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Original Contributions

DOES MENTORING BY ORTHOPEDIC SURGEONS IMPROVE FOREARM FRACTURE REDUCTION OUTCOMES BY PEDIATRIC EMERGENCY PHYSICIANS? EVALUATION OF A PROCESS IMPROVEMENT INTERVENTION PROGRAM

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☐ **Abstract—Background: Forearm fractures are among the most frequently encountered orthopedic injuries in children. The maintenance of satisfactory alignment can be problematic and postreduction displacement with resultant malunion can occur. Objectives: The objective of the study was to evaluate pediatric emergency medicine (PEM) physicians' performance on forearm fracture reduction to determine the impact of a Process Improvement Intervention Program (PIIP) on postreduction displacement rates after initial reduction. The PIIP was designed to improve our PEM physicians' skills and knowledge in how to properly apply and mold casts to better maintain the alignment of reduced forearm fractures. Methods: A PIIP was implemented during 2015–2016 when orthopedic surgeons mentored postfellowship-trained PEM physicians. Patient cohorts from pre- and post-PIIP implementation were investigated and compared to evaluate the impact of the PIIP on PEM physicians' initial fracture reduction success rates and postreduction displacement rates. Descriptive and analytical statistics including univariate and multivariate models were tested to understand changes in physicians' performance. Results: Pre- and postcohorts had similar demographic and clinical characteristics and similarly high initial reduction success rates. When distal and midshaft fracture types were combined, there was no significant difference in postreduction displacement rates between the 2 cohorts, but when stratified based on fracture type, the distal radius postcohort showed a statistically significant improvement in postreduction maintenance. Conclusions: A PIIP by pediatric orthopedic surgeons did not change the PEM physicians' initial fracture reduction success rate, but it did result in a statistically significant improvement in maintenance of reduction rates. © 2019 Elsevier Inc. All rights reserved.**

☐ **Keywords—forearm fractures; intervention; mentoring; pediatric emergency physicians; process improvement**

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INTRODUCTION

Background

Forearm fractures are among the most frequently encountered orthopedic injuries in children (1–3). Most forearm fractures in children can be treated with closed reduction and casting, but maintenance of satisfactory alignment can be problematic and postreduction displacement with resultant malunion can occur (4,5). Fortunately, younger children have excellent remodeling potential (6,7). If a skilled closed reduction is carried out with proper application of a well-formed cast, a satisfactory outcome is highly likely (8,9).

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Importance

The Accreditation Council for Graduate Medical Education (ACGME) 2017 Revised Program Requirements for Graduate Medical Education in Pediatric Emergency Medicine (PEM) states: "graduating PEM fellows must attain competency in closed reduction/splinting" (10). This is a skill that is not being uniformly taught among PEM fellowship programs. Most PEM fellows receive their training in large medical centers that are also likely affiliated with orthopedic residencies. In these settings, when a child with a forearm fracture comes to the emergency department (ED), the fracture will more likely be reduced by an orthopedic resident than by a PEM fellow, while the fellow provides the procedural sedation. By the time most PEM fellows complete their training, they have acquired significant expertise in sedating these patients, but it is unlikely that they will have had much actual hands-on experience with fracture reduction and casting. Having PEM physicians expertly reduce pediatric forearm fractures in the ED, particularly in nonacademic health care settings, is critical in reducing delays in patient care, decreasing wait times, and promptly addressing pain, while also increasing parental perceived satisfaction in care (11–13).

There are numerous orthopedic-based studies that establish initial fracture reduction success as an indicator of success for nonoperative management of forearm fractures (4,14,15). Studies have also shown that appropriate cast molding leads to better results (14). There are several studies that have reviewed who performs the initial reduction in regard to successful treatment—i.e., how do results vary if the initial reduction is performed by an orthopedic resident, orthopedic attending, or by the ED attending (16–18). To our knowledge, none have evaluated the effect of additional postresidency or fellowship mentoring of emergency physicians by orthopedic surgeons on treatment success of pediatric forearm fractures.

Objectives

The objectives of this study were to evaluate PEM physicians' forearm fracture reduction success rates, and to subsequently determine: 1) whether an intensive mentoring program improves the PEM physicians' maintenance of reduction success rates during follow-up; and 2) other factors associated with the initial reduction success and maintenance of reduction at follow-up.

METHODS

Study Design and Setting

We conducted an interventional study that focused on pediatric forearm fracture reduction and casting performed by PEM physicians by evaluating initial reduction success and maintenance of reduction at follow-up before and after implementation of a mentoring program by our pediatric orthopedic surgeons.

Our medical complex is a regional, tertiary care pediatric hospital with a level 2 trauma center, staffed by board-certified/eligible PEM physicians. The annual ED census is approximately 45,000 patients with >200 children treated each year for forearm fractures. Our hospital is not affiliated with an orthopedic residency. The current practice in our ED is for almost all forearm fractures to be reduced and casted by the attending PEM physicians. None of the attending PEM physicians in our group has had formal fracture reduction training beyond what they received during their residency and fellowship years. Approximately 25 years ago, 2 pediatric orthopedic surgeons on our hospital staff offered voluntary mentoring in fracture reduction and casting to all members of the PEM physician group at the time. This helped meet the orthopedic needs of the ED and decreased the call burden on the orthopedists. Since then, our PEM physician group has maintained an ongoing internal mentoring program with experienced members of the PEM physician group proctoring each new PEM member in techniques of fracture reduction and casting. However, no formal training program had been developed or implemented within the group until September 2015.

Goals and Hypothesis

Our initial assumption was that our PEM physicians could reduce and cast pediatric forearm fractures with results like those of orthopedic surgeons and other emergency physicians. To verify this, we compared our reduction success rates with the previously published outcomes when performed by both orthopedic surgeons and other emergency physicians.

After evaluation of the precohort phase, we recognized that at baseline, when compared with published outcomes by other emergency physicians, we had a relatively high initial reduction success rate and a similar maintenance of reduction rate (16–18). When compared with outcomes by orthopedic surgeons, however, we identified an opportunity for improvement in the maintenance of reduction rates (14,19). We were not satisfied with our precohort loss of reduction rates at the follow-up visits. We therefore determined to carry out a process improvement intervention program (PIIP) with a primary goal of decreasing the loss of reduction rate, thereby decreasing the need for repeat closed reduction or operative intervention. We hypothesized that a PIIP would result in improved maintenance of reduction rates in the treatment of pediatric forearm fractures.

Interventions

In collaboration with our orthopedic surgery group, we developed and implemented a PIIP. The intervention consisted of 1-on-1 mentoring of all 16 members of the PEM physician group by one of our pediatric orthopedic surgeons. This (individual) orthopedic surgeon demonstrated and reviewed proper techniques of casting to each of the 16 PEM physicians with emphasis on molding to better maintain the postreduction position of the reduced fracture. Mentoring with each individual was deemed to be successfully completed by the orthopedic surgeon when the PEM physician was able to redemonstrate a requisite level of competence and knowledge in proper casting and molding techniques. A teaching video reviewing casting and molding techniques was recorded for the PEM physicians to refer to later, if needed. To evaluate the effectiveness of the PIIP on PEM physicians' performance, including success on patients' initial and follow-up outcomes, we used a pre/post design to compare outcomes from 2 pediatric forearm fracture cohorts treated by the same group of PEM physicians before and after the mentoring intervention.

Study Timeline

The PIIP started on September 1, 2015 and ended on June 30, 2016 (9 months). During this time, every PEM physician in the group received a consistent level of mentoring by the same orthopedic surgeon to assure a standardized level of competence. The composition of the pre- and postcohort PEM physician groups was not identical. Three members of the precohort PEM group left before completion of the PIIP and 3 new members joined the postcohort group during the PIIP. None of the 3 new PEM physician members had undergone any additional formal training in fracture reduction and casting before joining the group, and all 3 new members participated in the PIIP mentoring.

Two time periods surrounding the PIIP were used as the temporal framework for patient data extraction. Time period 1 (T1) was from August 1, 2014 to September 31, 2015 (13 months). Time period 2 (T2) was from July 1, 2016 to June 30, 2017 (12 months). Patient data from T1 and T2 formed the pre- and postintervention patient cohorts, respectively (T1 = precohort; T2 = postcohort).

Physician Participants and Patient Eligibility

All PEM physicians on staff at our institution participated in the training program.

All potentially eligible patients were identified using Current Procedural Terminology (CPT) billing codes 25605 (closed treatment of a distal radial and ulna fracture with manipulation), or 25565 (closed treatment of radial and ulnar shaft fracture with manipulation). Patients for the precohort were retrospectively identified from the electronic medical records of all children <18 years of age at diagnosis who had been treated in our ED during T1 for forearm fractures and had initial treatment by a PEM physician. The same patient selection criteria were applied prospectively during T2.

Patients were excluded if they had any of the following: Monteggia fractures, pathologic fractures, complex intra-articular fractures, multiple traumas, or if the initial reduction attempt in the ED had been carried out by an orthopedist. Eligible patients who were followed until completion of healing, but who then sustained a repeat fracture through the same or a different site and were treated again in the ED, were considered as separate encounters for data analysis purposes.

Data Collection and Measurements

For all patients in both cohorts, information collected was paralleled and aligned with the time of the initial ED treatment, the first post-treatment orthopedic follow-up visit, and subsequent post-treatment visits.

Data extracted from the electronic medical record included patient identifiers (name and medical record number), demographic characteristics (sex, age at time of fracture, and date of injury), relevant clinical characteristics at diagnosis (distal vs. midshaft fracture location), and whether the initial reduction in the ED was successful. The initial reduction was deemed successful if the fracture was reduced to a position of clinically accepted parameters based on patient and fracture characteristics. Fracture angulation, displacement, and shortening were measured for each fracture at the time of initial presentation.

Additional data were collected on all patients who were seen in follow-up by one of the orthopedic surgeons within our hospital system. Data collected at the first and subsequent orthopedic visits included residual postreduction degree of angulation, percent displacement, extent of shortening, and whether unacceptable displacement had occurred since the time of initial reduction. Loss of reduction was a clinical determination made by the orthopedic surgeon at patient follow-up appointments and was dichotomized in the measurement.

Each patient in the study progressed to 1 of 3 possible endpoints: 1) an operative procedure or repeat closed reduction was performed by the orthopedic surgeon to correct fractures with unsuccessful initial reductions or which had progressed to an unacceptable degree of loss of reduction; 2) alignment and callus formation noted on radiographs were deemed to have healed satisfactorily by the orthopedist and the cast was removed; or 3) the patient was lost to follow-up.

Outcomes and Analysis

Two primary outcomes were measured and analyzed in this study: 1) initial fracture reduction success rate and 2) maintenance of reduction rate (reversely, loss of reduction rate) at the first and subsequent follow-up visits.

Descriptive statistics of patients' demographic and raw fracture characteristics were conducted comparing pre- and postcohorts for all eligible fracture cases using chi-squared tests or analysis of variance. In addition, fracture complexity was calculated by adding the 3 dichotomized variables (angulation, displacement, and shortening) to form a composite score ranging from 0–3 (with a score of 0 representing a fracture with no angulation, displacement, or shortening and a score of 3 representing a fracture with angulation, displacement, and shortening). The composite score was compared between groups using Wilcoxon rank-sum tests. Comparative analyses were performed on patients who had initial reduction success and completed the first follow-up.

We then compared the initial reduction success and maintenance of reduction rates of patients between pre- and postcohorts. The clinical features of the patient's fracture (midshaft vs. distal) were introduced to stratify the sample in the univariate comparison. Reduction success at the first follow-up was also compared between the 2 cohorts using chi-squared tests and stratifying by fracture type.

Initial reduction success and maintenance of reduction at follow-up were both formed into dichotomized parameters as independent outcome variables to indicate first and secondary success (initial success = 1, initial failure = 0; reduction maintained = 1, reduction lost = 0) for modeling purposes. Multivariate logistic regression models were constructed to test for pre- and postcohort changes in these 2 independent primary outcomes, adjusting for potential confounding factors. We further adopted bootstrapping methods in all models to assess the sensitivity of the original regression estimates for odds ratios (ORs), bias, and the bias-corrected 95% confidence intervals (95% CI). All statistical analyses were performed using Stata 14 software (Stata Corp., College Station, Texas).

RESULTS

Characteristics of the Fracture Cases

In total, 399 eligible forearm fracture cases were involved in the study (precohort n = 201, postcohort n = 198). Figure 1 shows the patient study population flow charts by cohort.

Patients' demographic and clinical characteristics at baseline were not statistically different between the 2

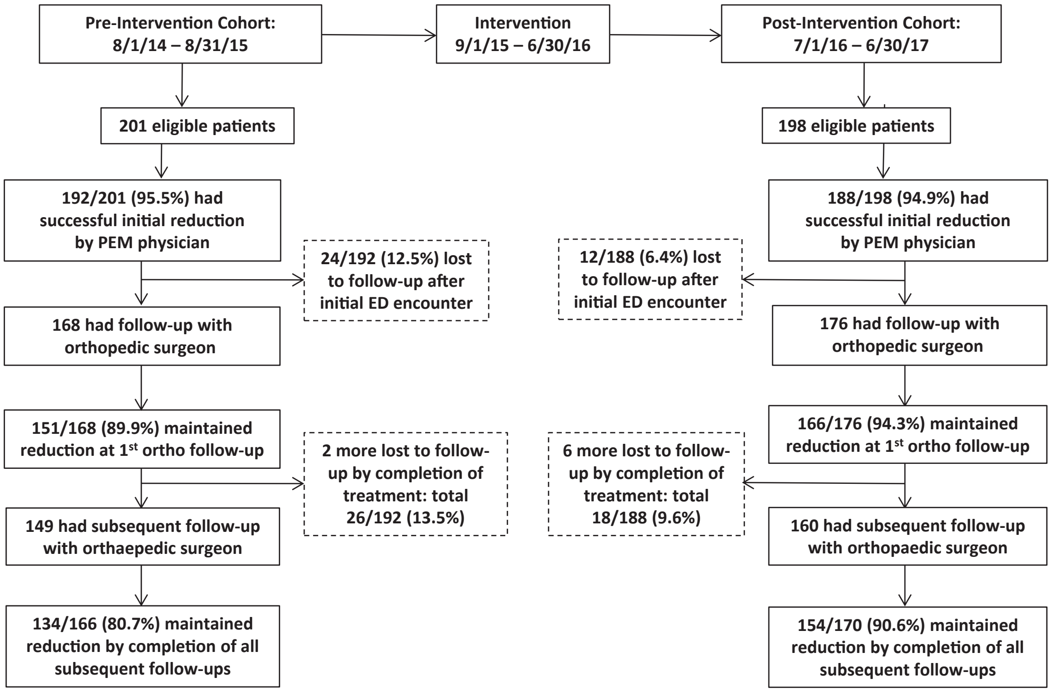

Figure 1. Comparative Pre- / post- study population flow charts. ED = emergency department; PEM = pediatric emergency medicine.

cohorts, except that the precohort had a lower proportion of displaced fractures than the postcohort (p = 0.022). This difference was seen among all fractures whether they were reduced successfully or were not reduced successfully.

For all fractures that were successfully reduced and seen at first follow-up (n = 344) there was no statistically significant difference regarding age, sex, fracture category, nonsummer season (October–March) injury, or fracture complexity except for percentage of being shortened (p = 0.036). For patients (n = 19) whose fractures were not successfully reduced by the PEM physicians, the only significantly different characteristic between cohorts was degree of displacement (p = 0.037; Table 1).

Twelve and a half percent of the precohort patients were lost before the first follow-up, compared with only 6.4% in the postcohort (p = 0.043; Table 2). Patient characteristics of those lost to follow-up were analyzed and were not significantly different than those who were not lost to follow-up regarding age, sex, and fracture location or complexity.

Univariate Analyses for Success Rates

Initial reduction. More than 95% (192/201; 95.5%) of patients in the precohort had successful initial reductions compared with 94.9% (188/198) in the postcohort (p = 0.788; combined initial success rate 95.2%). There was a greater percentage of fractures in the distal CPT category in both cohorts (70% in the precohort and 76% in the postcohort) compared with the midshaft CPT category. The initial success rates in both cohorts were also similar when stratified by fracture category (distal 95.1%, midshaft 95.3%, χ^2 = 0.026, p = 0.960; Table 2).

Boys had a higher initial success rate than girls (97.1% vs. 94.3%,), but this difference was not significant (χ^2 = 0.072, p = 0.219). With older age, the initial reduction success dropped (χ^2 = 24.724, p = 0.000). As fracture complexity increased, the success rate decreased from 98.6% for a composite score of 1 to 95.4% for a composite score of 2 and to 90.5% for a composite score of 3 (χ^2 = 8.737, p = 0.013). Cases from the nonsummer season had poorer initial success compared with summer cases, but the difference was not significant (92.6% vs. 96.4%, χ^2 = 2.742, p = 0.098).

Postreduction. In total, 344 patients had an initial successful reduction and completed their first orthopedic follow-up visit. Three hundred seventeen of these patients (92.2%) maintained the reduction at their first follow-up. When the 2 cohorts were combined, we found that age group, fracture composite score, nonsummer season, sex, and fracture CPT category were not significant in discriminating the loss of reduction rate in the univariate analyses. Further comparison of initial success of reduction between those lost to the first follow-up and those followed to completion of treatment also showed no statistical difference.

When both fracture clinical categories were combined, univariate analysis showed that 10.1% of patients in the precohort incurred an unacceptable loss of reduction by the time of the first follow-up visit (89.9% maintained) compared with 5.7% in the postcohort (94.3% maintained, p = 0.126). However, when stratified by fracture category, maintenance of reduction rates in distal fractures showed statistically significant improvement in the postcohort (95.6%) versus precohort (88.0%; p < 0.001; Table 2).

Analysis at subsequent follow-up visits again showed that the postcohort had a lower loss of reduction rate when both fracture categories were combined. For patients who were initially reduced successfully and completed subsequent follow-up (n = 309, precohort n = 149, postcohort n = 160), an additional 10.1% of patients in the precohort went on to incur an unacceptable loss of reduction (89.9% maintained) compared with only an additional 3.7% (96.3% maintained) in the postcohort (p = 0.027). Of the 166 patients in the precohort who were not lost to follow-up and were subsequently followed to completion of orthopedic care, 134 maintained reduction (80.7%). In comparison, of the 170 patients who were not lost to follow-up and were seen through all subsequent orthopedic visits in the postcohort, 154 maintained reduction (90.6%; χ^2 = 6.21, p = 0.0127).

Multivariate Analyses

Initial reduction success model. In the regular logistic model, likelihood of initial reduction success was associated with having a lower fracture composite score (1 [OR = 18.25 {95% CI 4.144–18.365}] or 2 [OR = 4.47 {95% CI 1.776–11.239}] compared with 3) and with being male (OR = 2.41 [95% CI 1.074–5.406]). Other factors, including fracture CPT category, age, cohort, and season, were not statistically significant in predicting initial reduction success. When bootstrapping was adopted in the logistic regression, a smaller composite score was similarly associated with higher likelihood of successful initial reduction; however, other factors, including cohort and sex, were all insignificant (Table 3).

Postreduction success model. Maintenance of reduction results were analyzed by cohort, controlling for sex, age, CPT category, fracture composite score, and season of injury. Postcohort cases were more likely to maintain

Table 1. Pre- and Postcohort Comparison: Patients' Demographic and Clinical Characteristics at Diagnosis

Patient Characteristics at Diagnosis	Precohort	Postcohort	*p* Value	χ^2	*F/z*
All patients at baseline, n (N = 399)	201	198			
Male sex, n (%)	138 (68.7)	125 (63.1)	0.244	1.355	
Mean age at diagnosis, months (SD)	102.1 (43.0)	101.1 (45.3)	0.459		0.050
≤12, n (%)	1 (0.5)	0 (0.0)			
>12 to ≤36 months, n (%)	9 (4.5)	9 (4.6)			
>36 months to ≤7 years, n (%)	70 (34.8)	72 (36.4)	0.830	1.483	
>7 years to ≤14 years, n (%)	103 (51.2)	96 (48.5)			
>14 years, n (%)	18 (9.0)	21 (10.6)			
Fracture category,*n (% midshaft fracture)	60 (29.9)	47 (23.7)	0.168	1.900	
Angulated, n (%)	201 (100)	198 (100)	—	—	
Displaced,†n (%)	119 (59.2)	139 (70.2)	0.022	5.280	
Shortened, n (%)	60 (29.9)	45 (22.7)	0.106	2.610	
Composite score of complexity (rank sum)	39,504	40,296	0.520		−0.644
Nonsummer season of injury, n (%)	67 (33.3)	54 (27.3)	0.188	1.734	
Patients who completed first follow-up despite initial reduction results, n (n = 358)	175	183			
Male sex, n (%)	120 (68.6)	117 (63.9)	0.354	0.860	
Mean age at diagnosis, months (SD)	100.2 (41.2)	99.7 (44.9)	0.914		0.109
≤12, n (%)	0 (0)	0 (0)		0.710	
>12 to ≤36 months, n (%)	9 (5.1)	9 (4.9)			
>36 months to ≤7 years, n (%)	62 (35.4)	66 (36.1)	0.871		
>7 years to ≤14 years, n (%)	90 (51.4)	89 (48.6)			
>14 years, n (%)	14 (8.0)	19 (10.4)			
Fracture category,*n (% midshaft fracture)	53 (30.3)	42 (23.0)	0.116	2.469	
Angulated, n (%)	175 (100)	183 (100)	—	—	
Displaced,†n (%)	105 (60.0)	129 (70.5)	0.037	4.350	
Shortened, n (%)	55 (31.4)	42 (23.0)	0.071	3.255	
Composite score of complexity (rank sum)	31,075	33,186	0.714		−0.367
Nonsummer season of injury, n (%)	58 (33.1)	50 (27.3)	0.230	1.439	
Patients whose fracture successfully reduced and who completed first follow-up, n (n = 344)	168	176			
Male sex, n (%)	114 (67.9)	112 (63.6)	0.388	0.745	
Mean age at diagnosis, months (SD)	97.9 (39.8)	97.9 (44.4)	0.999		0.000
≤12, n (%)	0	0		1.809	
>12 to ≤36 months, n (%)	9 (5.4)	9 (5.1)			
>36 months to ≤7 years, n (%)	61 (36.3)	65 (36.9)	0.613		
>7 years to ≤14 years, n (%)	88 (52.4)	85 (48.3)			
>14 years, n (%)	10 (6.0)	17 (9.7)			
Fracture category,*n (% midshaft fracture)	51 (30.4)	40 (22.7)	0.109	2.572	
Angulated, n (%)	168 (100)	176 (100)	—	—	
Displaced, n (%)	100 (59.5)	122 (69.3)	0.058	3.603	
Shortened,†n (%)	52 (31.0)	37 (21.0)	0.036	4.419	
Composite score of complexity (rank sum)	28,980	30,360	0.884		−0.146
Nonsummer season of injury, n (%)	54 (32.1)	48 (27.3)	0.323	0.977	

SD = standard deviation.
* *Current Procedural Terminology* codes 25565.
† Statistically significant.

reduction (OR = 2.61 [95% CI 1.203–5.665] in the regular model, $p = 0.015$; OR = 2.61 [95% CI 1.201–5.672] in the bootstrapping model, $p = 0.018$). Younger age at injury (OR = 1.18 [95% CI 1.073–1.288] in the regular model and OR = 1.18 [95% CI 1.073–1.288] in the bootstrapping model) and lower composite score ($OR_1 = 4.07$ [95% CI 1.665–4.580], $OR_2 = 2.32$ [95% CI 1.131–4.799] in the regular model and $OR_1 = 4.08$ and $OR_2 = 2.33$, respectively, in the bootstrapping model, both using 3 as a reference score) were significantly associated with a higher likelihood of maintaining the initial reduction. Season of injury, sex, and fracture type were not significantly associated with maintenance of reduction (Table 4).

DISCUSSION

When children with closed forearm fractures present to EDs, delay in definitive care can occur if the ED provider is not skilled in fracture reduction and casting, if the on-call orthopedic surgeon is not able to come to the ED on a timely basis, or if there is no orthopedic surgeon available. Delay in care may result in prolongation of pain, added patient and caregiver worry, unnecessary

Table 2. Pre- and Postcohort Comparison: Initial Success, Reduction Maintenance, and First Follow-up, Stratified by Fracture Clinical Category

Patient Outcomes	Precohort (n = 201)	Postcohort (n = 198)	*p* Value	χ^2
Success number and rate, n (%)	192 (95.5)	188 (95.0)	0.788	0.072
Initial success by cohort	58 (96.7)	44 (93.6)	0.458	0.550
Initial success within midshaft fracture category* by cohort	134 (95.1)	144 (95.4)	0.876	0.025
Initial success within distal fracture category† by cohort				
Reduction maintained until first follow-up,‡n (%)	151 (89.9)	166 (94.3)	0.126	2.340
Reduction maintained rate within midshaft fracture category* by cohort	48 (94.1)	36 (90.0)	0.732	0.624
Reduction maintained rate within distal fracture category† by cohort	103 (88.0)	129 (95.6)	0.000	15.871
First follow-up for cases with initial success§				
First follow-up completed by cohort (n, %)	168 (87.5)	176 (93.6)	0.043	4.078
First follow-up completed within midshaft fracture category* by cohort	51 (87.9)	40 (90.9)	0.631	0.231
First follow-up completed within distal fracture category† by cohort	117 (87.3)	136 (94.4)	0.040	4.237

* *Current Procedural Terminology* codes 25565.
† *Current Procedural Terminology* code 25605.
‡ Denominator was the number of cases that had initial success of reduction at the emergency department and completed the first follow-up (n = 344).
§ Denominator was the number of cases that had initial success of reduction at the emergency department (n = 380).

crowding of the ED, and added costs. Postponement of definitive care with admission to the hospital or transfer to another facility may in turn necessitate utilization of an operating room, which further adds to overall costs of care (11,12). None of these situations are ideal for the patient.

Outcomes of pediatric forearm fracture reductions carried out by emergency physicians have only recently been published. Two studies compared forearm fracture reduction outcomes by PEM physicians with those of upper level orthopedic residents. Pershad et al. showed that 9% of forearm fractures reduced by PEM physicians and 3% of fractures reduced by orthopedic residents required remanipulation (16). In a study by Khan et al., remanipulation was required in 8.3% of patients treated by emergency physicians and 12.5% of patients treated by orthopedic residents (17).

In 2017, Milner et al. compared forearm fracture reduction outcomes achieved by PEM physicians with outcomes achieved by pediatric orthopedic surgeons (18). Like our medical complex, the 2 hospitals in their study also did not have associated orthopedic residencies. All their PEM physicians had received training in forearm fracture reduction and splinting techniques through a fracture reduction program started in their hospitals in 2007 by 2 of their board-certified pediatric orthopedic surgeons. In their study, PEM physicians had a lower proportion of successful initial reductions than orthopedic surgeons (81.6% vs. 89.6%) and fractures reduced by their PEM physicians were significantly more likely to

Table 3. Multivariate Logistic Model for Initial Reduction Success (n = 399)

Patient Characteristics	OR	SE	*z*	*p* Value	95% CI
Regular model					
Sex (reference: female)	2.41	.993	2.13	0.033	1.074–5.406
Age (year)	1.05	.050	1.17	0.242	.963–1.159
Cohort (reference: precohort)	2.09	.877	1.76	0.078	.920–4.759
Composite score (reference: 3)					
1	18.25	13.803	3.84	0.000	4.144–18.365
2	4.47	2.103	3.18	0.001	1.776–11.239
Season (reference: summer)	1.18	.512	0.37	0.710	.501–2.758
CPT category (reference: distal fracture)	1.67	.871	0.99	0.324	.602–4.640
Bootstrapping model					
Sex (reference: female)	2.41	2.919	0.73	0.468	0.224–25.876
Age (year)	1.06	0.102	0.57	0.570	0.873–1.278
Cohort (reference: precohort)	2.09	0.867	1.78	0.075	0.929–4.713
Composite score (reference: 3)					
1	18.25	10.106	5.24	0.000	6.164–17.028
2	4.47	1.986	3.37	0.001	1.870–10.676
Season (reference: summer)	1.17	0.495	0.38	0.700	0.516–2.681
CPT category (reference: distal fracture)	1.67	1.133	0.76	0.449	0.443–6.313

CI = confidence interval; CPT = *Current Procedural Terminology*; OR = odds ratio; SE = standard error.

Table 4. Multivariate Logistic Model for Initial Reduction Maintained Through First Follow-up (n = 344)*

Patient Characteristics	OR	SE	*z*	*p* Value	95% CI
Regular model					
Sex (reference: female)	1.30	0.492	0.68	0.497	0.614–2.727
Age (year)	1.18	0.055	3.47	0.001†	1.073–1.288
Cohort (reference: precohort)	2.61	1.032	2.43	0.015†	1.203–5.665
Composite score (reference: 3)					
1	4.07	1.869	3.05	0.003†	1.665–4.580
2	2.32	0.860	2.30	0.028†	1.131–4.799
Season (reference: summer)	0.73	0.280	−0.83	0.405	0.340–1546
CPT category (reference: distal fracture)	1.74	0.798	1.21	0.226	0.709–4.277
Bootstrapping model					
Sex (reference: female)	1.30	0.554	0.60	0.545	0.560–2.993
Age (year)	1.18	0.055	3.46	0.001†	1.073–1.288
Cohort (reference: precohort)	2.61	1.031	2.40	0.018†	1.201–5.672
Composite score (reference: 3)					
1	4.08	1.870	3.07	0.002†	1.665–4.580
2	2.33	0.860	2.29	0.022†	1.130–4.804
Season (reference: summer)	0.73	0.259	−0.90	0.368	0.360–1.459
CPT category (reference: distal fracture)	1.74	0.925	1.04	0.296	0.614–4.933

CI = confidence interval; CPT = *Current Procedural Terminology*; OR = odds ratio; SE = standard error.
* Model only included cases with initial reduction success in the emergency department.
† Statistically significant.

require repeat manipulation (17.2% vs. 5.2%) than those reduced by their orthopedic surgeons (18).

Results of the first phase of our study showed that our initial reduction success rate (95.2%) compared well with other published reports. Initial reduction, however, is only 1 step in the process of treating fractures. Maintenance of the reduction can prove challenging, as is evidenced by the wide range of displacement rates (7–64%) cited by previous authors, though most have settled on a rate closer to 30% (4,5,15,19–21). Individual factors contributing to an increased risk of displacement remain a matter of discussion, with patient age, initial complete displacement, distance from the physis, isolated radial fracture, associated ulnar fracture, fracture comminution, obliquity of the fracture, reduction quality, poor casting technique, cast molding, and the surgeon's experience all suggested as risk factors (4,5,22–24).

In a prospective randomized controlled trial of children with completely displaced distal radius fractures whose fractures were reduced by orthopedic surgeons, McLauchlan et al. noted that 21.2% in the closed reduction group had to undergo a second procedure because of an unacceptable position (25). Voto et al. reported that 7% of their cases required further intervention and identified poor cast molding, loose casts, and malreduction as the most common reasons for loss of reduction (14).

Fortunately, not all subsequent displacement progresses to unacceptable alignment or requires repeat reduction or operative repair. Depending on the age of the patient, the location of the fracture, and the extent of displacement, many children will undergo remodeling and will ultimately progress to satisfactory outcomes. In a 2015 prospective study by Assadollahi et al. of 135 distal radius fractures that underwent closed reduction and cast immobilization by orthopedic surgeons, displacement occurred in 28.8% of fractures; however, only 7.4% of fractures required a second procedure (8). Samora et al. reported on the potential efficacy of cast wedging. They noted that cast wedging can offer a simple, nonoperative, noninvasive alternative method for treatment of excessive angulation in some long-bone fractures treated with casting and may serve as an alternative to surgical fixation when patients present with loss of reduction (9).

Although numerous factors have been cited as contributing to the risk for displacement, we focused on trying to improve 2 factors that we could control through training: 1) making a well-formed cast and 2) emphasizing the importance of molding to prevent recurrence of fracture displacement. It is our impression that we achieved our goal. Our statistical models suggest that this PIIP was associated with decreased loss of fracture reduction not only at the initial follow-up but also through completion of all subsequent visits with the orthopedic surgeon.

Significance

We contend that PEM physicians should be able to definitively reduce and cast most forearm fractures in children. We were able to demonstrate that a focused mentoring program of post–fellowship-trained PEM physicians by orthopedic surgeons improved fracture reduction maintenance. Adoption of this model may lead to more efficient delivery of highly skilled treatment for pediatric fractures by emergency physicians, thus better addressing the patient's pain, reducing delays in care, decreasing patient and caregiver worry, lessening ED crowding, and reducing cost.

Limitations

The study was pre- and postinterventional comparison in nature, but no patient or physician randomization was involved. Only a single center was involved and some of the data were retrospective. The composition of the pre- and postcohort PEM physician groups was not identical. As mentioned in the Methods, 3 members of the precohort PEM group left before the PIIP was completed and 3 new members joined the postcohort group. However, none of the new PEM physicians had undergone any additional formal training in fracture reduction and casting before joining the group. In addition, all 3 new members participated in the PIIP mentoring. Thus, physician bias was minimized.

Management decisions about the adequacy of alignment, the need for reintervention, and the need for follow-up visits were made at the discretion of each treating orthopedic surgeon. A single pediatric orthopedic surgeon evaluated all the pre- and postreduction radiographs in both cohorts. Although this evaluator was extensively involved in the design and analysis of the study, the fracture measurements (displacement, angulation, and shortening) were performed in a blinded fashion, so no management decision bias is expected.

CONCLUSIONS

The nature of the practice of emergency medicine is such that a PEM physician's breadth of knowledge and procedural skillset must overlap with many specialties. PEM physicians should be able to definitively reduce and cast most forearm fractures in children. Not all current graduates of PEM fellowships, however, are given the opportunity to acquire competency in this skillset during their training. Until all PEM training programs can ensure that their fellows have more hands-on training in fracture reduction and casting, post-training collaboration between dedicated orthopedic surgeons and PEM physicians can serve as a mechanism for PEM physicians to master this skill. Our study demonstrates that mentoring of postgraduate PEM physicians by their orthopedic surgery physician colleagues, with focus on proper cast application techniques, can result in improvement in loss of reduction rates and subsequent long-term clinical outcomes.

Acknowledgments—TLH conceived the study, obtained institutional review board approval, and supervised data collection. TLH and RW designed the process improvement intervention program, mentored the study participants, and supervised the conduct of the participants. JM and BP provided statistical advice on study design. JM provided statistical analysis of the data. TLH drafted the manuscript and RW, JM, and BP contributed substantially to its revision. TLH, RW, and JM created the figures and tables. TLH takes responsibility for the entire article. We thank Paul Amoroso, MD, MPH, of the MultiCare Institute for Research and Innovation for his many helpful contributions to the preparation of this article.

REFERENCES

1. Galano GJ, Vitale MA, Kessler MW, et al. The most frequent traumatic orthopaedic injuries from a national pediatric inpatient population. J Pediatr Orthop 2005;25:39–44.
2. Khosla S, Melton LJ 3rd, Dekutoski MB, et al. Incidence of childhood distal forearm fractures over 30 years: a population-based study. JAMA 2003;290:1479–85.
3. Hedström EM, Svensson O, Bergström U, Michno P. Epidemiology of fractures in children and adolescents. Acta Orthop 2010;81:148–53.
4. Proctor MT, Moore DJ, Paterson JMH. Redisplacement after manipulation of distal radial fractures in children. J Bone Joint Surg Br 1993;75:453–4.
5. Zamzam MM, Khoshhal KI. Displaced fracture of the distal radius in children. Factors responsible for redisplacement after closed reduction. J Bone Joint Surg Br 2005;87:841–3.
6. Johari AN, Sinha N. Remodeling of forearm fractures in children. J Pediatr Orthop B 1999;8:84–7.
7. Do TT, Strub WM, Foad SL, et al. Reduction versus remodeling in pediatric distal forearm fractures: a preliminary cost analysis. J Pediatr Orthop B 2003;12:109–15.
8. Assadollahi S, Ooi K, Hau R. Distal radial fractures in children: risk factors for redisplacement following closed reduction. J Pediatr Orthop 2015;35:224–8.
9. Samora JB, Klingele KE, Beebe AC, et al. Is there still a place for cast wedging in pediatric forearm fractures? J Pediatr Orthop 2014;34:246–52.
10. Residency Review Committee. ACGME program requirements for graduate medical education in pediatric emergency medicine. ACGME approved focused revision: effective: July 1, 2013. Available at: https://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/324_pediatric_emergency_medicine_2017-07-01.pdf. Accessed December 8, 2018.
11. Gulati A, Dixit A, Taylor GJ. Pediatric fractures: temporal trends and cost implications of treatment under general anesthesia. Eur J Trauma Emerg Surg 2012;38:59–64.
12. Betham C, Harvey M, Cave G. Manipulation of simple paediatric forearm fractures: a time-based comparison of emergency department sedation with theatre-based anaesthesia. N Z Med J 2011;124:46–53.
13. Institute of Medicine. Report Brief. The future of emergency care in the United States health system. Washington, DC: National Academy of Sciences; 2006.
14. Voto SJ, Weiner DS, Leighley B. Redisplacement after closed reduction of forearm fractures in children. J Pediatr Orthop 1990;10:79–84.
15. Miller BS, Taylor B, Widmann RF, et al. Cast immobilization versus percutaneous pin fixation of displaced distal radius fractures in children: a prospective, randomized study. J Pediatr Orthop 2005;25:490–4.
16. Pershad J, Williams S, Wan J, et al. Pediatric distal radial fractures treated by emergency physicians. J Emerg Med 2009;37:341–4.
17. Khan S, Sawyer J, Pershad J. Closed reduction of distal forearm fractures by pediatric emergency physicians. Acad Emerg Med 2010;17:1169–74.

18. Milner D, Krause E, Hamre K, et al. Outcome of pediatric forearm fracture reductions performed by pediatric emergency medicine providers compared with reductions performed by orthopedic surgeons: a retrospective cohort study. Pediatr Emerg Care 2018;34:451–6.
19. Devalia KL, Asaad SS, Kakkar R. Risk of redisplacement after first successful reduction in paediatric distal radius fractures: sensitivity assessment of casting indices. J Pediatr Orthop B 2011;20:376–81.
20. Kay S, Smith C, Oppenheim WL. Both-bone midshaft forearm fractures in children. J Pediatr Orthop 1986;6:306–10.
21. Hove LM, Brudvik C. Displaced paediatric fractures of the distal radius. Arch Orthop Trauma Surg 2008;128:55–60.
22. Alemdaroglu KB, Iltar S, Cimen O, et al. Risk factors in redisplacement of distal radial fractures in children. J Bone Joint Surg Am 2008;90:1224–30.
23. McQuinn AG, Jaarsma RL. Risk factors for redisplacement of pediatric distal forearm and distal radius fractures. J Pediatr Orthop 2012;32:687–92.
24. Chess DG, Hyndman JC, Leahey JL, et al. Short arm plaster cast for distal pediatric forearm fractures. J Pediatr Orthop 1994;14:211–3.
25. McLauchlan GJ, Cowan B, Annan IH, et al. Management of completely displaced metaphyseal fractures of the distal radius in children. A prospective, randomized controlled trial. J Bone Joint Surg Br 2002;84:413–7.

ARTICLE SUMMARY

1. Why is this topic important?

Forearm fractures are among the most frequently encountered orthopedic injuries in children. Having pediatric emergency medicine (PEM) physicians expertly reduce and cast pediatric forearm fractures in the emergency department (ED), particularly in nonacademic health care settings, reduces delays in patient care, decreases ED wait times, more promptly addresses the patient's pain, increases parental perceived satisfaction in care, and decreases costs.

2. What does this study attempt to show?

Although the 2017 Accreditation Council for Graduate Medical Education Revised Program Requirements for Graduate Medical Education in Pediatric Emergency Medicine state that "graduating PEM fellows must attain competency in closed reduction/splinting," this is a skill that is not being uniformly taught among all PEM fellowship programs. Mentoring of postgraduate PEM physicians by their orthopedic surgeon colleagues, with a focus on proper cast application techniques, is a means through which postgraduate physicians can acquire this expert skill even if they did not have the opportunity to learn it during their training.

3. What are the key findings?

At baseline, PEM physicians were able to reduce forearm fractures with a success rate comparable to that of orthopedic surgeons. However, their maintenance of reduction rate was not as good as that of orthopedists. This study showed that a process improvement mentoring program of PEM physicians by orthopedic surgeons resulted in significantly improved maintenance of reduction rates, with maintenance rates approaching those of orthopedic surgeons.

4. How is patient care impacted?

Adoption of this model may lead to more efficient delivery of expert treatment of pediatric fractures by emergency physicians, thereby more efficiently addressing patients' pain, reducing delays in care, decreasing patient and caregiver worry, lessening ED crowding, and reducing costs.