.0) Na = 30	0.5678
OR/cast room time (h)†	6.5 (3.8-9.0)	7.8 (3.7-9.0)	7.4 (3.7-9.0)	0.1568
Blood loss (mL)†	150.0 (100.0-212.0), Na = 59	150.0 (100.0-238.0), Na = 49	150.0 (100.0-238.0), Na = 108	0.5480
Surgical procedure				0.2494
Closed reduction	39 (44.8)	27 (31.0)	66 (37.9)	
Flexible IM nails	31 (35.6)	34 (39.1)	65 (37.4)	
Rigid IM nails	4 (4.6)	9 (10.3)	13 (7.5)	
Plating	10 (11.5)	15 (17.2)	25 (14.4)	
External fixation	3 (3.4)	2 (2.3)	5 (2.9)	
Reduction				0.4758
Closed	79 (90.8)	75 (86.2)	154 (88.5)	
Open	8 (9.2)	12 (13.8)	20 (11.5)	

Bold values indicate statistical significance $P < 0.05$.
*Mean (SD).
†Median (interquartile range).
ED indicates emergency department; IM, intrmedullary nail; OR, operating room.

specific treatment recommendations regarding the timing of treatment were not provided.

Although there have been many studies on the treatment of femoral fractures by patient age, there have been few studies on the time between hospital presentation and treatment. In one study of the timing of femur fracture reduction in the setting of poly-trauma, patients treated within 24 hours had no significant differences in the development of pulmonary complications compared with those treated at >24 hours after presentation to the hospital.[12] Another found that early femur fracture treatment (<48 h) resulted in shorted hospital stays and fewer pulmonary, renal, and infectious complications, but no differences in orthopaedic complications.[13] In our study, we found no difference in time between injury occurrence and presentation to the ED, showing that this did not impact the decision of when to treat. We did find that significantly more patients presenting during daytime hours (8 AM to 5 PM) were treated in <18 hours compared with those presenting at nighttime. This is most likely due to the nonurgent or emergent nature of treating isolated diaphyseal femur

TABLE 4. Immediate Postoperative and Long-term Outcomes

	n (%)			
	Tx <18 h, n = 87	**Tx > 18 h, n = 87**	**All Patients, N = 174**	***P***
Postop				
Immobilization	61 (70.1)	46 (53.5), Na = 1	107 (61.8), Na = 1	**0.0362**
Multiple surgeries	2 (2.3)	1 (1.1)	3 (1.7)	1.000
Total length of stay (d)*	2 (1-3)	3 (2-4)	2 (1-4)	**0.0047**
Postop length of stay (d)*	2 (1-3)	2 (1-3)	2 (1-3)	0.2209
Follow-up (d)*	311.0 (188.7-393.0)	304.6 (216.6-424.0)	311.1 (190.8-414.0)	0.5345
Outcomes				
Complete fracture time to heal (d)†	258.9 (157.3), Na = 21	232.0 (134.7), Na = 26	245.4 (146.6), Na = 47	0.4970
Time to full weight-bearing (d)†	48.1 (20.2), Na = 1	52.5 (34.3)	50.3 (28.1), Na = 1	0.3696
Decr. ROM	3 (3.5), Na = 1	7 (8.1), Na = 1	10 (5.8), Na = 2	0.3283
Limb length discrepancy	1 (1.2), Na = 2	0 (0.0), Na = 3	1 (0.6), Na = 5	1.0000
Gait disturbance	3 (3.5), Na = 1	3 (3.8), Na = 7	6 (3.6), Na = 8	1.0000
Genu varus/valgus	2 (2.3)	4 (4.6)	6 (3.4)	0.6820
Loss of reduction	5 (5.7)	2 (2.3), Na = 1	7 (4.0), Na = 1	0.4435
Persistent pain	7 (8.0)	5 (5.8), Na = 1	12 (6.9), Na = 1	0.7806
Surgical site infection	6 (6.9)	1 (1.1)	7 (4.0)	0.1174

Bold values indicate statistical significance $P < 0.05$.
*Median (interquartile range).
†Mean (SD).
ROM indicates range of motion.

fractures which can be safely delayed till full daytime staffing and ORs/cast rooms are available.

Despite a paucity of evidence that time to treatment impacts long-term orthopaedic outcomes, a cut-off of 18 hours for time to treatment is a component used by USNWR in ranking pediatric orthopaedic departments around the country. Considering that these rankings are viewed widely by hospital administrators and patients alike, clinically meaningful criteria should be used instead. Our study represents the first to determine whether early treatment of isolated femoral shaft fractures impacts clinical outcomes in a pediatric population. Our results show that treating femur fractures within 18 hours has no statistically significant differences in any outcome. Both early and late treatment groups returned to full weight-bearing in a similar amount of time and achieving complete radiographic fracture healing. Overall complication incidence was similar for both treatment groups, and complications occurred in <10% of the study cohort, representing similar rates to other studies.[14] Of note, those treated within 18 hours had a significantly shorter median length of total hospital stay (2 vs. 3 days) yet had the same length of postoperative stay (2 days). Although it does not seem to impact long-term clinical outcomes, time to treatment may still be an important variable in consideration of cost to both hospitals and patients. A study by Heyworth and colleagues found that the cost of treating closed femoral shaft femur fractures in pediatric patients continued to increase over the study period nationally but believed that this still grossly underestimated the true cost of treatment given potential requirements for physical therapy, missed school days for patients, and missed work days for caregivers.[15]

As with any study, this has inherent limitations. First, is its retrospective nature, resulting in some follow-up data not being available. In addition, this cohort was collected over a 20-year period which may exhibit some temporal effects in treatment trends and surgeon variability. All outcomes were based on surgeon notes during clinical follow-up rather than prospective data collection. Although this reduces potential recall bias, it does represent potentially decreased accuracy in determining when certain clinical outcomes and complications occurred, namely complete radiographic healing, time to complete weight-bearing, and time to loss of reduction. Finally, this study was not designed as an equivalence study, and thus our cohort sizes may be too small to detect all statistically significant differences between groups. However, some differences in outcomes, while not statistically significant, are still of clinical interest, such as the average time to complete radiographic healing which was almost 27 days longer for those with an early fracture treatment.

In our study, 18-hour delay in time to treatment of isolated femoral shaft fractures in pediatric patients was not significantly associated with differences in clinical outcome or long-term complication rates. Additional studies to determine optimal treatment times of femur fractures to minimize health care costs, improve clinical outcomes, and to determine evidence-based metrics for hospital rankings are needed.

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