Violence: Recognition, Management, and Prevention

INTRACRANIAL INJURY AMONG CHILDREN WITH ABUSE-RELATED LONG BONE FRACTURES

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□ **Abstract—Background:** Intracranial injury (ICI) from abusive head trauma is the leading cause of death among young abused children but is difficult to detect. Long bone fracture (LBF) may lead to the recognition of abuse in young abused children. **Objectives:** This study is the first to report the incidence and features of ICI in children with abuse and LBFs. **Methods:** This is a retrospective study of children younger than 3 years with the diagnosis of LBF in the National Trauma Data Bank from 2009 to 2014. LBF, abuse, and clinical features were identified using International Classification of Diseases, Ninth Revision codes. Abuse-related LBF with and without ICI were compared to identify risk factors for ICI. **Results:** There were 4345 encounters for abuse-related LBF in kids ages < 3 years; 970 (22%) had ICI. Infants < 1 year of age were more likely to have ICI compared with older children (odds ratio [OR] 1.79, 95% confidence interval [CI] 1.38–2.33). After adjusting for age, fracture of the ulna, radius, tibia, or fibula were associated with greater odds of ICI (OR 3.35, 95% CI 2.81–4.00). Abuse-related LBF with additional findings of skull fracture, rib fracture, or head/neck bruising had an increased odds of ICI (OR 8.27, 95% CI 6.85–9.98; OR 2.67, 95% CI 2.28–3.14; OR 2.41, 95% CI 1.99–2.92, respectively). **Conclusions:** ICI occurred in nearly 1 in 4 children under 3 years old with abuse-related LBF. Abuse-related LBF with skull fracture, rib fracture, head/neck bruising, or patient age < 1 year should prompt consideration for ICI with head imaging. © 2020 Elsevier Inc. All rights reserved.

□ **Keywords**—long bone fracture; abusive head trauma; intracranial injury; skeletal survey; head CT; skull fracture

INTRODUCTION

Fracture is the most common diagnosis in abused children under 3 years of age presenting in the emergency department (ED) (1). The most common fracture pattern identified in abused children is a single diaphyseal long bone fracture (LBF), which may occur in any long bone, including humerus, radius, ulna, femur, tibia, or fibula (2–7). Abusive LBF are most common among children under 3 years of age (4,8). Once children with abuse-related LBF are identified, providers can utilize the opportunity to intervene to assess for and prevent further and potentially life-threatening trauma. There is a reported increase in domestic and child abuse with the novel coronavirus (COVID-19) pandemic (9,10). During national disasters and shelter-in-home restrictions, studies have historically shown an increase in child abuse (11). EDs now have the added task of donning, doffing, and coronavirus screening, which may distract from the identification and treatment of abused children.

Intracranial injury (ICI) from abusive head trauma (AHT) is the leading cause of death in abused children under 2 years of age, but it remains difficult to detect (12). A 5-year retrospective review found that 31% of

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childhood AHT diagnoses were missed at their initial presentation (13). Rubin et al. and Laskey et al. report that abused infants and toddlers with ICI evident on computed tomography (CT) or magnetic resonance imaging (MRI) commonly present without neurologic symptoms such as seizure, vomiting, or lethargy, which underscores the difficulty in recognizing ICI in young children (12,14). Although the American Academy of Pediatrics recommends a skeletal survey (SS) to detect occult fracture in all children younger than 2 years of age with injuries suspicious for child abuse, recommendations to screen for occult head injury in possibly abused children are less directive and rely on clinical discretion. A head CT or MRI is required to evaluate for ICI, but imaging decisions must be weighed against risks, such as the irradiation associated with head CT and potential sedation for head MRI (15).

Despite the fact that both the incidences of ICI and abuse-related fracture are highest in very young children, few studies have examined the co-occurrence of ICI and abuse-related LBF (13,16–18). Maguire et al. estimated the probability of ICI in hospitalized children with head trauma and reported that LBF alone has a 35% positive predictive value for ICI (19). However, the rates of ICI in children with diagnosis of abuse and LBF remains unknown.

OBJECTIVES

Children with fractures or concern for ICI often present to, or are transferred to, trauma centers for specialized care. To our knowledge, the rates of ICI in children with LBF have not been studied in trauma center patients. In the current study we evaluate a multicenter trauma database to determine the rate of ICI in children under 3 years of age with LBF, and characterize the risk of ICI based on fracture location, gender, age, and other physical examination findings. LBF patterns associated with an increased risk of ICI may provide more definitive guidance for the use of head imaging in abused children with LBF.

MATERIALS AND METHODS

Design and Study Sample

This was a cross-sectional retrospective study of patients under 3 years of age using data from the National Trauma Data Bank (NTDB), years 2009–2014. The NTDB is managed by the American College of Surgeons Committee on Trauma. Data are collected from over 700 hospitals in the United States, including more than 95% of all American College of Surgeons-verified Level I and II trauma centers, which are required to report data as part

of their verification requirement (20). This study was determined to be exempt from review by the Institutional Review Board.

All NTDB patients under 3 years old with a diagnosis of child abuse and LBF were included in the study. The population of patients were first identified by International Classification of Diseases, Ninth Revision (ICD-9) codes for at least one LBF of the humerus, radius, ulna, femur, tibia, or fibula (Appendix A, available online). Patients with bone or bleeding disorders, who may have increased risk of fractures and ICI, were excluded from the study (Appendix B, available online) (3). Secondly, the population was narrowed down to patients with LBF and abuse. Abuse was classified by ICD-9 diagnosis or external cause of injury codes for physical abuse or assault (Appendix A) that have been used in previous publications (3,21–24). Patients with injuries resulting from motor vehicle accidents were also excluded so that the remaining population presents with a significant injury precipitating LBF without an obvious mechanism. Finally, patients who left against medical advice or were transferred to a new facility were excluded from the study due to concerns for incomplete evaluation.

Definition of Outcomes

Children with abuse-related LBF were considered to have ICI based on the presence of ICD-9 codes for ICI, which includes ICI with skull fracture (Appendix C, available online). Patients with skull fractures alone but no ICI were not designated as ICI (Appendix D, available online).

AHT is defined by the Centers for Disease Control and Prevention as intracranial or skull injury. Our study excluded skull fractures alone, without ICI, to focus on the abused child with life-threatening injury to the brain. Among these abused children, a head CT is necessary to detect the life-threatening intracranial injury. In addition, previous studies have seen that skull fractures are equally as common after accidental trauma and AHT, but skull fractures with intracranial injury are more common and more often life threatening after AHT (25). Figure 1 demonstrates the study population.

Definition of Covariates

Age, sex, race/ethnicity, payment method, and ED disposition were obtained from the NTDB. Race was recategorized as follows: White, Black/African American, Asian, American Indian, Other (Native Hawaiian or other Pacific Islander, other race), and Unknown/Missing. Insurance status was provided in the payment method listed in the NTDB, and was categorized as private (private/

commercial, Blue Cross/Blue Shield), public (Medicaid, Medicare, Tricare or other government), self-pay, other (not billed, workers compensation, no fault automobile), or unknown/missing.

Patients with more than one LBF location were included in each of their location categories. Because ICD-9 codes could not distinguish multiple fractures in the same bone or fractures in right vs. left limbs, abuse-related LBF were grouped by their locations to evaluate patterns using two methods.

- Method 1: Patients with at least one humerus, ulna, or radius fracture were identified as "upper extremity fracture." Patients with at least one femur, tibia, or fibula fracture had "lower extremity fracture." Those with at least one upper extremity and one lower extremity fracture were categorized as "upper + lower extremity injury."
- Method 2: Patients were categorized based on radial/ulnar/fibula/tibia (RUFT) vs. humerus/femur (HF) extremity injuries. Patients with at least one humerus or femur fracture were identified with "HF fracture" patterns. Patients with at least one ulna, radius, tibia, or fibula fracture were categorized as "RUFT fracture" pattern. Those with at least one RUFT and one HF extremity fracture were categorized with "RUFT + HF extremity injury."

Other covariates of interest included Injury Severity Score (ISS), skull fracture, rib fracture, retinal hemorrhage, and head and neck bruising (Appendix D), as they have all been shown in previous studies to be associated with abuse-related injury (12,19,26–28). Procedures of SS, head CT, and MRI brain imaging were identified via ICD-9 procedure codes (Appendix D).

Statistical Analysis

We compared the demographics and injury characteristics of children diagnosed with abuse-related LBF that had a concurrent diagnosis of ICI to children without a diagnosis of ICI. Pearson's chi-squared or Fisher's exact tests, when appropriate, were used to determine significant differences between demographic and injury characteristics of children diagnosed with ICI. Over a fourth of patients diagnosed with ICI in our dataset did not have any code for head imaging. We conducted a sensitivity analysis limited to patients that had a procedure code for head imaging for comparison with the original analysis.

Mixed-effects models for binary responses were used to identify injury characteristics associated with ICI in children with abuse-related LBF. All regression analyses were adjusted for clustering of patients by hospital. Cramer's V statistic was used to evaluate all demographic
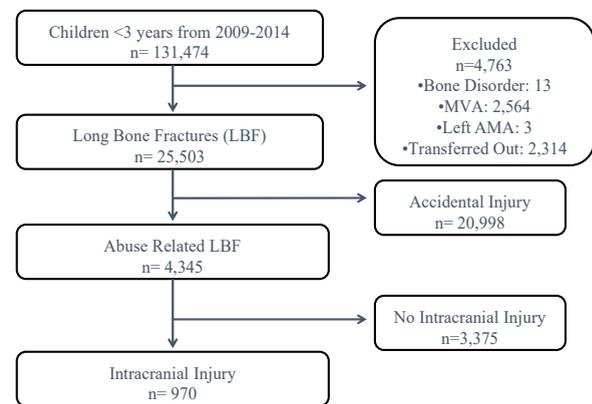
Figure 1. Abuse related LBF study population from National Trauma Data Bank 2009-2014. MVA = motor vehicle accident; AMA = against medical advice.

or injury covariates for multicollinearity. ISS was excluded because it is highly correlated with ICI and LBF, compared with LBF alone (29). Age was dichotomized (under 1 year old or 1 to < 3 years old). All injury characteristics were assessed for interaction with the two age categories, under 1 year old or 1 to < 3 years old, because children under 1 year old are more likely to suffer abuse and ICI (12,13,16,17). Diagnosis codes for forearm or lower leg fracture that did not explicitly specify radius/ulna or tibia/fibula were excluded from regression models. Results from regression analyses are presented as odds ratios (OR) and 95% confidence intervals (95% CI). Statistical analyses were performed using Stata, and regression analyses were conducted using Stata's mixed effect meqrlogit model (2013; StataCorp LP, College Station, TX).

RESULTS

Between 2009 and 2014, there were 25,503 children under 3 years old with LBF in the NTDB. Abuse was diagnosed in 4345 (17.0%) of these patients. Demographics and disposition of children under 3 years of age with abuse-related LBF are reported in Table 1. ICI occurred in 22% of patients with abuse-related LBF, and most ICI was classified as subdural hematoma (n = 621; 64.0%). Most children with ICI (92.7%) were under 1 year of age, and significantly fewer children (87.6%) without ICI were under 1 year of age ($p < 0.001$). Children under 1 year with abuse-related LBF were more likely to have ICI, compared with children 1 year and older (OR 1.79, 95% CI 1.38–2.33). More than half of ICI patients went to the intensive care unit (56.0%), compared with only 7.1% of those without ICI ($p < 0.001$).

We compared injury features of patients with documented ICI to those without ICI (see Table 2). Children

Table 1. Comparison of Demographics and Disposition among Children with ICI and without ICI, NTDB 2009–2014

	ICI, n = 970	No ICI, n = 3375	p-Value
Demographic characteristics			
Age			
<1 year	899 (92.7)	2956 (87.6)	<0.001
≥1 year, <2 years	46 (4.7)	230 (6.8)	
2–<3 years	25 (2.6)	189 (5.6)	
Male*	559 (57.7)	1901 (56.3)	0.46
Race			
White	487 (50.2)	1739 (51.5)	0.35‡
Black/African American	226 (23.3)	855 (25.3)	
Asian	7 (0.7)	22 (0.7)	
American Indian	9 (0.9)	29 (0.9)	
Other	2 (0.2)	5 (0.2)	
Unknown/missing	239 (24.6)	725 (21.5)	
Ethnicity – Hispanic/Latino†	174 (24.5)	547 (21.1)	0.05
Primary payer			
Private	128 (13.2)	498 (14.6)	0.71
Public	719 (74.1)	2444 (72.4)	
Self-pay	36 (3.7)	121 (3.6)	
Other	18 (1.9)	54 (1.6)	
Unknown/missing	69 (7.1)	262 (7.8)	
Disposition from ED			
Home	1 (0.1)	53 (1.6)	<0.001
Inpatient	287 (29.6)	2738 (81.1)	
ICU	543 (56.0)	238 (7.1)	
OR	29 (3.0)	117 (3.5)	
Died	3 (0.3)	19 (0.6)	
Other facility	1 (0.1)	4 (0.1)	
Unknown/missing	106 (10.9)	206 (6.1)	

ICI = intracranial injury; NTDB = National Trauma Data Bank; ED = emergency department; ICU = intensive care unit; OR = operating room.
* 0.05% of values for sex were missing.
† 24.1% of records are missing values for ethnicity.
‡ Due to small cell count, analyzed using Fischer's exact test as well as OR (95% CI).

with diagnosed ICI had higher proportions of radius, ulna, tibia, and fibula fracture, but lower proportions of humerus and femur fracture, compared with children without ICI. Fracture patterns differed between children with ICI and those without (Figure 2). The patterns of RUFT and HF extremity fractures differed significantly between patients with and without ICI. ICI patients exhibited significantly higher ISS, rates of skull and rib fractures, retinal hemorrhaging, and head or neck bruising than those without ICI.

There was no significant difference in the number of SS completed in the ICI group vs. the abuse-related LBF without ICI. When conducting a sensitivity analysis to examine only patients who had received a head imaging study as determined by ICD-9 codes, similar patterns emerged (Table 3). Children with head imaging who were diagnosed with ICI were more likely to have concurrent radius, ulna, and tibia fractures, and less likely to have concurrent humerus and femur fractures, however, the rates of fibula fractures were no longer significantly different between the groups.

Using a mixed-effects model to account for clustering by hospital, we found that children under 1 year of age with abuse and LBF had 87% greater odds of ICI (OR 1.87, 95% CI 1.43–2.45, data not shown) compared

with 1- to 2-year-olds. When injury characteristics were assessed for interaction between the two age categories, under 1 year old or 1 to < 3 years old, the only significant interaction occurred among femur fractures. Children 1 to < 3 years old with a femur fracture were significantly less likely to have concurrent ICI compared with children under 1 year old with a femur fracture ($p = 0.01$). Regression models examining the association between injury characteristics and ICI with adjustment for age are shown in Table 4. Children with radius, ulna, tibia, and fibula fractures had significantly higher odds of having ICI compared with children without. Children with ICI had over 8 times the odds of having a skull fracture compared with those without diagnosed ICI (OR 8.27, 95% CI 6.85–9.98). In addition, children with rib fracture or head and neck bruising had significantly higher odds of having ICI compared with children without rib fracture or head and neck bruising.

Children with upper or upper + lower extremity fractures had significantly higher odds of having ICI compared with those with lower extremity fractures (Table 4). In addition, children with HF or HF + RUFT extremity fractures had signfically higher odds of having ICI compared with those with an HF extremity fracture (Figure 2; Table 4).

Table 2. Comparison of Features among Patients with ICI and without ICI, NTDB 2009–2014

	ICI, n = 970	No ICI, n = 3375	OR (95% CI)
Age			
<1 year	899 (92.6)	2956 (87.6)	1.79 (1.38–2.33)
≥1 year, <2 years	46 (4.7)	230 (6.8)	0.68 (0.49–0.93)
2–<3 years	25 (2.5)	189 (5.6)	0.45 (0.29–0.69)
LBF location			
Humerus	256 (26.4)	1107 (32.8)	0.68 (0.58–0.79)
Radius	214 (22.1)	436 (12.9)	1.65 (1.38–1.96)
Ulna	158 (16.3)	340 (10.1)	1.53 (1.25–1.86)
Femur	424 (43.7)	1851 (54.8)	0.62 (0.55–0.70)
Tibia	383 (39.5)	874 (25.9)	1.52 (1.33–1.74)
Fibula	97 (10.0)	246 (7.3)	1.27 (0.99–1.61)
Fracture patterns			
Upper extremity only	310 (32.0)	1032 (30.6)	1.05 (0.92–1.21)
Lower extremity only	486 (50.1)	1876 (55.6)	0.86 (0.77–0.97)
Upper + lower extremity	174 (17.9)	467 (13.8)	1.33 (1.11–1.59)
HF extremity fracture	372 (38.4)	2093 (62.0)	0.53 (0.47–0.60)
RUFT extremity fracture	363 (37.4)	624 (18.5)	2.26 (1.96–2.60)
HF + RUFT extremity fracture	235 (24.2)	658 (19.5)	1.28 (1.09–1.50)
Other injury characteristics			
Injury Severity Score (ISS)	21 (20, 29)	4 (4, 8)	<0.001* 26.3 (15.54–45.21)
ISS ICD > 15	926 (95.5)	170 (5.0)	18.95 (15.85–22.66)
Skull fracture	385 (39.7)	252 (7.5)	5.32 (4.47–6.32)
Rib fracture	389 (40.1)	646 (19.1)	2.09 (1.81–2.42)
Retinal hemorrhage	43 (4.4)	7 (0.2)	21.37 (11.58–43.21)
Head and neck bruising	233 (24.0)	431 (12.8)	1.88 (1.58–2.24)

ICI = intracranial injury; NTDB = National Trauma Data Bank; OR = odds ratio; CI = confidence interval; LBF = long bone fracture; HF = humerus/femur; RUFT = radial/ulnar/fibula/tibia; ICD = International Classification of Diseases.
* Due to small cell count, analyzed using Fischer's exact test as well as OR (95% CI).

DISCUSSION

To our knowledge, this is the first study to report the rate of ICI among abuse-related LBF patients presenting to trauma centers. ICI was diagnosed in nearly 1 in 4 children under 3 years of age with concurrent diagnosis for abuse and LBF. Studies have examined children with LBF, child abuse, and ICI, but abuse and fracture is commonly identified within the ED and more research is needed (1). Whereas previous studies have identified the rates of abuse in children under 3 years old with head injury or fracture, this is the first study to report

	Adjusted OR* (95% CI)
HF Extremity	Reference
RUFT Extremity	3.35 (2.81-4.00)
HF + RUFT Extremity	1.82 (1.50-2.20)

Radius Ulnar Fibula Tibia
Humerus Femus

*Adjusted for age
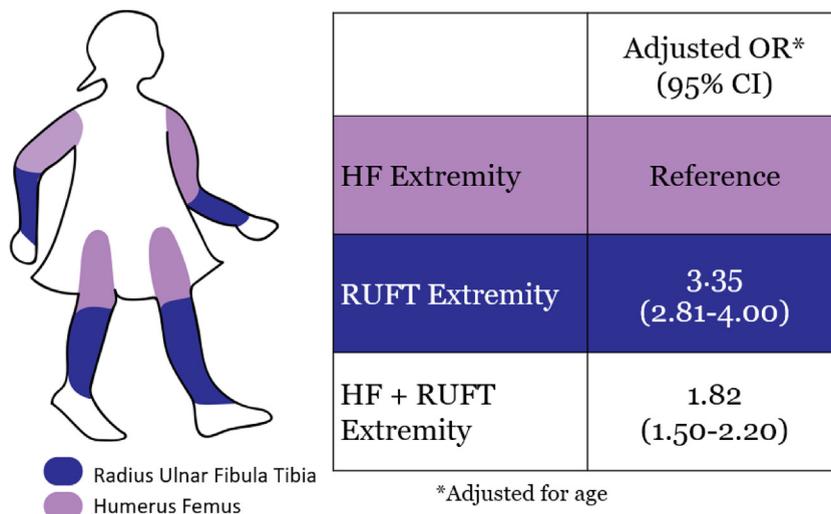
Figure 2. HF versus RUFT fractures and intracranial injury. HF = humerus/femur; RUFT = radial/ulnar/fibula/tibia.

Table 3. Subanalysis of Children with Documented Head Imaging: Comparing Features of Children with ICI and without ICI, NTDB 2009–2014

	ICI, n = 542	No ICI, n = 1223	OR (95% CI)
Age			
<1 year	515 (95.0)	1132 (92.6)	1.03 (0.89–1.86)
≥ 1 year, <2 years	18 (3.3)	51 (4.2)	0.79 (0.46–1.28)
2–<3 years	9 (1.7)	40 (3.3)	0.51 (0.24–1.06)
LBF fracture characteristics			
LBF location			
Humerus	136 (25.1)	414 (33.9)	0.74 (0.59–0.92)
Radius	115 (21.2)	163 (13.3)	1.59 (1.23–2.06)
Ulna	91 (16.8)	134 (11.0)	1.53 (1.15–2.04)
Femur	244 (45.0)	640 (52.3)	0.86 (0.72–1.03)
Tibia	218 (40.2)	378 (30.9)	1.30 (1.07–1.58)
Fibula	55 (10.2)	118 (9.7)	1.05 (0.75–1.41)
Fracture patterns			
Upper extremity only	161 (29.7)	360 (29.4)	1.01 (0.82–1.25)
Lower extremity only	286 (52.8)	663 (54.2)	0.97 (0.82–1.25)
Upper + lower extremity	95 (17.5)	200 (16.4)	1.07 (0.82–1.25)
HF extremity	208 (38.4)	702 (57.4)	0.67 (0.56–0.81)
RUFT extremity	201 (37.1)	252 (20.6)	1.80 (1.46–2.23)
HF + RUFT extremity	133 (24.5)	269 (22.0)	1.12 (0.88–1.42)
Other Injury Characteristics			
Injury Severity Score (ISS)	21 (4, 29)	5 (4, 8)	<0.001*
			9.47 (4.55–21.34)
ISS ICD >15	525 (96.9)	64 (5.2)	18.51 (14.50–24.45)
Skull fracture	203 (37.5)	102 (8.3)	4.49 (3.46–5.81)
Rib fracture	218 (40.2)	283 (23.1)	1.74 (1.42–2.13)
Retinal hemorrhage	26 (4.8)	4 (0.3)	<0.001*
			14.67 (7.91–35.67)
Head and neck bruising	133 (24.5)	170 (13.9)	1.76 (1.38–2.26)
Skeletal survey	303 (55.9)	707 (57.8)	0.97 (0.82–1.14)

ICI = intracranial injury; NTDB = National Trauma Data Bank; OR = odds ratio; CI = confidence interval; LBF = long bone fracture; HF = humerus/femur; RUFT = radial/ulnar/fibula/tibia; ICD = International Classification of Diseases; ISS = injury severity score.
* Due to small cell count, analyzed using Fischer's Exact test as well as OR (95% CI).

the rate of ICI in children under 3 years old with abuse and LBF [16]. Given that 1 in 4 children under 3 years of age had ICI and abuse-related LBF, our data suggest that when treating young children with LBF suspicious for abuse, providers must consider ICI and head imaging. Early detection of ICI, particularly subdural hematomas, can prevent abused children from suffering fatal consequences such as respiratory depression, epileptic seizures, and mortality [30].

The majority of abuse-related LBF patients in our study were under 1 year of age, and being an infant with LBF was associated with an increased risk of ICI when compared with toddlers. This is consistent with other studies that have reported that children under 1 year of age have the highest rates of abuse and AHT [12,13,16,17]. We found significant relationships between LBF location and ICI. RUFT extremity fractures were associated with an increased risk of ICI compared with HF extremity fractures, even after adjusting for age. Similarly, upper extremity fractures were associated with a greater risk of ICI compared with lower extremity fractures. More research is needed to understand how fracture patterns may be reflective of mechanisms of abuse that may precipitate ICI.

Table 4. Adjusted Odds of ICI in Children Under Three Years Old with Abuse-Related Long Bone Fracture (LBF)

	aOR (95% CI)*
LBF location	
Humerus	0.72 (0.61–0.85)
Radius	1.91 (1.58–2.30)
Ulna	1.69 (1.37–2.09)
Femur	0.64 (0.55–0.75)†
Tibia	1.76 (1.51–2.05)
Fibula	1.32 (1.02–1.70)
Fracture patterns	
Lower extremity	1
Upper extremity	1.21 (1.02–1.43)
Upper + lower extremity	1.32 (1.08–1.63)
HF extremity	1
RUFT extremity	3.35 (2.81–4.00)
HF + RUFT extremity	1.82 (1.50–2.20)
Other injury characteristics	
Skull fracture	8.27 (6.85–9.98)
Rib fracture	2.67 (2.28–3.14)
Head and neck bruising	2.41 (1.99–2.92)

ICI = intracranial injury; aOR = adjusted odds ratio; CI = confidence interval; HF = humerus/femur; RUFT = radial/ulnar/fibula/tibia; ICD = International Classification of Diseases.
* Adjusted for age bivariate (<1 year and 1–2 years).
† Significant interaction with age. Femur fracture*age bivariate (OR 0.68; 95% CI 0.47–0.996).

Further, we saw increased odds of comorbid injuries, such as skull fracture, rib fracture, and head and neck bruising, in children with LBF and ICI, compared with those with only abuse-related LBF. Previous studies have indicated that these comorbid injuries are commonly found in conjunction with AHT, and distinguish AHT from accidental head injury (9,14,15,21–23,26). Our study found that among children with diagnoses of LBF and abuse, additional features of skull fractures, rib fractures, or head and neck bruising also have greater odds of ICI.

Limitations

NTDB data may be subject to coding inaccuracies and physician nonreport. We could not include abuse cases if they were not coded by ICD-9 codes; however, ICD-9 codes have been found to be specific and effective in identifying documented child abuse (23,31,32). In addition, ICD-9 codes and the NTDB do not delineate the patient's presenting problem or which diagnosis was made first, AHT or abuse-related LBF. Therefore, we are unable to report if the children with a limp were later found to have ICI or if the obtunded children with facial bruising were later found to have a lower extremity fracture. Table 1 highlights that ICI patients had significantly higher ISS compared with patients without ICI, which suggests that patients with ICI present more critically ill, such as the obtunded patient described above. Although we cannot determine the presenting complaint, we did report the rate of ICI among patients with ICD-9 codes for abuse and LBF and highlighted features associated with higher rates of ICI. Another limitation of ICD-9 codes is the inability to analyze the number of fractures diagnosed during an encounter because laterality and frequency in a single bone is not accurately captured. To address this issue, we created HF/RUFT and upper/lower extremity fracture designations to help identify patterns in LBF. Although children with and without ICI had similar rates of SS, associations in the LBF patterns may be inaccurate if fractures were not detected. Approximately 17% of patients were missing procedure data, making it difficult to confirm diagnoses of ICI or LBF. We also found inconsistencies with coding for imaging; only 56% of patients with an ICD-9 code for ICI diagnosis had an associated procedure code for head imaging. Given that head imaging is required to make a diagnosis of ICI, it seems likely that head imaging is underreported in the NTDB. To address these concerns, we conducted a sensitivity analysis on patients with head imaging procedure codes indicated in their encounter record, wherein we found no significant differences in identified associations. Like head imaging, SS were likely underreported in the NTDB data, especially if SS were completed at a referring hospital. Ultimately, because only 17% of patients had procedure data, it is exceedingly important that accepting trauma centers ensure that the SS and appropriate head imaging is completed. The NTDB is a dataset of patient encounters and, as a result, an individual with multiple encounters may be represented more than once in our data. Patients who present with late effects of injury are not included in the NTDB. Finally the NTDB collects data from trauma centers which potentially selected for patients who sought out a higher level of care with more significant injuries; therefore, the rates of ICI among abused LBF patients may be lower if data were available from EDs outside of the NTDB.

CONCLUSIONS

ICI occurred in nearly 1 in 4 children under 3 years old with abuse-related LBF evaluated at a trauma center; therefore, trauma center providers are very likely to find ICI among patients with abuse and LBF. Although there was a significant risk of ICI among all children under 3 years old with abuse-related LBF, abused children with LBF and age under 1 year, upper extremity fracture, skull fracture, rib fracture, or head and neck bruising were more likely to suffer ICI. Fractures of the ulna, radius, tibia, or fibula were more than 3 times more likely to have a concurrent ICI diagnosis compared with fractures of the humerus or femur. These features may be utilized in future research to stratify the risk of ICI in vulnerable patients under 3 years old presenting with abuse-related injuries. Providers must consider head imaging in abused patients with LBF under 3 years of age to expedite surgical intervention or prevent reinjury or death in children with ICI.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jemermed.2020.06.006.

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ARTICLE SUMMARY

1. Why is this topic important?

Fracture is the most common diagnosis in abused children under 3 years of age. Intracranial injury (ICI) is the leading cause of death in abused children but is difficult to identify, and a diagnosis of ICI is often missed.

2. What does this study attempt to show?

This study reports the incidence and characteristics of ICI among children under 3 years old presenting in trauma centers with long bone fractures.

3. What are the key findings?

ICI occurred in nearly 1 in 4 children under 3 years of age with abuse-related long bone fracture. ICI was associated with radial, ulnar, tibia, and fibula or upper extremity fractures, skull fractures, rib fractures, and was more likely in children < 1 year of age.

4. How is patient care impacted?

Trauma center providers are very likely to find ICI among patients with abuse and LBF. Providers must consider head imaging in abused patients with LBF under 3 years of age to expedite surgical intervention or prevent reinjury or death in children with ICI.