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CLINICAL ARTICLE

Adverse outcomes in child abuse: a 7-year analysis of patients with traumatic brain injury

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OBJECTIVE Child abuse is a critical public health issue that profoundly affects pediatric health and well-being. Child abuse patients who have sustained traumatic brain injuries (TBIs) present with a unique subset of injuries with complex medical and social implications. This study aims to explore the socioeconomic disparities, injury characteristics, and outcomes in child abuse patients who have sustained TBIs.

METHODS The authors conducted a retrospective review of their institutional emergency department (ED) database (June 2016–June 2023) to identify pediatric TBI cases (patient age ≤ 18 years) using ICD-10 codes based on a modified Centers for Disease Control and Prevention framework. Documented cases of child abuse, neglect, or inadequate supervision with investigations by a multidisciplinary child protection team were identified by reviewing the records of ED admissions. Patient demographics, zip codes, injury characteristics, and clinical outcomes were collected. The Injury Severity Score (ISS) and the Trauma and Injury Severity Score (TRISS), with higher ISSs and lower TRISSs indicating more severe injuries, respectively, were obtained. The Social Deprivation Index was used to assess neighborhood disadvantage, with higher scores indicating adverse health outcomes. Standard bivariate and multivariate regression analyses were performed.

RESULTS This study included 2954 patients with TBI, whose mean age was 7.05 ± 5.50 years; 36.6% of the patients were female and 40.4% were White. Among the overall cohort of TBI cases, 86.6% were non–child abuse cases, while 13.4% were child abuse cases. The child abuse cohort had a significantly lower average age (2.02 vs 7.83 years, $p < 0.001$) than the non–child abuse group. In multivariate regression models, child abuse patients had higher odds of being conveyed to the hospital via private transport (adjusted odds ratio [aOR] 2.201, $p < 0.001$); had higher odds of residing in a deprived neighborhood, as indicated by the SDI (aOR 1.009, $p < 0.001$); and had sustained more severe injuries on admission, as indicated by the ISS and TRISS (aOR 1.064, $p < 0.001$; aOR 0.970, $p < 0.001$, respectively). Child abuse patients had higher odds of a prolonged hospital stay (aOR 4.061, $p < 0.001$), a nonroutine discharge (aOR 6.186, $p < 0.001$), ED transfer to the intensive care unit (aOR 2.696, $p < 0.001$), and death on admission (aOR 3.131, $p < 0.001$).

CONCLUSIONS This study highlights neighborhood disadvantage, more severe injuries, and adverse outcomes in child abuse–related TBI, emphasizing the need for targeted interventions to address socioeconomic disparities and improve healthcare for this vulnerable population.

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KEYWORDS child abuse; pediatric trauma; traumatic brain injury; TBI; high-value care outcomes; neighborhood disadvantage

In the United States, at least 1 in 7 children experiences child abuse or neglect, and maltreatment is associated with up to 9.0% of pediatric traumas.[1,2] Child abuse has lifelong consequences including posttraumatic stress disorder, delayed brain development, lower educational attainment, and future violence victimization and perpetration, resulting in a total lifetime economic burden similar to that for heart disease and diabetes.[3–5] Therefore, a better understanding of the injury characteristics, admission details, and their correlation with socioeconomic status in child abuse cases is crucial to inform targeted interventions and improve outcomes for this vulnerable population.

In light of these significant consequences, much of the current literature has focused on identifying risk factors associated with child abuse to develop targeted prevention programs and enhance screening efforts. The interplay

ABBREVIATIONS aOR = adjusted odds ratio; ED = emergency department; EMR = electronic medical record; ICU = intensive care unit; ISS = Injury Severity Score; LOS = length of stay; OR = operating room; SDI = Social Deprivation Index; TBI = traumatic brain injury; TRISS = Trauma and Injury Severity Score; ZCTA = ZIP Code Tabulation Area.

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between social demographics and child maltreatment is complex, with factors such as poverty, a lower parental education level, housing instability, food insecurity, and a lack of insurance related to increased rates of child abuse.[6] Moreover, some of the literature exploring community-level social determinants of health has revealed that children who live in more impoverished neighborhoods tend to have more severe injuries and adverse outcomes.[7] Additionally, children who identify with racial minorities, have an uninsured status, or have Medicaid insurance tend to have worse overall survival.[8]

Traumatic brain injuries (TBIs) in child abuse patients are associated with significant morbidity, mortality, and poor outcomes, with head injuries as the leading cause of physical abuse deaths.[9,10] In this study, we aimed to leverage 7 years of pediatric TBI cases from a level 1 trauma center to explore and compare the differences in patient characteristics, neighborhood socioeconomic status, injury severity, and clinical outcomes between children who sustained TBI due to abuse and those injured through nonabusive means.

Methods

Patient Selection and Recorded Variables

Our institution, located in an urban Mid-Atlantic area, serves as a pediatric emergency department (ED) and level 1 pediatric trauma center, managing a diverse patient load of 25,000 annually. We serve the East Baltimore community and function as a referral hub for the broader Maryland region, including Delaware, Pennsylvania, Virginia, Washington, DC, and West Virginia, as well as for international patients. Upholding the tenets of the Emergency Medical Treatment and Labor Act, we ensure that all patients receive care regardless of their ability to pay. Our research team comprises dedicated nurses and physicians from various specialties, operating under the guidance of our institutional review board, which approved a waiver of informed consent for this retrospective study, aligning with Health Insurance Portability and Accountability Act guidelines. We followed the STROBE guidelines to minimize bias in our study.

We conducted a retrospective review of our institutional ED database for the period from June 2016 to June 2023, covering a total of 5977 cases. Subsequently, we identified pediatric TBI cases (patient age ≤ 18 years) by implementing the framework proposed by the Centers for Disease Control and Prevention's National Center for Injury Prevention and Control, using ICD-10 codes. The specific ICD-10 codes used to identify TBIs, along with their frequencies within our dataset, are detailed in Supplementary Table 1.[11,12] Child abuse cases were identified through a review of electronic medical records (EMRs). At our institution, concerns of child abuse, neglect, or inadequate supervision raised after ED admission prompt an evaluation by the child protection team. This multidisciplinary team, comprising emergency medicine physicians, pediatric surgeons, critical care specialists, neurosurgeons, social workers, and child life specialists, assesses and evaluates suspected cases based on injury mechanism, patterns, and history and provides the necessary individualized medical intervention. For the purposes of this study, the child abuse group was defined as those cases investigated by the child protection team.[13,14] Furthermore, to conduct a sensitivity analysis, we utilized the following set of ICD-10 codes, defined in the prior literature, to categorize child abuse cases as an additional identification method: T7492X, T7692XA, T7412XA, T7612XA, and T744XXA.[15] Subsequently, we stratified the patients associated with these ICD-10 codes.

We obtained data on demographic variables such as age, sex, race, and ethnicity, as well as clinical data such as mode of transport to the hospital and timing of admission. We categorized the mode of transport into four groups: public ambulance, private ambulance and private vehicle, medevac helicopter, and other (public safety vehicle, walk-in, unspecified). However, recognizing that private ambulances provide emergency medical services comparable to those of public ambulances, we recategorized the transport modes to reflect this functional similarity. Therefore, we restratified the modes of transport into the following categories: ambulances (both public and private), private vehicles, medevac helicopter, and other modes of transport. An additional analysis based on this revised categorization is presented in Supplementary Table 2. We collected patient zip codes to investigate neighborhood disadvantage in TBI admissions. Our approach involved the use of the Social Deprivation Index (SDI), a composite measure developed through factor analysis based on data from the American Community Survey.[16] The SDI incorporates seven demographic indicators: percent living in poverty, percent with < 12 years of schooling, percent single-parent households, percent living in rented housing units, percent living in an overcrowded housing unit, percent of households without a car, and percent unemployed adults under 65 years of age. In this study, we used scores from the SDI, which are derived from ZIP Code Tabulation Areas (ZCTAs). ZCTAs are generalized representations of US Postal Service zip codes defined by the US Census Bureau. The SDI was intended to measure levels of socioeconomic disadvantage in local communities, assess their correlation with health outcomes, and inform targeted interventions aimed at addressing health disparities.[17]

To assess the severity of traumatic injuries, we used the Injury Severity Score (ISS) and the Trauma and Injury Severity Score (TRISS; also known as Trauma Score, Injury Severity Score, and age combination index). The ISS quantifies trauma severity using the Abbreviated Injury Scale (AIS), which assigns severity ratings to individual injuries.[18] It is calculated by summing the squares of the highest AIS scores in the three most affected body regions. A higher ISS indicates more severe injuries. The TRISS incorporates four key elements: patient age, ISS as an anatomical assessment, Revised Trauma Score as a physiological evaluation, and the nature of the trauma (blunt or penetrating).[19] Higher TRISS scores indicate a higher likelihood of survival.

Patient clinical outcomes, including ED length of stay (LOS) in hours, ED transfer to the intensive care unit (ICU) or operating room (OR) as proxies for severity of traumatic injury, direct discharge from ED, hospital LOS in days, discharge disposition, and death, were obtained.[20,21] Nonroutine discharge disposition from the hospital was defined as any discharge that did not involve the patient returning to their home or returning home with healthcare services.[22] Such dispositions included discharges to inpatient rehabilitation facilities, acute care hospitals, foster care arrangements, or cases of death. Prolonged LOS was defined as hospital stays that fall within the upper quartile of the overall cohort's LOS, consistent with previous research.[23]

Data Imputation

To prevent case deletion due to missing data, we employed the missForest method.[24] This technique utilizes random forest models to impute missing values. For each variable with missing data, missForest constructs a random forest model using all other variables in the dataset as predictors. The advantages of using this approach include its ability to handle both continuous and categorical data, minimal parameter tuning requirements, and an internally validated error estimate. Supplementary Table 3 provides a detailed breakdown of the percentage of missing data for the covariates included in the imputation.

Statistical Analysis

Data collection was conducted using Microsoft Excel version 2016 (Microsoft Corp.), and analysis was performed using R statistical software (version 4.3.2, The R Foundation for Statistical Computing). Continuous variables were expressed as the mean ± standard deviation, and categorical variables were expressed as frequencies (percent). The Shapiro-Wilk test was used to assess normality. Because the data did not follow a normal distribution, the Mann-Whitney U-test was utilized for continuous variables and Fisher's exact test was utilized for categorical variables in a bivariate analysis. To mitigate the risk of type I errors, we applied the Bonferroni correction to our multiple hypothesis tests, ensuring more robust findings.[25]

All multivariate logistic regression models were controlled for age, sex, race, and ethnicity based on an a priori conceptual framework. In subsequent analyses, sociodemographic status, injury characteristics, and outcomes were included in separate regression models to avoid potential collinearity issues. This strategy allowed us to assess the association of each variable with child abuse while maintaining the assumptions required for logistic regression. Density bar plots were generated to illustrate the distribution of SDIs, ISSs, TRISSs, and hospital LOSs across the two subgroups: child abuse and non–child abuse TBI cohorts. These plots combine histograms and density lines to provide a clear comparison of the differences in distribution between the two cohorts.

For sensitivity analysis, we performed a complete set of bivariate and multivariate logistic regressions using the ICD-10 codes to stratify child abuse patients. In the present study, p values < 0.05 were considered statistically significant, and all p values were two-sided.

Results

Demographic and Clinical Characteristics of Study Cohort

Table 1 presents an overview of the cohort demographics, admission details, and clinical outcomes. The study cohort of 2954 eligible patients had a mean age of 7.05 ± 5.50 years, 36.6% were female, and 40.4% identified as White and 7.2% as Hispanic/Latino. Eight hundred ninety-two patients (30.2%) used private transportation to the hospital, 30.8% were transferred from other facilities, 15.1% were admitted between 0000 and 0759 hours, 30.4% were admitted during the summer, 31.9% presented to the ED on the weekend, and most of the cohort (96.5%) had blunt injury. The mean SDI, ISS, and TRISS were 54.63 ± 30.25, 8.11 ± 7.23, and 97.79 ± 7.41, respectively. Just over half of the cohort (52.3%) was directly discharged from the ED, 4.1% needed operative intervention, 19.3% were transferred from the ED to the ICU, and 2.2% were deceased. The mean ED LOS was 5.39 ± 3.64 hours, and the hospital LOS was 2.61 ± 5.54 days. Seven hundred forty-two patients (25.1%) had a prolonged ED LOS, 28.4% had a prolonged hospital LOS, and 8.3% had a nonroutine discharge disposition from the hospital.

Bivariate Analyses

Among the entire cohort, 396 TBIs (13.4%) were attributable to child abuse, neglect, or insufficient supervision documented by the multidisciplinary child protection team, and 86.6% were not attributable to child abuse (Table 2). The child abuse patients were significantly younger than their nonabuse counterparts (2.02 ± 3.59 vs 7.83 ± 5.34, p < 0.001). A significantly greater proportion of the child abuse cohort was identified as non-White (65.4%) and Hispanic (10.4%) compared to the nonabuse cohort (58.8% and 6.8%, respectively), with corresponding p values of 0.013 and 0.016.

A significantly higher percentage of the child abuse cohort had private transport to the hospital (56.3%; i.e., private vehicle or private ambulance) and transfers from other facilities (58.6%) compared to the nonabuse cohort (26.2% and 26.5%, respectively; p < 0.001 for both). Additionally, a higher proportion of the child abuse cohort was admitted between 0000 and 0759 hours (27.0%) than the nonabuse cohort (13.3%; p < 0.001). Conversely, a smaller proportion of child abuse patients were admitted during the summer (24.2%) and on weekends (26.5%) compared to the nonabuse cohort (31.4% and 32.7%, respectively; p = 0.004 and 0.015, respectively). The child abuse cohort presented to the ED with more severe injuries, as indicated by higher mean ISSs (11.48 ± 7.55) and lower TRISSs (95.89 ± 9.75), compared to the nonabuse cohort (7.59 ± 7.03 and 98.09 ± 6.93, respectively; p < 0.001 for both). Additionally, the child abuse cohort resided in more disadvantaged neighborhoods, as indicated by a higher mean SDI (60.74 ± 27.90 vs 53.68 ± 30.49, p < 0.001).

A smaller proportion of child abuse patients was directly discharged from the ED than their nonabuse counterparts (24.5% vs 56.6%, p < 0.001). A greater proportion of child abuse patients were transferred to the ICU (38.4%) and died in-hospital (4.5%) compared to their nonabuse counterparts (16.3% and 1.8%; p < 0.001 and 0.002, respectively). A greater proportion of the child abuse cohort had a prolonged ED LOS (30.1%) and extended hospital LOS (56.6%) compared to the nonabuse cohort (24.4% and 24.0%, p = 0.018 and < 0.001, respectively). Finally,

TABLE 1. Demographics and clinical characteristics of the overall TBI cohort (n = 2954)

Characteristic	Value
Demographics	
Age in yrs	7.05 ± 5.50
Age category in yrs	
0–2	931 (31.5)
3–5	414 (14.0)
6–10	613 (20.8)
11–18	996 (33.7)
Female sex	1082 (36.6)
Race	
White	1192 (40.4)
Black	1298 (43.9)
Other	464 (15.7)
Hispanic ethnicity	214 (7.2)
Admission details, sociodemo status, & injury CHARs	
Mode of transport to hospital	
Public ambulance	1667 (56.4)
Private vehicle/ambulance	892 (30.2)
Medevac helicopter	318 (10.8)
Other*	77 (2.6)
Transfer from other facility	910 (30.8)
Patient arrival time in hrs	
0000–0759	446 (15.1)
0800–1559	813 (27.5)
1600–2359	1695 (57.4)
Season of admission	
Fall	713 (24.1)
Winter	555 (18.8)
Spring	787 (26.6)
Summer	899 (30.4)
Weekend admission	941 (31.9)
SDI	54.63 ± 30.25
ISS	8.11 ± 7.23
TRISS	97.79 ± 7.41
Injury type	
Blunt	2852 (96.5)
Other (penetrating, bite)	102 (3.5)
Patient outcome	
Direct discharge from ED	1544 (52.3)
ED transfer to OR	122 (4.1)
ED transfer to ICU	569 (19.3)
ED LOS in hrs	5.39 ± 3.64
Prolonged ED LOS, i.e., ≥6.75 hrs	742 (25.1)
Discharge disposition	
Home	2684 (90.9)
Home w/ services	25 (0.8)
Nonroutine discharge	245 (8.3)
Inpatient rehab facility	119 (4.0)
Acute care hospital	7 (0.2)
Foster care	33 (1.1)
Other	21 (0.7)
Morgue/medical examiner	65 (2.2)
Hospital LOS in days	2.61 ± 5.54
Prolonged hospital LOS, i.e., ≥2 days	839 (28.4)
Death on admission	65 (2.2)

CONTINUED IN NEXT COLUMN »

» CONTINUED FROM PREVIOUS COLUMN

CHAR = characteristic; rehab = rehabilitation; sociodemo = sociodemographic.
Values are expressed as mean ± standard deviation or number (%).
* Public safety vehicle, walk-in, unspecified.

a significantly higher proportion of the child abuse cohort had nonroutine discharge dispositions (24.0% vs 5.9%) and foster care discharges (7.8% vs 0.1%) compared to the non–child abuse cohort ($p < 0.001$ for both).

Multivariate Logistic Regression Analyses

We adjusted our logistic regression models for age, sex, race, and ethnicity and applied a Bonferroni correction for multiple comparisons (18 scenarios, $\alpha = 0.0027$) to ensure robust results (Table 3). The results of our base model exploring the association of age, sex, race, and ethnicity with child abuse are presented in Supplementary Table 4; younger age and non-White race were independently associated with increased odds of child abuse (aOR 0.729, $p < 0.001$ and aOR 1.683, $p < 0.001$, respectively), whereas sex and ethnicity were not significantly associated ($p = 0.858$ and 0.138, respectively). Taking this information into account, we found that child abuse patients had higher odds of being conveyed to the hospital via private transport (aOR 2.201, $p < 0.001$), transferred from other facilities (aOR 2.606, $p < 0.001$), and admitted between 0000 and 0759 hours (aOR 2.060, $p < 0.001$). Child abuse patients were more likely to sustain severe injuries, with each 1-point increase in the ISS associated with increased odds of child abuse (aOR 1.064, $p < 0.001$), whereas each 1-point increase in the TRISS was associated with decreased odds of child abuse (aOR 0.970, $p < 0.001$). Additionally, they were more likely to reside in deprived neighborhoods, as indicated by higher SDI scores (aOR 1.009, $p < 0.001$). Child abuse patients exhibited significantly reduced odds of direct discharge from the ED (aOR 0.321, $p < 0.001$) and an increased likelihood of ICU admission (aOR 2.696, $p < 0.001$), nonroutine discharge (aOR 6.186, $p < 0.001$), prolonged hospital LOS (aOR 4.061, $p < 0.001$), and death on admission (aOR 3.131, $p < 0.001$). The results of our multivariate regression models for the correlation of weekend admissions and seasonal admissions were not as robust as the other variables indicated above, with $p > 0.0027$.

TABLE 2. Bivariate analysis comparing the child abuse cohort with the rest of the TBI cohort (n = 2954)

Characteristic	Non–Child Abuse Cohort	Child Abuse Cohort	p Value
No. of patients	2558 (86.6)	396 (13.4)	
Demographics			
Age in yrs	7.83 ± 5.34	2.02 ± 3.59	**<0.001**
Age category in yrs			**<0.001**
0–2	614 (24.0)	317 (80.1)	
3–5	381 (14.9)	33 (8.3)	
6–10	593 (23.2)	20 (5.1)	
11–18	970 (37.9)	26 (6.6)	
Female sex	926 (36.2)	156 (39.4)	0.218
Race			**0.013**
White	1055 (41.2)	137 (34.6)	
Non-White	1503 (58.8)	259 (65.4)	
Hispanic ethnicity	173 (6.8)	41 (10.4)	**0.016**
Admission details, sociodemo status, & injury CHARs			
Mode of transport to hospital			**<0.001**
Public ambulance	1542 (60.3)	125 (31.6)	
Private vehicle/ambulance	669 (26.2)	223 (56.3)	
Medevac helicopter	303 (11.8)	15 (3.8)	
Other*	44 (1.7)	33 (8.3)	
Transfer from other facility	678 (26.5)	232 (58.6)	**<0.001**
Patient arrival time in hrs			**<0.001**
0000–0759	339 (13.3)	107 (27.0)	
0800–1559	717 (28.0)	96 (24.2)	
1600–2359	1502 (58.7)	193 (48.7)	
Season of admission			**0.004**
Summer	803 (31.4)	96 (24.2)	
Other seasons	1755 (68.6)	300 (75.8)	
Weekend admission	836 (32.7)	105 (26.5)	**0.015**
SDI	53.68 ± 30.49	60.74 ± 27.90	**<0.001**
ISS	7.59 ± 7.03	11.48 ± 7.55	**<0.001**
TRISS	98.09 ± 6.93	95.89 ± 9.75	**<0.001**
Injury type			**0.025**
Blunt	2462 (96.2)	390 (98.5)	
Other	96 (3.8)	6 (1.5)	
Patient outcome			
Direct discharge from ED	1447 (56.6)	97 (24.5)	**<0.001**
Transfer to OR	103 (4.0)	19 (4.8)	0.496
Transfer to ICU	417 (16.3)	152 (38.4)	**<0.001**
ED LOS in hrs	5.35 ± 3.46	5.63 ± 4.62	0.820
Prolonged ED LOS, i.e., ≥6.75 hrs	623 (24.4)	119 (30.1)	**0.018**
Nonroutine discharge disposition	150 (5.9)	95 (24.0)	**<0.001**
Hospital LOS in days	2.23 ± 4.75	5.08 ± 8.73	**<0.001**
Prolonged hospital LOS, i.e., ≥2 days	615 (24.0)	224 (56.6)	**<0.001**
Death on admission	47 (1.8)	18 (4.5)	**0.002**

Values are expressed as the mean ± standard deviation or number (%), unless indicated otherwise. Boldface type indicates statistical significance ($p < 0.05$).
* Public safety vehicle, walk-in, unspecified.

TABLE 3. Multivariate models investigating differences in injury characteristics and outcomes between TBI cohorts with and without child abuse

Characteristic	aOR	95% CI	p Value
Admission details, sociodemo status, & injury CHARs			
Mode of transport to hospital			
Public ambulance	Reference	Reference	Reference
Private vehicle/ambulance	2.201	1.687–2.879	**<0.001**
Medevac helicopter	0.615	0.334–1.060	0.096
Other*	18.12	9.696–34.300	**<0.001**
Transfer from other facility	2.606	2.041–3.332	**<0.001**
Patient arrival time in hrs			
0800–1559	Reference	Reference	Reference
1600–2359	1.012	0.766–1.344	0.931
0000–0759	2.060	1.467–2.895	**<0.001**
Weekend admission	0.763	0.587–0.986	**0.040**
Season of admission			
Other seasons	Reference	Reference	Reference
Summer	0.708	0.541–0.920	**0.010**
SDI	1.009	1.005–1.014	**<0.001**
ISS	1.064	1.049–1.080	**<0.001**
TRISS	0.970	0.958–0.983	**<0.001**
Injury type			
Blunt	Reference	Reference	Reference
Other	0.436	0.164–0.965	0.061
Patient outcome			
Direct discharge from ED	0.321	0.246–0.415	**<0.001**
Transfer to OR	1.642	0.919–2.820	0.080
ED transfer to ICU	2.696	2.086–3.482	**<0.001**
ED LOS	0.999	0.969–1.028	0.950
Prolonged ED LOS, i.e., ≥6.75 hrs	1.201	0.925–1.553	0.163
Nonroutine discharge disposition from hospital	6.186	4.356–8.825	**<0.001**
Hospital LOS	1.077	1.057–1.098	**<0.001**
Prolonged LOS, i.e., ≥2 days	4.061	3.185–5.190	**<0.001**
Death on admission	3.131	1.604–5.997	**<0.001**

All models have been adjusted for age, sex, race, and ethnicity. Boldface type indicates statistical significance.
* Public safety vehicle, walk-in, unspecified.

The results of our sensitivity analysis, consistent with our prior findings, are outlined in Supplementary Tables 5 and 6.

Data Visualization

Finally, utilizing density bar plots, we outlined the differences between the child abuse cohort and the non–child abuse cohort. As illustrated in Fig. 1, the child abuse cohort exhibited higher SDI scores, higher ISS scores, lower TRISS scores, and a more prolonged hospital LOS compared to the nonabuse cohort.

Discussion

Importance of TBI in Pediatric Patients

Abuse is a significant cause of TBI in children, contributing to substantial morbidity and death. In the US, abuse ranks as the third most common cause of pediatric head injuries, following falls and motor vehicle accidents.[26,27] Although head trauma constitutes a small proportion of child abuse cases, it is responsible for a very high proportion of fatal or life-threatening child abuse–related injuries.[28] Prior research has largely focused on broader aspects of child abuse, but our study specifically highlights the critical subset of abuse-related head trauma, aiming to address the significant gaps in the current understanding of this issue. This study contributes to the existing body of research by focusing on the most severe subgroup of child abuse cases—TBI. We examined data spanning 7 years at a level 1 trauma center, offering a comprehensive analysis that integrated patient demographics, admission characteristics, injury outcomes, and the influence of area-level socioeconomic deprivation and neighborhood disadvantages. This multidimensional approach allowed us to

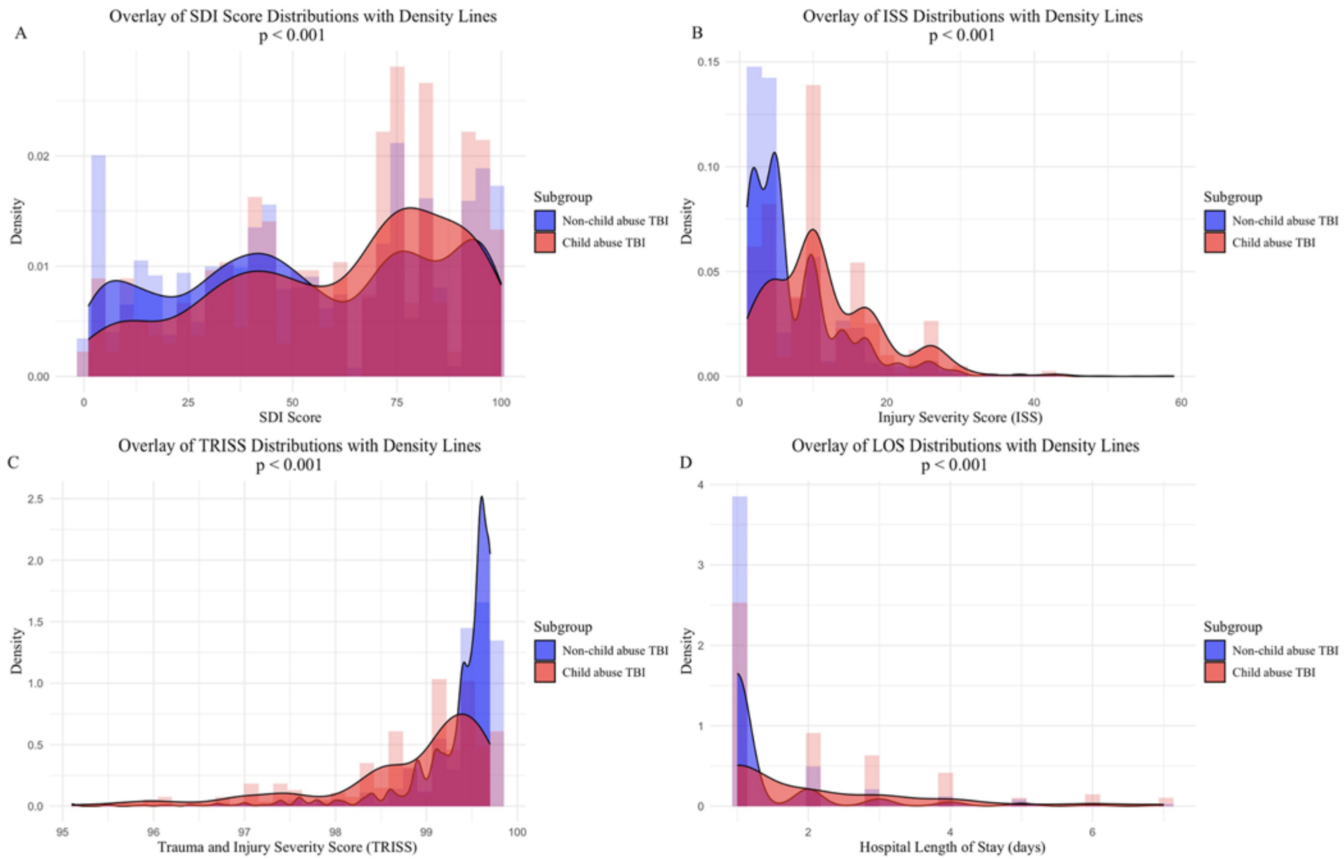

FIG. 1. Comparative density distributions of key metrics between non–child abuse TBI and child abuse TBI cohorts: SDI score (**A**), ISS (**B**), TRISS (**C**), hospital LOS (**D**). Figure is available in color online only.

provide valuable insights into the intersection of social factors and the clinical severity of child abuse in pediatric patients with TBI. The terms "child abuse" and "nonaccidental pediatric trauma" have been used interchangeably in the literature.[29,30] In this study, we used the term "child abuse." Child abuse is a medical diagnosis made by a multidisciplinary team, and it is thoroughly grounded in an evaluation of clinical, imaging, and laboratory findings. While "child abuse" defines the medical cause of harm, it does not constitute a legal determination of a perpetrator's intent.[31]

Key Findings

In our study, abused children were younger, arrived at hospitals through nonpublic transportation methods, and often presented during overnight hours on weekdays, particularly during school months (as opposed to summer). Although our data showed fewer child abuse admissions in summer, this difference seems driven by an increased proportion of summertime TBIs in the nonabuse cohort rather than a surge in child abuse admissions outside the summer season. Abused children disproportionately came from socioeconomically deprived areas and sustained more severe blunt-force injuries, leading to longer hospital stays, nonroutine discharges, and higher mortality rates. Notably, these children were more frequently admitted to ICUs, underscoring the critical nature of their injuries.

These findings align with the existing literature, which consistently reports that patients in child abuse cases are younger than those in non–child abuse cases.[32] A 4-year retrospective study found that 92.5% of pediatric trauma cases were attributable to nonabuse, with a mean patient age of 6.8 years, whereas patients in child abuse cases (7.5%) had a mean age of 1.8 years.[33] Similarly, another study reported a mean patient age of 12 months for child abuse cases, compared to a mean patient age of 76 months in nonabuse cases.[34] Our study, reviewing pediatric patients with TBI, corroborated these trends, with child abuse accounting for 13.4% of cases and a mean patient age of 2.0 years versus 7.8 years in the nonabuse cases.

Consistent with previous research on child abuse cases overall, our findings indicated no significant sex difference in the likelihood of child abuse, suggesting that sex is not a primary determinant in the occurrence of nonaccidental trauma in pediatric populations.[35–37]

Regarding the timing of admissions, our results parallel findings from Niederkrotenthaler et al., which demonstrated that admissions during winter, spring, and fall were associated with slightly higher odds of diagnosing abusive head trauma than nonabusive head trauma.[38,39] Moreover, the authors showed that neither household income nor urban versus rural hospital location was a significant risk factor for abusive head trauma compared to nonabusive head trauma after adjustment for potential confounders.[39]

However, this contradicts our findings, which highlighted a significant link between neighborhood deprivation and nonaccidental head trauma, as demonstrated by the greater odds of a higher SDI score in abuse cases, according to our multivariate regression models. Another study, conducted in a county in New Mexico, revealed that over the 9-year study period, the risk of substantiated child maltreatment was increasingly concentrated in the most deprived neighborhoods. The findings revealed that the risk of maltreatment in the most deprived 20% of neighborhoods, based on financial strength, was 130.78% higher than that in the least deprived 20%.[40] Similarly, in a cross-sectional study conducted over 13 years in British Columbia, Canada, and involving children younger than 2 years who had confirmed abusive head trauma, the researchers assigned dissemination area–based social and material deprivation scores to the residential areas where abusive head trauma cases occurred. The findings revealed that for each increase in material and social deprivation quintiles, abusive head trauma rates rose by 42% and 25%, respectively.[28] Furthermore, the Fourth National Incidence Study of Child Abuse and Neglect reported that children residing in rural areas were twice as likely to experience maltreatment than those living in urban settings.[41]

Previous studies have demonstrated that abused pediatric patients tend to experience more severe injuries, as evidenced by higher mortality rates,[33,35,42] elevated trauma severity scores,[35] a greater need for surgical interventions,[34] longer hospital and ICU stays,[33,34,36] and increased functional limitations among survivors.[36] These findings are consistent with those in our study, as evidenced by elevated ISSs prolonged hospital stays, nonroutine discharges, and increased mortality rates. While we identified prolonged hospital stays and nonroutine discharge dispositions as correlates of more severe trauma and poorer outcomes, these metrics must be considered within the broader context of child abuse management. In cases of child abuse, additional hospital days are often necessary to ensure a safe discharge plan, involving child protective services, social workers, and other multidisciplinary teams. This process can result in longer hospitalizations and nonroutine discharges (e.g., to foster care or supervised care facilities) independent of the severity of the injury itself. Therefore, LOS and discharge disposition in pediatric TBI patients with suspected abuse should be understood as multifactorial outcomes, reflecting both clinical severity and the social, legal, and protective measures required to safeguard the child's well-being. In a retrospective study of 473 pediatric acute injury cases, the authors demonstrated that injuries in nonaccidental trauma patients were more severe than in accidental trauma cases, with significantly higher ISSs, ICU admission rates, and mortality rates.[43] Furthermore, a retrospective study of infant trauma cases identified as child abuse showed that mortality rates were significantly higher in abused infants than in infants with accidental trauma (41.6% vs 13.9%).[44] Additionally, abused infants were more likely to sustain TBI than their counterparts with accidental trauma.

Study Limitations

While our study offers important insights into the socioeconomic disparities, injury characteristics, and outcomes in child abuse patients sustaining TBI, there are several limitations that must be addressed. First, the retrospective design of the study limits our ability to establish causal relationships. The single-center setting, although comprehensive in its coverage, may not adequately represent the broader spectrum of pediatric TBI management practices across different geographic regions or healthcare systems. While the child protection team's multidisciplinary evaluation is an established approach for assessing suspected child abuse cases, it can be influenced by subjective clinical judgment and variability in documentation quality, introducing potential bias. Additionally, stratification of cases using ICD-10 codes may have been affected by inaccuracies or inconsistencies in EMR documentation. These factors could result in case misclassification, limiting the scope of our findings. Consequently, our results should be interpreted with caution, as variations in clinical and coding practices can impact both patient identification and outcome classification. Furthermore, despite adjusting for key demographic and clinical variables, there may be other unmeasured confounders that influence the observed outcomes. Additionally, the use of the SDI based on ZCTAs may not fully capture the nuanced socioeconomic factors affecting individual patients.

We must also recognize the potential for bias in child abuse reporting, especially toward racial and socioeconomic minorities.[45] Both implicit and explicit biases among mandated reporters can lead to disproportionate reporting and increased scrutiny of families from marginalized communities, highlighting the need to interpret these findings with caution and to account for broader systemic influences.

Future studies should aim to include multicenter data and a more granular neighborhood disadvantage index to enhance generalizability. Moreover, incorporating social work and legal information, such as details on legal actions taken against perpetrators or confessions made in child abuse cases, could provide a more comprehensive understanding of the broader context surrounding these injuries. Prospective study designs should also be considered to better understand causality. Continued efforts to develop and implement risk-adjusted care strategies are essential for improving the management and outcomes of pediatric TBI, particularly in vulnerable populations affected by child abuse.

Conclusions

Our study investigates neighborhood deprivation, injury severity, and adverse outcomes in pediatric child abuse patients sustaining TBI. The findings reveal that child abuse patients are more likely to be transported to the hospital via private means and admitted during nighttime hours. They tend to have prolonged hospital stays, nonroutine discharges, ICU admissions, and higher mortality rates on admission. These insights highlight the critical need for targeted interventions to address social inequities and improve healthcare delivery for this vulnerable population. By integrating comprehensive trauma scoring systems and socioeconomic assessments into clinical practice, healthcare providers can better allocate resources and develop tailored treatment plans to optimize outcomes for pediatric TBI patients. Also, from a policy perspective, the findings of this study endorse structural interventions targeting neighborhood-level disadvantage as a means of supporting parents and promoting the well-being of children and families. Future research should extend these findings through multicenter collaborations to enhance generalizability and refine risk-adjusted care strategies, ultimately improving management and outcomes for pediatric TBI patients affected by abuse.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Kazemi, Robinson. Acquisition of data: Kazemi. Analysis and interpretation of data: Kazemi. Drafting the article: Kazemi, Jiang. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Kazemi. Statistical analysis: Kazemi. Administrative/technical/material support: Kazemi. Study supervision: Robinson, Cohen.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

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