Socioeconomic Deprivation and Its Adverse Association with Adolescent Fracture Care Compliance

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Background: Socioeconomic deprivation increases fracture incidence in adolescents, but its impact on fracture care is unknown. The area deprivation index (ADI), which incorporates 17 factors from the U.S. Census, measures socioeconomic deprivation in neighborhoods. This investigation aimed to determine the impact of socioeconomic deprivation and other socioeconomic factors on fracture care compliance in adolescents.

Methods: This study included patients who were 11 to 18 years of age and received fracture care at a single urban children's hospital system between 2015 and 2017. Demographic information (sex, race, caregiver status, insurance type) and clinical information (mechanism of injury, type of treatment) were obtained. The ADI, which has a mean score of 100 points and a standard deviation of 20 points, was used to quantify socioeconomic deprivation for each patient's neighborhood. The outcome variables related to compliance included the quantity of no-show visits at the orthopaedic clinic and delays in follow-up care of >1 week. Risk factors for suboptimal compliance were evaluated by bivariate analysis and multivariate logistic regression.

Results: The cohort included 457 adolescents; 75.9% of the patients were male, and the median age was 16.1 years. The median ADI was 101.5 points (interquartile range, 86.3 to 114.9 points). Bivariate analyses demonstrated that higher ADI, black race, single-parent caregiver status, Medicaid insurance, non-sports mechanisms of injury, and surgical management are associated with suboptimal fracture care compliance. Adolescents from the most socially deprived regions were significantly more likely to have delays in care (33.8% compared with 20.1%; p = 0.037) and miss scheduled orthopaedic visits (29.9% compared with 7.1%; p < 0.001) compared with adolescents from the least deprived regions. ADI, Medicaid insurance, and initial presentation to the emergency department were independent predictors of suboptimal care compliance, when controlling for other variables.

Conclusions: Socioeconomic deprivation is associated with an increased risk of suboptimal fracture care compliance in adolescents. Clinicians can utilize caregiver and insurance status to better understand the likelihood of fracture care compliance. These findings highlight the importance of understanding differences in each family's ability to adhere to the recommended follow-up and of implementing measures to enhance compliance.

Although public health statistics highlight differences in health care based on sex, age, race, and ethnicity, the role of socioeconomic deprivation has not been well characterized[1,2]. Accurately defining socioeconomic deprivation and its role in patient care can help physicians to develop a more suitable treatment plan for their patients, with the goal of improving health outcomes. One method to quantify socioeconomic deprivation is the area deprivation index (ADI), a geographic-area measure of the socioeconomic deprivation experienced by a neighborhood that incorporates 17 social and economic factors from the U.S. Census, including median family income and frequency of single-parent households[3]. The index was created to have a mean score of 100 points with standard deviation of 20 points, with higher scores indicating more deprived geographic areas. The ADI includes measures across multiple realms of socioeconomic status (housing,

employment, education, and poverty), thus providing a more robust assessment of social deprivation than any 1 metric in isolation[4].

Socioeconomic deprivation has been associated with a wide spectrum of poor health in adults and children[5-15]. Within orthopaedic surgery, numerous studies have analyzed the relationship between socioeconomic deprivation and fracture incidence in adults, noting that individuals from more deprived regions are at a higher risk for fracture[16-20]. There is a similar relationship between social deprivation and fracture risk in adolescents, including the humerus, the distal part of the radius, or hand fractures[21-23].

Adolescents are often overlooked and are grouped together with younger children despite differences in skeletal maturity and fracture epidemiology[22,24]. In addition, adolescents are more likely to be lost to follow-up after emergency department (ED) care for orthopaedic injuries[25]. Impending skeletal maturity and the diminished remodeling capacity of adolescents compared with younger children accentuate the importance of appropriate fracture follow-up care, as this age group is particularly susceptible to complications, such as loss of reduction and malunion that may result from poor compliance.

This study aimed to determine the impact of socioeconomic deprivation and other socioeconomic factors on fracture care compliance in adolescents. That is, we sought to determine which adolescent demographic and clinical factors are associated with delays in care and no-show visits during follow-up fracture care. Understanding this relationship is essential for developing effective and pragmatic strategies for improving fracture care in a potentially at-risk population.

Materials and Methods
Study Population and Data Sources

This retrospective cohort study included adolescent patients who were 11 to 18 years of age, had sustained an appendicular or axial fracture, and received subsequent care at a single children's hospital's outpatient orthopaedic clinic between 2015 and 2017. This included a stand-alone children's hospital in the city and several satellite orthopaedic clinics in the surrounding suburbs that serve a racially and economically diverse population. Patients who were diagnosed with a fracture in the ED but were never seen by an orthopaedic provider in the outpatient setting were excluded from the investigation.
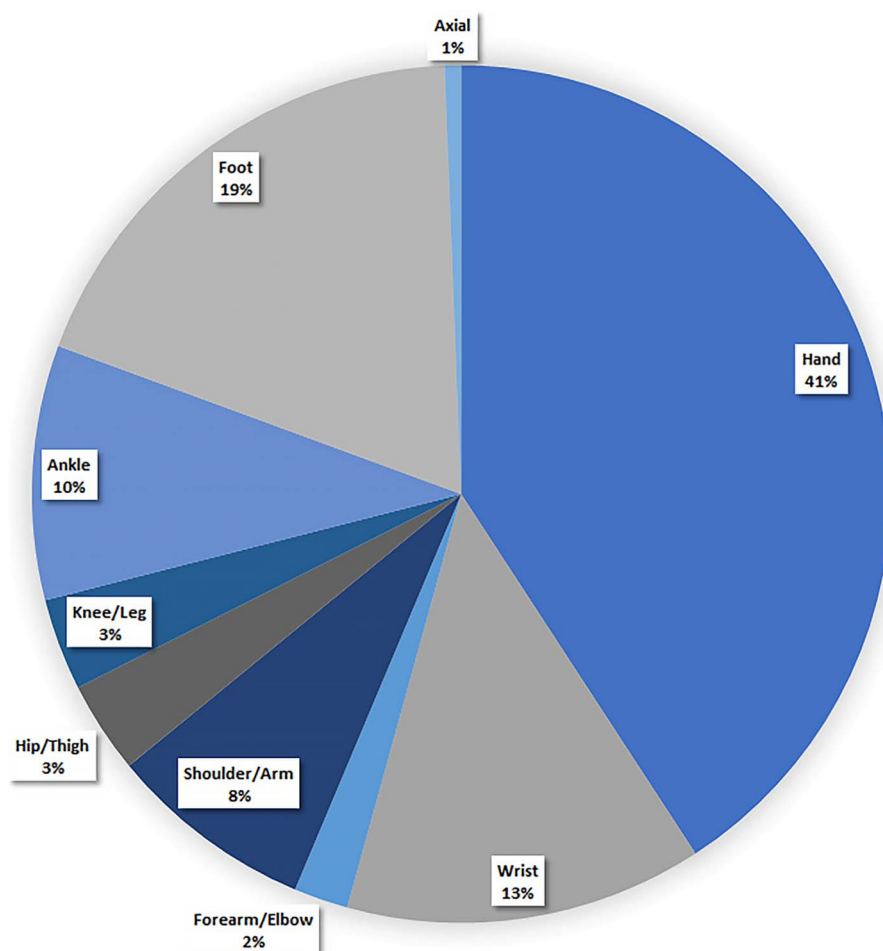

Fig. 1
Distribution of fractures across the study cohort.

TABLE I Impact of Demographic Characteristics on Fracture Care Compliance					
Demographic Characteristics	No. of Patients* (N = 457)	Delay in Care >1 Week† (N = 118 [25.8%])	P Value for Delays in Care	No-Show Visits† (N = 74 [16.2%])	P Value for No-Show Visits
Sex			0.368		0.724
Male	347 (75.9%)	86 (24.8%)		55 (15.8%)	
Female	110 (24.1%)	32 (29.1%)		19 (17.3%)	
Race			0.004‡		<0.001‡
White	226 (49.5%)	47 (20.8%)		19 (8.4%)	
Black	206 (45.1%)	68 (33.0%)		53 (25.7%)	
Other	25 (5.5%)	3 (12.0%)		2 (8.0%)	
Caregiver status§			0.002‡		0.001‡
2 parents	360 (78.8%)	81 (22.5%)		47 (13.1%)	
Single parent	86 (18.8%)	35 (40.7%)		24 (27.9%)	
Guardian	9 (2.0%)	2 (22.2%)		3 (33.3%)	
Insurance status			0.002‡		<0.001‡
Private	264 (57.8%)	53 (20.1%)		22 (8.3%)	
Medicaid	185 (40.5%)	64 (34.6%)		49 (26.5%)	
Self-pay	8 (1.8%)	1 (12.5%)		3 (37.5%)	
ADI#			0.037‡		<0.001‡
Least deprived	169 (37.0%)	34 (20.1%)		12 (7.1%)	
Quartile 2	80 (17.5%)	18 (22.5%)		6 (7.5%)	
Quartile 3	51 (11.2%)	13 (25.5%)		9 (17.6%)	
Most deprived	157 (34.4%)	53 (33.8%)		47 (29.9%)	

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the number of patients, with the row percentage in parentheses. ‡Significant at $p < 0.05$ for bivariate statistical analysis. §Two patients had not specified their caregiver as 1 of the options listed here (2 parents, single parent, or guardian), so they were excluded from this comparison. #The ADI quartiles are determined by national data.

Variables and Outcome Measures

Demographic information was abstracted from the electronic medical record including age, sex, race, type of health insurance, and caregiver status. Race was characterized as white, black, and other. Health insurance was categorized as private, Medicaid, and self-pay. Caregiver status was characterized as whether the child lived with a single parent, lived with 2 parents, or lived with a guardian. The ADI database was used to determine the socioeconomic status of each patient, based on his or her home address in the medical record and the corresponding 9-digit ZIP code[3]. The International Classification of Diseases, Tenth Revision (ICD-10) codes were used to categorize the various fractures based on anatomic location. Clinical data were also abstracted from the electronic medical record and included the date of the injury, the initial presenting facility (ED, outside ED, urgent care or primary care physician's office, orthopaedic clinic), the mechanism of the injury (sports, fall, other), and the treatment method (cast or splint, closed reduction and subsequent splint or cast, or surgery).

Medical records were reviewed to obtain information with regard to fracture care compliance. The specific variables of interest included the number of no-show visits at orthopaedic clinics and any delays in follow-up care of >1 week, including those who were lost to follow-up, after establishing care for the fracture at our orthopaedic clinic. Delays in care were calculated on the basis of the timing of follow-up recommended by the attending surgeon. No-show visits were defined as scheduled appointments with an orthopaedic provider that were not rescheduled prior to the patient missing the scheduled appointment. The collection of outcome variables was limited to the duration of the orthopaedic provider's recommended follow-up for a given patient's fracture. The presence of either outcome was considered to be suboptimal fracture care compliance.

Statistical Analysis

The distribution of continuous variables was determined by the Kolmogorov-Smirnov test for normality. The mean and the standard deviation were used to describe normally distributed continuous variables. Non-normal continuous variables were summarized using the median and the range. The ADI was further stratified on the basis of established quartiles from national data[18,26]. Categorical variables were summarized using the frequency and the percentage. Bivariate statistical analyses were conducted to identify factors associated with suboptimal care compliance and included the chi-square and Fisher exact tests for categorical variables and the Mann-Whitney U test for nonparametric continuous variables.

TABLE II Impact of Clinical Characteristics on Fracture Care Compliance

Clinical Characteristic	No. of Patients* (N = 457)	Delay in Care >1 Week† (N = 118 [25.8%])	P Value for Delay in Care	No-Show Visits† (N = 74 [16.2%])	P Value for No-Show Visit
Mechanism			0.08		0.03‡
Sports	242 (53.0%)	53 (21.9%)		28 (11.6%)	
Fall	116 (25.4%)	32 (27.6%)		21 (18.1%)	
Other	99 (21.7%)	33 (33.3%)		25 (25.2%)	
Location of fracture§			0.09		0.06
Upper extremity	295 (64.6%)	69 (23.4%)		42 (14.2%)	
Lower extremity	149 (32.6%)	46 (30.9%)		32 (21.5%)	
Presenting facility			0.01‡		<0.01‡
ED	142 (31.1%)	50 (35.2%)		37 (26.0%)	
Outside ED	184 (40.3%)	38 (20.6%)		22 (12.0%)	
Urgent care or primary care physician	89 (19.5%)	21 (23.6%)		9 (10.1%)	
Orthopaedic clinic	42 (9.2%)	9 (21.4%)		6 (14.3%)	
Type of treatment#			0.03‡		<0.01‡
Cast or splint	362 (79.2%)	87 (24.0%)		52 (14.4%)	
Closed reduction and cast or splint	33 (7.2%)	7 (21.2%)		3 (9.1%)	
Surgery	60 (13.1%)	24 (40%)		19 (31.7%)	

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the number of patients, with the row percentage in parentheses. ‡Significant at p < 0.05 for bivariate statistical analysis. §This category excluded 13 patients with pelvic or vertebral fractures. #This category excluded 2 patients with fractures managed with observation.

Significant associated factors from bivariate analysis were included in the binomial logistic regression analysis to identify independent risk factors, when controlling for all other varia-
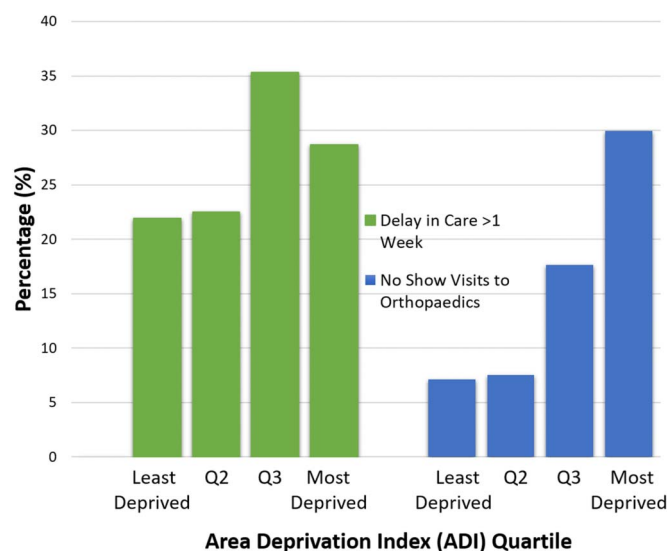

Fig. 2
Effects of the ADI quartile on fracture care compliance. For each given quartile of the ADI, the percentage of patients with delays in care >1 week and no-show visits to orthopaedic clinic are shown. Significant differences were found among the 4 groups, with the highest percentages in the most deprived patients for no-show visits and in quartile 3 for delays in care.

bles, for the outcomes of interest. The multicollinearity of all variables was assessed using the variance inflation factor and tolerance for each model. Interaction terms were tested, based on potential confounders as determined by literature review. When appropriate, interaction terms were included in the model. Model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test. For all analyses, significance was set at p < 0.05. Statistical analyses were performed using SPSS version 23 (IBM) and Stata release 15 (StataCorp).

Results

Study Cohort

We identified 457 patients who met inclusion criteria; the majority of these patients were male (75.9%). Nearly half of the patients (49.5%) were white, and 45.1% were black. The median age at the time of injury was 16.1 years (range, 11.1 to 18 years). More than three-quarters (78.8%) of the patients had 2 parents as primary caregivers, and 18.8% of patients were cared for by single parents. Private insurance (57.8%) and Medicaid (40.5%) were the 2 most common insurance statuses. The median ADI of the cohort was 101.5 (interquartile range [IQR], 86.3 to 114.9), which is comparable with its national mean (100)[4].

Isolated fractures occurred in 429 patients (93.9%). Twenty-three patients (5.0%) had 2 fractures, and 5 patients (1.1%) had 3 fractures on initial presentation. Upper-extremity fractures were the most common, with injuries to the hand occurring in >40% of cases (Fig. 1). Sports-related injuries were the most common mechanism of injury (52.9%). The majority of

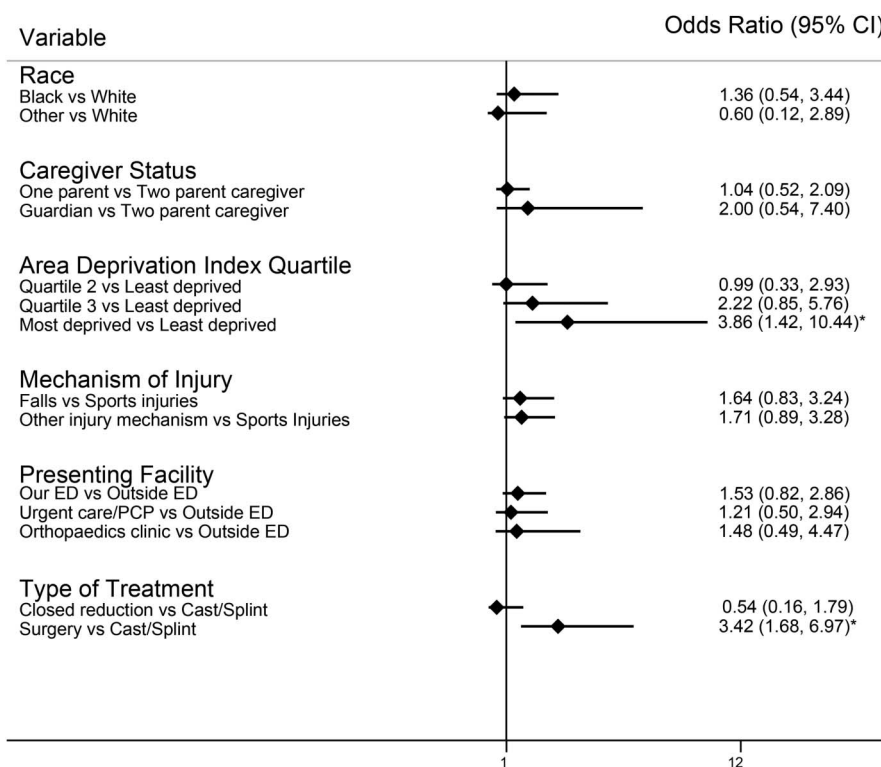| Variable	Odds Ratio (95% CI)
Race	
Black vs White	1.36 (0.54, 3.44)
Other vs White	0.60 (0.12, 2.89)
Caregiver Status	
One parent vs Two parent caregiver	1.04 (0.52, 2.09)
Guardian vs Two parent caregiver	2.00 (0.54, 7.40)
Area Deprivation Index Quartile	
Quartile 2 vs Least deprived	0.99 (0.33, 2.93)
Quartile 3 vs Least deprived	2.22 (0.85, 5.76)
Most deprived vs Least deprived	3.86 (1.42, 10.44)*
Mechanism of Injury	
Falls vs Sports injuries	1.64 (0.83, 3.24)
Other injury mechanism vs Sports Injuries	1.71 (0.89, 3.28)
Presenting Facility	
Our ED vs Outside ED	1.53 (0.82, 2.86)
Urgent care/PCP vs Outside ED	1.21 (0.50, 2.94)
Orthopaedics clinic vs Outside ED	1.48 (0.49, 4.47)
Type of Treatment	
Closed reduction vs Cast/Splint	0.54 (0.16, 1.79)
Surgery vs Cast/Splint	3.42 (1.68, 6.97)*

Fig. 3

Multivariate logistic regression model for no-show visits. The ORs and 95% CIs for factors associated with no-show visits to the orthopaedics clinic are provided. *P < 0.01. PCP = primary care physician.

patients presented to an ED (71.3%), although some presented to either urgent care centers or a primary care physician's office (19.5%), or directly to an orthopaedic outpatient clinic (9.2%). Surgical management was required in 13.1% of cases, but the majority of fractures were treated nonoperatively, with splinting or casting alone in 79.2% of patients.

More than one-quarter of adolescents (25.8%) had a delay in care of >1 week during the course of orthopaedic care for the fracture, and 16.2% did not appear for at least 1 scheduled orthopaedic appointment (range, 0 to 4 appointments). These missed visits occurred throughout the course of fracture follow-up (29.7% in the first month, 43.2% between 1 and ≤3 months after the injury, 17.6% between >3 and ≤6 months after the injury, and 9.5% at >6 months after the injury). Many of these patients missed scheduled visits to check radiographic fracture alignment (39 [52.7%]), potentially resulting in an undetected loss of reduction, or for cast removal (16 [21.6%]), potentially resulting in excessive casting. The majority (14 of 16) of patients who missed visits for cast removal did not return to our clinic; the median ADI of this cohort was 114.8 points.

As shown in Table I, both demographic and socioeconomic factors were found to be related to suboptimal fracture care compliance (p < 0.05). Black patients and adolescents with single-parent caregivers or Medicaid insurance were significantly more likely (p < 0.05) to demonstrate poor compliance. A higher ADI quartile was also associated with poorer rates of

fracture care compliance (Table I). Patients who initially presented to our institution's ED were significantly more likely to demonstrate poor compliance compared with those who presented directly to orthopaedics, their pediatrician, or an outside hospital's ED (p = 0.010 for delays in care and p = 0.001 for no-show visits) (Table II). Additionally, patients who underwent surgical management were significantly more likely to have delays in care (40.0% compared with 24.0%; p = 0.027) and miss scheduled orthopaedic visits (31.7% compared with 14.4%; p = 0.002) compared with those who had closed reductions and cast or splint placement. Those treated surgically had a mean of 1.7 additional visits to orthopaedics for the given injury compared with those who underwent nonoperative management. The location of the primary injury (upper extremity compared with lower extremity or appendicular compared with axial) had no significant impact on compliance with fracture care, nor did the total number of fractures, although there was a trend toward more frequent poor compliance with lower-extremity fractures (Table II).

The stratification of the ADI by quartile demonstrated that adolescents from the most deprived regions are 4 times more likely than those from the least deprived regions (29.9% compared with 7.1%; p < 0.001) to not show up for orthopaedic clinic visits after fracture (Fig. 2). The relationship between the ADI quartile and the risk of delay in care was also significant (p = 0.037), with the highest rates demonstrated in quartile 3 (Fig. 2).
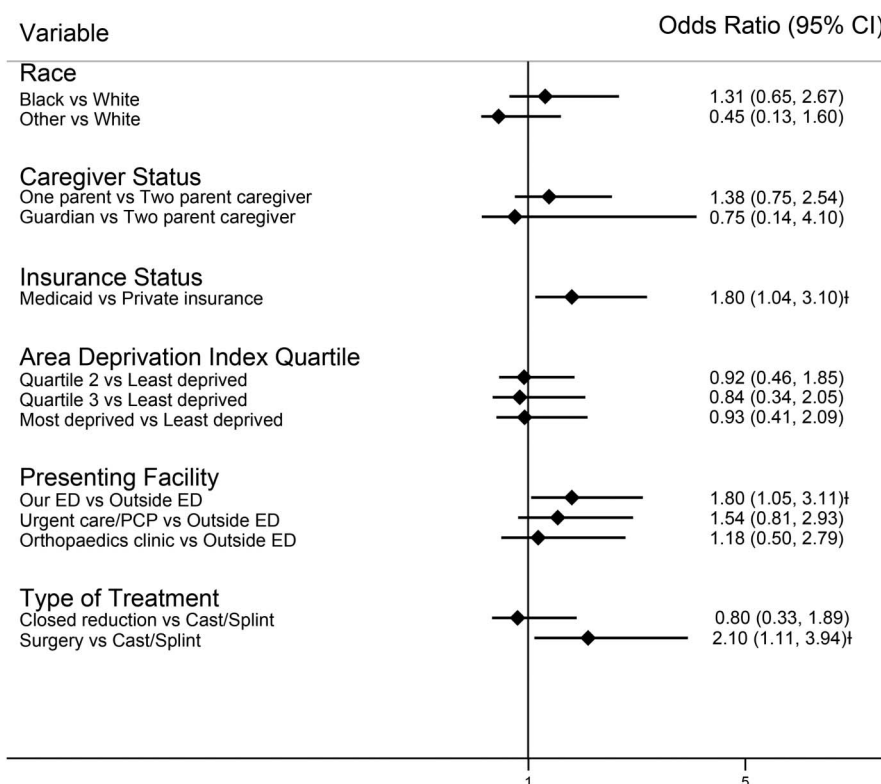
Fig. 4

Multivariate logistic regression model for delays in care. The ORs and 95% CIs for factors associated with delays in care >1 week are provided. †P < 0.05. PCP = primary care physician.

Through multivariate analysis, it was determined that insurance status was a confounding variable with the ADI for predicting no-show visits. It was therefore excluded from the no-show multivariate model (Fig. 3). After removing it and the corresponding interaction terms from the no-show model, no significant interaction terms were identified. The ADI quartile was a significant independent predictor of no-show visits (most deprived quartile odds ratio [OR], 3.86 [95% confidence interval (CI), 1.42 to 10.44]; p = 0.008) (Fig. 3) but not delays in care (Fig. 4). Undergoing surgical management was an independent risk factor for both no-show visits (OR, 3.42 [95% CI, 1.68 to 6.97]; p = 0.001) and delays in care (OR, 2.10 [95% CI, 1.11 to 3.94]; p = 0.021). Medicaid insurance status (OR, 1.80 [95% CI, 1.04 to 3.10]; p = 0.035) and initial presentation to our ED (OR, 1.80 [95% CI, 1.05 to 3.11]; p = 0.034) were additional independent risk factors for delays in care. The results of the Homer-Lemeshow test demonstrated good fit for both models (no-show visits: H = 5.38, p = 0.72; and delays in care: H = 6.21, p = 0.62).

Discussion

This retrospective cohort study demonstrated that a variety of socioeconomic factors, including socioeconomic deprivation, help to determine an adolescent patient's risk of poor care compliance after sustaining a fracture. Specifically, our data indicate that adolescents from the most socially and economically deprived regions are significantly more likely to miss scheduled orthopaedic clinic visits and to have delays in care compared with those from less deprived regions. Furthermore, the most deprived ADI quartile was an independent predictor of no-show visits. Proxies for the ADI, such as single-parent caregiver status and insurance type, may be easier to ascertain and utilize as potential predictors of suboptimal care compliance. Socioeconomic deprivation has similarly been shown to impact the perceived health of pediatric patients. Okoroafor et al. demonstrated that, within a cohort of 975 children with upper-extremity fractures, the most deprived quartile had significantly lower function, mobility, pain interference, and peer relation PROMIS (Patient-Reported Outcomes Measurement Information System) scores than those from the least deprived quartile[26].

In our study, delays in care and no-show visits were both pervasive among all pediatric orthopaedic patients. It is crucial for providers to emphasize the importance of fracture care follow-up with each patient and family. However, we have also identified certain demographic and clinical factors associated with suboptimal fracture care compliance in adolescents. Clinicians can utilize the findings of this study to determine which patients may benefit from extra time spent emphasizing the importance of timely follow-up care.

Demographic factors associated with poor care compliance included race, insurance type, and caregiver status. Skaggs et al. previously found that children with Medicaid insurance have limited access to orthopaedic care across the United States,

likely related to Medicaid physician reimbursement rates[27]. Specifically, a follow-up study found that Medicaid patients are significantly less likely to receive orthopaedic care for a fracture within 7 days of requesting an appointment[28]. In light of our findings, it appears crucial not only to help those with public insurance and/or socioeconomic disadvantage access the necessary orthopaedic care, but also to establish mechanisms to ensure appropriate follow-up care. In other fields, a variety of strategies have been explored to enhance compliance, including automated text messages or alternative clinic hours to minimize missed work and school for adolescents and their families[29,30]. Targeted strategies for those at the highest risk for delays in care and no-show visits may include implementing the presence of orthopaedic providers at primary care clinics in underserved areas or extending weekday office hours to optimize compliance and access to fracture care for all patients.

In terms of clinical risk factors, the mechanism of injury, the initial presenting facility, and the type of treatment were significantly associated with poor fracture care compliance, although only the latter 2 were found to be significant independent risk factors. Interestingly, children injured during sports were less likely to demonstrate poor compliance. Participation in sports is often linked to higher socioeconomic status, and those from more socioeconomically deprived areas likely do not have the same opportunities for organized athletic activities[31]. One should be cautious when interpreting the effect of surgical management on compliance, as these patients typically require longer periods of follow-up and therefore have more opportunities for no-show visits and delays in care. Nonetheless, practitioners should be aware of the particular risk for poor compliance when arranging follow-up care after a surgical procedure.

Given our finding that initial presentation to the ED is an independent predictor of poor fracture care compliance, it is important to consider that many patients who are seen in the ED for initial fracture care are lost to follow-up without ever receiving the appropriate orthopaedic care. In a study of publicly insured pediatric patients who had a forearm fracture and received care in the ED, Jamal et al.[25] demonstrated that >14% of patients did not attend an orthopaedic follow-up appointment, although rates as high as 34.7% have been identified previously[32]. More importantly, older age was associated with a failure to follow up, even in patients with high fracture severity. In light of this, our results are even more profound, because patients who were never seen by orthopaedic providers in the outpatient setting were excluded from our study. Therefore, the proportion of patients who were lost to follow-up and/or did not show up for the initial visits to the orthopaedic clinic is likely substantially higher. Furthermore, the increased frequency of poor compliance observed in adolescents who initially presented to our ED is likely attributable to the largely urban, and potentially socially deprived, population that our hospital serves.

The limitations of this study included its retrospective nature and the inclusion of patients from only a single urban children's hospital system, which may have limited the generalizability of our results. One must also consider the possibility of ecological fallacy when using area-based measures, such as the ADI, to quantify social deprivation for individual patients. We attempted to mitigate this possibility by introducing interaction terms and checking for multicollinearity, thereby identifying and removing variables that could inflate confounding from the model. It is also unknown if patients, particularly those later in the follow-up period (i.e., for cast removal or final radiographs) sought care at other institutions after establishing care with our providers. Additionally, the reasons for no-show visits and delays in care and the underlying severity of the fracture were not evaluated. Transportation, time off from work, and care for other children are all potential barriers that are likely related to socioeconomic status and can impact fracture care compliance. Fracture severity may dictate the frequency of follow-up after an injury. Modifications of established classification systems, such as the OTA/AO fracture classification, should be explored in future studies to determine the impact of injury severity on compliance. Missing visits in the immediate post-injury phase may increase the risk of complications, including a loss of reduction and malunion; however, this was not quantified in our cohort. Future studies should focus on the impact of poor care compliance after fracture on clinical outcomes. Finally, adolescents differ from children in that parents may grant them more autonomy in their decision-making and care. Therefore, factors beyond those considered in this study may play a greater role in determining the likelihood of fracture care compliance in adolescents.

In summary, socioeconomic deprivation and clinical factors are associated with an increased risk of poor fracture care compliance in adolescents. Variables that contribute to the ADI, including single-parent caregiver status and insurance type, are potential factors that clinicians can utilize in daily practice to better understand each adolescent's likelihood of fracture care compliance. Overall, these findings highlight the importance of understanding differences in each family's ability to adhere to the recommended follow-up course and of implementing measures to enhance compliance for all patients. ∎

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