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Research Article

Predictors for Nonaccidental Trauma in a Child With a Fracture—A National Inpatient Database Study

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Abstract

Background: Despite heightened awareness and multidisciplinary efforts, a predictive model to help the clinician quantify the likelihood of nonaccidental trauma (NAT) in a child presenting with a fracture does not exist. The purpose of this study was to develop an evidence-based likelihood of NAT in a child presenting with a fracture.

Methods: Using the 2012 Kids' Inpatient Database, we identified all available pediatric inpatients admitted with an extremity or spine fracture. Children with a fracture were subcategorized based on the diagnosis of NAT. Multivariate analysis using multiple logistic regression was used to generate odds ratios and create a predictive model for the probability of NAT in a child with a fracture.

Results: Of the 57,183 pediatric fracture cases, 881 (1.54%) had a concurrent diagnosis of NAT. Of these children, those presenting with multiple fractures had the highest rate of NAT (2.8%). The overall mortality rate in patients presenting with fractures and abuse was 1.8%, which was twice as high as patients without abuse (odds ratio [OR] = 2.0). Based on multivariate analysis, younger age (OR = 0.5), black race (OR = 1.7), intracranial injury (OR = 3.7), concomitant rib fracture (OR = 7.2), and burns (OR = 8.3) were positive predictors of NAT in a child with a fracture. A weighted equation using regression coefficients was generated and plotted on a receiver operative characteristic curve, demonstrating excellent correlation and probability of NAT (area under curve = 0.962). (Equation – ln $(P/(1-P))$ = -1.79 to 0.65 (age in years) + 0.51 (black race) + 1.97 (rib fracture) + 1.31 (intracranial injury) + 2.12 (burn)).

Conclusion: Using a large, national inpatient database, we identified an overall prevalence of 1.54% of NAT in children admitted to the hospital with a fracture. Based on five independent predictors of NAT, we generated an estimated probability chart that can be used in the clinical workup of a child with a fracture and possible NAT. This evidence-based algorithm needs to be validated in clinical practice.

Level of Evidence: Prognostic study, Level III (case-control study).

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Child abuse or nonaccidental trauma (NAT) is a growing problem facing society and represents a substantial burden on the healthcare system in the United States.[1,2] In 2012, there were over 3.4 million referrals for child abuse in the United States, and Child Protective Services estimates

Table 1

Prevalence and Mortality of Extremity and Spine Fractures With Child Abuse During Hospitalization in KID 2012

					Deaths in Patient With and Without Abuse		
	No. of Patients	No. of Patients with Abuse (%)	No. of Deaths in Patient With Abuse (%)	No. of Deaths in Patient Without Abuse (%)	*P* Value	OR	OR, 95% Confidence Interval
Lower limb fracture	21,238	370 (1.74)	(1.1)	79 (0.4)	0.03	2.9	1.1-7.9
Upper limb fracture	22,236	300 (1.35)	* (2.0)	71 (0.3)	<0.0001	6.3	2.7-14.7
Pelvic fracture	1,633	* (0.12)	0	42 (2.6)	0.82	N/A	N/A
Vertebral fracture	5,192	16 (0.31)	* (6.3)	113 (2.2)	0.27	2.9	0.4-22.1
Multiple fractures	6,884	193 (2.80)	* (2.6)	202 (3.0)	0.73	0.9	0.3-2.1
Overall fractures	57,183	881 (1.54)	16 (1.8)	507 (0.9)	0.004	2.0	1.2-3.4

CI = confidence interval, HCUP = Healthcare cost and utilization project, KID = Kids' Inpatient Database, OR = odds ratio
Note that for cells with fewer than 10 patients, an asterisk (*) replaces the numerical figure, per HCUP patient protection guidelines.

that 686,00 children were victims of abuse (9.2 per 100,000 children).[3] In addition, there were 1,640 deaths reported from child abuse, a rate of 2.2 per 100,000 children. According to a 2008 study conducted by the Centers for Disease Control and Prevention, the total lifetime cumulative economic burden of both nonfatal and fatal maltreatment for the United States was estimated at $124 billion.[4]

Child abuse and maltreatment can be subdivided into four distinct groups—neglect, physical abuse, sexual abuse, and emotional abuse. Although neglect is the most common form of child abuse (78%), physical abuse has been reported in 18% of all abuse cases that typically result in bodily harm either with or without intention.[5] In addition, it has been estimated that as many as 30% of physically abused children present with orthopaedic injuries that require treatment.[6]

Given the prevalence of child abuse in the United States and the predilection of musculoskeletal complications associated with physical abuse, orthopaedic surgeons are often an integral part of the initial triage and management of these patients. Whether performing a consultation in the emergency department or an inpatient setting, orthopaedic surgeons are trained to recognize certain fracture patterns as indicators of NAT; however, the association of these indicators has not been well quantified for clinical use.[7–11]

The Kids' Inpatient Database (KID) is part of a larger collection of databases organized and funded by the Agency for Healthcare Research and Quality.[12] It is a unique all-payer database that collects comprehensive information on pediatric (age < 21 years) hospital admissions on a national scale. KID was first compiled and released in 1997 with subsequent updates every three years. The most recent release in 2012 contains over 7.4 million pediatric admissions from 4,100 hospitals across 44 states. Each admission entry in KID contains demographic, clinical, and charge information, up to 15 diagnosis codes, and up to four external causes of injury codes. The database allows for queries using either individual ICD-9 codes or using KID bundled diagnosis codes. For example, KID 230 includes all ICD-9 diagnosis codes for a fracture of the lower extremity that allows more rapid searching of the large database and comprehensive grouping of fractures by anatomic location.

The primary purpose of our study was to identify objective clinical and demographic factors that are associated with physical abuse in a child presenting with a fracture using a national inpatient database. In addition, we planned to quantify the relationship between fracture site and mortality rates. Finally, we wanted to generate an evidence-based clinical prediction algorithm to help alert orthopaedic surgeons of potential NAT in a child presenting with a fracture.

Methods

Using the KID 2012 database, hospitalizations for all fractures of the upper extremity, lower extremity, pelvis, and vertebrae were included in our analyses. We identified all admissions with fractures using KID bundled diagnosis codes and ICD-9 codes

Table 2

Risk Factors (Univariate Analysis) of Overall Fracture With Child Abuse During Hospitalization in KID 2012

	Patient With Abuse (%)	Patient Without Abuse (%)	*P* Value	OR	OR, 95% Confidence Interval
Demographics					
Age in year [mean (standard error)]	1 (0.09)	13 (0.03)	<0.0001	N/A	N/A
Female [n (%)]	402 (45.6)	18,421 (32.7)	<0.0001	1.7	1.5-2.0
Black race [n (%)]	197 (24.7)	7,667 (14.8)	<0.0001	1.9	1.6-2.2
Associated injures					
Rib fracture [n (%)]	238 (27.0)	3,156 (5.6)	<0.0001	6.2	5.3-7.3
Skull and facial fractures [n (%)]	55 (6.2)	3,162 (5.6)	0.42	1.1	0.8-1.5
Intracranial injury [n (%)]	226 (25.7)	7,297 (12.9)	<0.0001	2.3	2-2.7
Spinal cord injury [n (%)]	* (1.0)	1,052 (1.9)	0.06	0.5	0.3-1.0
Burns [n (%)]	17 (1.9)	181 (0.3)	<0.0001	6.1	3.7-10.1

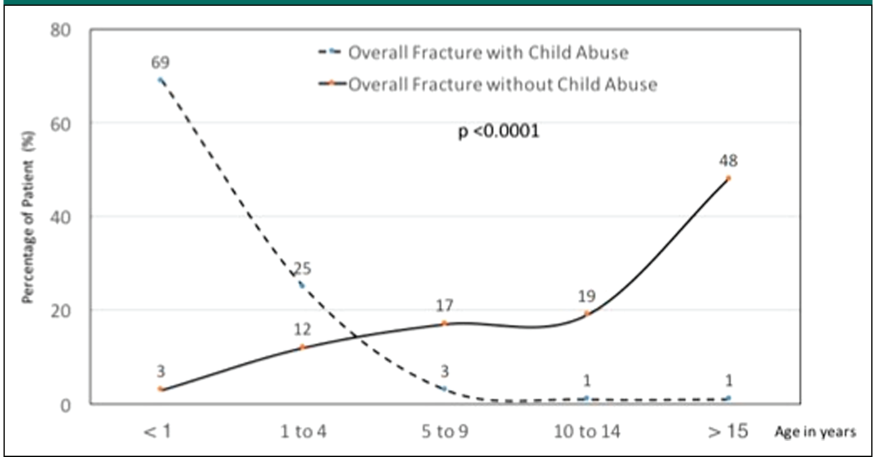
CI = confidence interval, HCUP = Healthcare cost and utilization project, KID = Kids' Inpatient Database, OR = odds ratio
Note that for cells with fewer than 10 patients, an asterisk (*) replaces the numerical figure, per HCUP patient protection guidelines.

(Table, Supplemental Digital Content 1, http://links.lww.com/JAAOS/A366 and Table, Supplemental Digital Content 2, http://links.lww.com/JAAOS/A367). Using these codes, we identified 57,183 pediatric admissions with a fracture. Each of these admissions was subcategorized based on the presence or absence of a child abuse diagnosis code (ICD-9 995.5 to 995.59). We then separated our larger fracture group into cohorts based on the presence (Abuse) or absence (No Abuse) of a child abuse diagnosis code.

For each admission, we collected individual data on sex, race, and age. In addition, we searched each hospitalization for associated nonorthopaedic injuries that could be potentially associated with child abuse including skull and facial fractures (KID 228), intracranial injuries (KID 233), rib fractures (ICD-9 807.00 to 807.19, 819.0, 819.1, 828.0, 828.1), spinal cord injury (KID 227), and burns (KID 240). Furthermore, we assessed mortality rates for all admissions with an orthopaedic fracture and compared it across Abuse and No Abuse categories.

Data were analyzed using SAS software version 9.4 (SAS Institute). Numerical data were expressed as mean and range or 95% confidence interval (CI). Univariate analysis was performed using unpaired *t*-test for continuous variables and chi-square for categorical variables. Comparison was made between the group of overall fracture patients with child abuse with those without child abuse. Stepwise multiple logistic regression with backward selection was used to identify independent clinical predictors of NAT. Variables with a *P*-value of less than 0.20 in the univariate analysis were chosen for the multivariate model, with significance determined using the likelihood ratio chi-square test. Regression model fit was estimated with the Hosmer-Lemeshow[13] goodness-of-fit test. A multiple logistic regression model was made for predictions on log odds scale ($a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$), exponential function moved back from the log odds scale to the odds (odds = exp (log odds)), and then converted from odds to probability (odds/(1 + odds)). A receiver operating characteristic curve was constructed to assess the diagnostic performance of the group of

Figure 1



Graph showing age groups in total fracture by child abuse.

Table 3

Multiple Logistic Regression for Risk Factors of Overall Fracture With Child Abuse During Hospitalization in KI KID 2012

Multivariate Predictor	Regression Coefficient	Standard Error	Wald Chi-Square	*P* Value	OR	OR, 95% CI
Intercept	−1.79	0.06	802.1	<0.0001	—	—
Age in year	−0.65	0.02	726.3	<0.0001	0.5	0.49-0.55
Race(1 = black, 0 = others)	0.51	0.10	25.5	<0.0001	1.7	1.36-2.02
Rib fracture(1 = yes, 0 = no)	1.97	0.12	253.2	<0.0001	7.2	5.62-9.13
Intracranial injury(1 = yes, 0 = no)	1.31	0.11	134.3	<0.0001	3.7	2.98-4.64
Burns(1 = yes, 0 = no)	2.12	0.42	25.0	<0.0001	8.3	3.63-19.12

CI = confidence interval, HCUP = Healthcare cost and utilization project, KID = Kids' Inpatient Database, OR = odds ratio

multivariate predictors in identifying overall fracture patients with child abuse. Sensitivity and specificity were calculated with standard formulae. Statistical significance was defined as $P < 0.05$.

Results

The overall prevalence of abuse (NAT) among pediatric inpatients with a fracture was 1.54% (Table 1). Of these patients, those presenting with multiple fractures had the highest rate of NAT (2.80%), followed by lower limb fractures (1.74%) and upper limb fractures (1.35%). The overall mortality rate in patients presenting with fractures and abuse was 1.8%, which was twice as high as patients without abuse (odds ratio [OR] = 2.0, 95% CI = 1.2 to 3.4). The mortality rate was also higher for children presenting with abuse and upper limb fractures (OR = 6.3, 95% CI = 2.7 to 14.7) and abuse and lower limb fractures (OR 2.9, 95% CI = 1.1 to 7.9).

Univariate Analysis

Among children admitted with an extremity or spine fracture, the age of patients diagnosed with abuse (mean = 1 year) was lower than patients without abuse (mean = 13 years) ($P < 0.0001$) (Table 2). Within the fracture group, female patients (OR = 1.7, 95% CI = 1.5 to 2.0) and children of black race (OR = 1.9, 95% CI = 1.6 to 2.2) were each more likely to be diagnosed with abuse. Further analysis of patient age in years and the prevalence of child abuse demonstrated an inverse relationship with increasing age subgroups ($P < 0.0001$) (Figure 1). In all patients presenting with a fracture, the presence of rib fractures was associated with abuse, having the largest magnitude (OR = 6.2, 95% CI 5.3 to 7.6), closely followed by burns (OR = 6.1, 95% CI = 3.7 to 10.1) and intracranial injury (OR = 2.3, 95% CI 2 to 2.7). The presence of skull/facial fractures and spinal cord injuries were not markedly associated with child abuse ($P > 0.05$).

Multivariate Analysis

Five independent multivariate predictors were identified for the presence of abuse: age in years, black race, rib fractures, intracranial injury, and burns. During the multivariate analysis, female sex was noted to be outside the range of significance (Table 3). The odds of a patient presenting with a fracture and burns also being a victim of abuse was approximately eight times greater than when burns are not present with a fracture. In an attempt to examine the potential for confounding relationship between the child's race and median household socioeconomic status, we analyzed the prevalence of child abuse with each of the two available variables, race and median household income (Table 5). Although there was a notable relationship between black race and lower median household income (Chi-square, $P < 0.0001$), using multiple logistic regression analysis, with the numbers available, median household income did not achieve statistical significance.

The notable multivariate predictors of abuse in children presenting with fractures (age, race, and the presence of rib fractures, intracranial injury, and burns) was used to generate the following weighted equation using the regression coefficient for each variable:

$$\ln\frac{P}{(1-P)} = -1.79 - 0.65\ (\text{age in years}) + 0.51\ (\text{Black race}) + 1.97\ (\text{rib fracture}) + 1.31\ (\text{Intracranial Injury}) + 2.12\ (\text{burn})$$

Here, P is the estimated probability of a diagnosis of NAT in a child with a fracture. Age is represented as a continuous variable in years, whereas race (black = 1, non-black = 0) and associated injuries (presence = 1, absence = 0) are binary variables.

Table 4

Predicted Probability (Percent) of Nonaccidental Trauma in a Patient With an Extremity or Spine Fracture

Black Race	Rib Fracture	Intracranial Injury	Burns	Age in Years								
				1	2	3	4	5	6	7	8	9
Yes	Yes	Yes	Yes	97	94	90	82	70	55	39	25	15
Yes	Yes	Yes	No	79	67	51	35	22	13	7	4	2
Yes	Yes	No	Yes	90	82	70	55	39	25	15	8	5
Yes	Yes	No	No	51	35	22	13	7	4	2	1	0.6
Yes	No	Yes	Yes	82	70	55	39	25	15	8	5	2
Yes	No	Yes	No	35	22	13	7	4	2	1	0.6	0.3
Yes	No	No	Yes	55	39	25	15	8	4	2	1	0.7
Yes	No	No	No	13	7	4	2	1	0.6	0.3	0.2	0.1
No	Yes	Yes	Yes	95	91	84	73	59	43	28	17	10
No	Yes	Yes	No	70	55	39	25	15	8	4	2	1
No	Yes	No	Yes	84	73	59	43	28	17	10	5	3
No	Yes	No	No	38	24	15	8	4	2	1	0.7	0.3
No	No	Yes	Yes	73	58	42	28	17	9	5	3	1
No	No	Yes	No	24	14	8	4	2	1	0.6	0.3	0.2
No	No	No	Yes	42	27	17	9	5	3	1	0.8	0.4
No	No	No	No	8	4	2	1	0.6	0.3	0.2	0.1	0.05

This equation was used to establish the estimated probability of the diagnosis of NAT in a child presenting with a fracture and any combination of the associated variables (Table 4). For example, a 2-year-old black child presenting with an orthopaedic fracture, rib fractures, and burns has an 82% probability of being diagnosed with NAT. A receiver operative characteristic curve (Figure 2) demonstrated a strong correlation of the five predictors in identifying child abuse (area under the curve = 0.962).

Discussion

Using the 2012 KID database, we noted a 1.54% prevalence of NAT in all children admitted to the hospital with a diagnosed fracture. The database was queried from a clinician's perspective by identifying all cases of pediatric fractures that would be typically evaluated by an emergency physician or orthopaedic surgeon. The prevalence of specific fracture sites associated with NAT varies greatly throughout the literature, primarily in regard to all fractures versus fracture patterns treated by orthopaedic surgeons (ie, extremity, vertebral, and pelvic fractures).[7,10,11,14–16] Our fracture site prevalence among children with child abuse closely approximates the distribution reported by Gera et al and Valvano et al.[7,16]

We noted that the mortality rates doubled when the fracture had been identified as a result of NAT. Upper limb fractures demonstrated the greatest association with the risk of death when the hospital admission had also been coded for child abuse (OR = 6.3, $P < 0.0001$). To our knowledge, no previous studies exist that specifically examined the association of fracture site, NAT, and mortality. Although previous authors reported mortality rates from 8 to 11% among children with NAT, this number is higher than the overall mortality of 1.8% of children diagnosed with NAT and a fracture that was observed in the current study.[9,17,18] The higher mortality in children with abuse in some of these series is likely due to inclusion of patients without a fracture that were excluded from our analysis.

According to our analysis, most fractures related to NAT (69%) occurred in patients who were younger than 1 year. Loder and Feinberg[11] using the 2000 KID database reported that 49% of the victims of child abuse were younger than the age of 1 year. Similarly, Leventhal et al examined trends in NAT using three consecutive versions of KID (1997, 2000, 2003) and reported that children younger than the age of 1 year represent 36% of abusive fractures identified.[19] The authors also reported that extremity fractures represented a much higher proportion of fractures from abuse in children younger than the age of 1 year. Bullock et al[10] also used the 1997, 2000, and 2003 editions of KID to examine physical injury and reported that 59% of children younger than 1 year of age who were hospitalized with physical injuries were victims of child abuse.

Table 4 *(continued)*

Predicted Probability (Percent) of Nonaccidental Trauma in a Patient With an Extremity or Spine Fracture

Age in Years										
10	11	12	13	14	15	16	17	18	19	20
8	5	2	1	0.7	0.4	0.2	0.1	0.05	0.03	0.01
1	0.7	0.3	0.2	0.08	0.04	0.02	0.01	0.006	0.003	0.002
2	1	0.7	0.4	0.2	0.1	0.05	0.03	0.01	0.007	0.004
0.3	0.2	0.08	0.04	0.02	0.01	0.006	0.003	0.002	0.0009	0.0005
1	0.7	0.4	0.2	0.1	0.05	0.03	0.01	0.007	0.004	0.002
0.2	0.08	0.04	0.02	0.01	0.006	0.003	0.002	0.0009	0.0004	0.0002
0.3	0.2	0.09	0.05	0.03	0.01	0.007	0.004	0.002	0.001	0.0005
0.04	0.02	0.01	0.01	0.003	0.002	0.0008	0.0004	0.0002	0.0001	0.00006
5	3	1.5	0.8	0.4	0.2	0.1	0.06	0.03	0.02	0.008
0.7	0.3	0.2	0.09	0.05	0.03	0.01	0.007	0.004	0.002	0.001
1.5	0.8	0.4	0.2	0.1	0.06	0.03	0.02	0.008	0.004	0.002
0.2	0.1	0.05	0.03	0.01	0.001	0.004	0.002	0.001	0.0005	0.0003
0.8	0.4	0.2	0.1	0.06	0.03	0.02	0.008	0.004	0.002	0.001
0.1	0.05	0.03	0.01	0.007	0.004	0.002	0.001	0.0005	0.0003	0.0001
0.2	0.1	0.06	0.03	0.02	0.01	0.004	0.002	0.001	0.0006	0.0003
0.03	0.01	0.007	0.004	0.002	0.001	0.0005	0.0003	0.0001	0.00007	0.00004

Table 5

Relationship Between Race/Child Abuse and Socioeconomic Status

	Median Household Income Quartiles for patient's Zip Code for KID 2012				
	$1-$24,999 (%)	$25,000-$34,999 (%)	$35,000-$44,999 (%)	$45,000 and Above (%)	*P* Value
Race [n (%)]					
Black (n = 7,677)	3,974 (51.8)	1,641 (21.4)	1,199 (15.6)	863 (11.2)	<0.0001
Not black (n = 43,683)	11,742 (26.9)	10,797 (24.7)	10,660 (24.4)	10,484 (24.0)	—
Overall fracture prevalence and child abuse [n (%)]					
Child abuse (n = 858)	364 (42.4)	227 (26.5)	182 (21.2)	85 (9.9)	<0.0001
No child abuse (n = 54,992)	16,617 (30.2)	13,396 (24.4)	12,746 (23.2)	12,233 (22.2)	—

KID = Kids' Inpatient Database

Furthermore, multiple single-center studies have retrospectively examined children diagnosed with NAT and orthopaedic injuries and reported that most patients were younger than the age of 1 year (54% to 70%).[7,10,16,17,19]

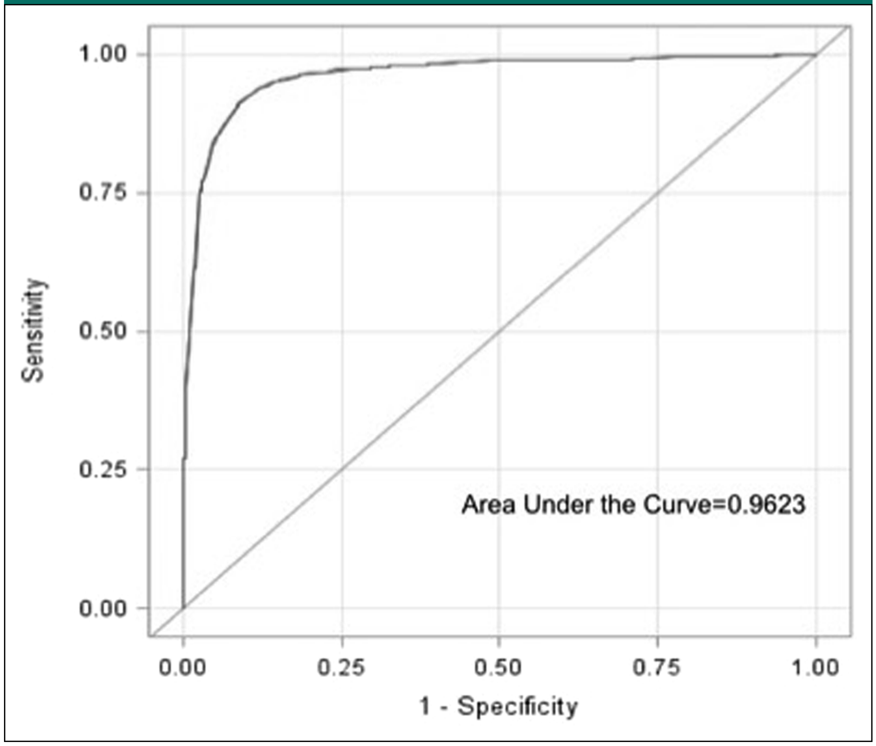
Of all ethnicities and races examined in this study, black children comprised 24.7% of all patients admitted with a fracture due to NAT, which is nearly twice as high a percentage as any other ethnic group. Bullock et al[10] found that black children make up 21% of abused children from KID 1997 to 2003 and an OR of 1.47 (95% CI = 1.36 to 1.6). Loder and Feinberg[11] reported similar numbers from the 2000 KID database, finding that 29% of children hospitalized with orthopaedic injuries and NAT were black. Rewers et al[9] identified children in Colorado with a femur fracture and reported that 31% of fractures in black children were due to NAT.

Our study identifies a subgroup of children (comprising 1.9% of all studied patients) presenting with a fracture and burns that is eight times more likely to be a victim of abuse than a child with a fracture alone. Loder and Feinberg identified a 10% prevalence of burns in patients suffering musculoskeletal injuries in 2000 KID, though he examined a broader group of injuries including sprains/strains open wounds and skull fractures. In addition, Bullock et al reported than burns represented 7.6% of nonorthopaedic injuries in patients hospitalized with physical injury and child abuse based on KID data from 1997 to 2003. Both of these studies used diagnosis codes for all musculoskeletal injuries, likely capturing additional patients with soft-tissue injuries than the children with fractures, which was the focus of our study.

According to our analysis of the 2012 KID database, the presence of rib fractures represents a sevenfold greater probability of child abuse. Similarly, Bullock et al[10] also reported that rib fractures were the most common fracture in children suffering NAT (27.2%). Leventhal et al[20] also found that rib fractures were the most common fracture attributed to abuse in children younger than the age of 3 years (61.%). They noted that 69.4% of children younger than 11 months old with rib fractures were diagnosed with abuse compared with 27.6% of children 24 to 36 month old with rib fractures.

The diagnosis of intracranial injury was also associated with child abuse in patients presenting with fractures (Abuse = 25.7%, No Abuse = 12.9%, $P < 0.0001$). Loder and Feinberg[11] identified 23% of patients hospitalized with orthopaedic injuries in 2000 KID suffered from concomitant intracranial injury. Leventhal et al[20] similarly reports that intracranial injuries are the most common nonorthopaedic injury in patients with musculoskeletal injury and child abuse. This rate is also in accordance with the rate of inflicted traumatic brain injury and abuse (27.5% to 32.2%) reported by Ellingson et al,[21] examining the 1997 to 2003 KID reports.

Figure 2



Graph showing receiver operating characteristic curve for the selected model.

There are several limitations in our study. Analysis based on a large national database has the inherent drawback of potential coding and sampling errors that may affect the results. However, using a national database does provide a large sample size that functions as a cross section of pediatric admissions across the country and can provide insights that would not be possible with a single-center study. An additional drawback of the KID database is that each entry represents a single admission without longitudinally tracking patients, such that it is possible for a single child to represent multiple entries into the database if they had multiple admissions, especially before being diagnosed with NAT. Furthermore, the KID database only identifies cases requiring hospital admission and therefore may underestimate the true prevalence of child abuse in patients with a fracture and possible NAT who were treated in the emergency department or outpatient clinic and never admitted to the hospital. Finally, the KID database does not include any associated clinical history and examination, radiographic findings, treatment rendered, and clinical outcome (besides mortality) to allow for a more detailed analysis. Despite these limitations, our analysis provides a perspective unique to the literature by sampling the database as a clinician evaluating a child with a fracture in the inpatient setting. In addition, based on our review, this is the first study that attempts to quantify each of the independent risk factors for NAT in a child with a fracture using a logistic regression model (Table 5).

Conclusion

Using the 2012 KID database, we identified five independent predictors of NAT in children presenting with a fracture. Using a multiple logistic regression model, we were able to quantify the odds of having an associated diagnosis of child abuse in a child admitted with a fracture. Using our equation based on logistic regression modeling, possibly embedded in an electronic medical record, clinicians may better be able to objectively identify victims of NAT when children present to the hospital with one or more fractures. We hope that future investigators can perform prospective studies to help validate this model in various clinical settings including children presenting to an emergency department and outpatient clinics with an extremity or spine fracture.

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