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# Non-Accidental Trauma is an independent risk factor for mortality among injured infants

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## Introduction:

There were over 650,000 children confirmed to be victims of abuse or neglect by the Centers for Disease Control (CDC) in 2016 and an estimated 1 in 4 children will experience abuse or neglect in their lifetime[1]. While trauma is the leading cause of death for all children[2], non-accidental trauma (NAT) is particularly prevalent in infants and toddlers[3, 4].

There has been a concerted effort on a national scale since the 1960s to identify and prevent the injuries associated with child abuse[5]. These efforts have included the formation of Child Protective Services, passage of the Child Abuse Prevention and Treatment Act, as well as the development of evidence-based practices for the prevention of child abuse by the CDC[6, 7]. Despite 40 years of targeted intervention, the mortality rates for NAT-children admitted to the hospital in the early 2000s was reported between 8–17%[3, 8–10].

Unfortunately, more contemporary estimates show similar mortality rates–a 2018 study focusing on socioeconomic determinants of NAT using the Kids Inpatient Database reported a mortality of 17% for inpatient pediatric patients[4]. So, deliberate government efforts, and even a new pediatric subspecialty devoted to victims of NAT[11], have failed to address the mortality for inpatient pediatric victims of NAT.

The problem of intentional trauma, unfortunately, is particularly high in infants. While the overall incidence of abuse in children is around 6 per 100,000 children, the highest incidence is in children < 1 year of age (58 per 100,000)[12]. Single institution studies examining NAT in pediatric patients have demonstrated the prevalence of distinct injury patterns and provided some perspective on outcomes associated with these mechanisms[10, 13–15]. However, these studies are restricted by the broad age range and the limited conclusions that can be drawn from single institution data. National database studies and multi-institution studies have also largely been focused on broad age ranges of pediatric patients[8, 16] or address largely demographic/socioeconomic factors in NAT[4, 17].

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To our knowledge, there has not been a recent, national descriptive analysis focusing solely on infant trauma patients. The objective of this study was to provide a contemporary description of trauma in infants and to determine its effect on mortality. We hypothesized that NAT would be independently associated with increased mortality when compared with accidental trauma (AT).

## Materials and Methods:

### A. Data Source and Cohort

The Pediatric Trauma Quality Improvement Program (TQIP) database was queried for all infants (age < 1 year) between 2014 and 2016. The Pediatric TQIP was first started by the American College of Surgeons (ACS) in 2014 as a way for participating centers to benchmark their trauma specific outcomes with other ACS-verified pediatric trauma centers participating in the program. Currently, there are over 100 ACS-verified, pediatric trauma centers that contribute to TQIP, and it collects a variety of patient demographic information, diagnoses, outcomes and patient disposition. Few authors have focused solely on infants, despite this population having been identified as particularly at risk[12]. Limiting the study to children <1 year of age also allowed for a more homogenous population of patients with more limited risk factors for injury (e.g. the inability to walk).

### B. Patient Demographics, Characteristics and Outcomes

NAT was defined by International Classifications of Disease version-9 (ICD-9) event codes (967 – 967.9). All other injuries and mechanisms were identified with the appropriate ICD-9 diagnosis code. For the purpose of this study, ICD-10 diagnosis codes were ignored as full implementation within the database did not take place until after the time period of the study. Patient demographic information was collected including race/ethnicity, sex, mechanism of injury, injury severity score (ISS), injuries, and Pediatric ACS-Level Verification. The outcomes evaluated included hospital length of stay (LOS), intensive care unit (ICU) LOS, ventilator days, complications (urinary tract infection, pneumonia, severe sepsis), and mortality. All missing data points were not imputed but treated as missing, which was < 10% for all fields examined. Descriptive statistics were used to compare NAT infants and AT infants, as well as those infants that died compared with those that survived.

### C. Statistical Analysis

Descriptive statistics were performed for all variables. Categorical data were reported as percentages, and continuous data were reported as medians with interquartile range (IQR). A Mann-Whitney U was used to compare continuous variables and Chi-square was used to compare categorical variables for bivariate analysis. Odds of mortality was determined using a stepwise, hierarchical multivariable logistic regression model. All variables were eligible for inclusion in the multivariable model. Initial selection was chosen based on univariate analysis (magnitude threshold $p<0.2$) and review of the literature[18, 19]. We then performed a stepwise, hierarchical regression to select the model with the best fit for the outcome of interest—mortality. Risk of mortality was reported with odds ratio (OR) and 95% confidence interval. Statistical significance was defined as $p<0.05$. All statistical analyses were performed with IBM SPSS Statistics for Windows, Version 24. (Armonk, NY: IBM Corp).

## Results:

### A. Baseline Characteristics

We identified 14,965 infants between 2014–2016 who were victims of trauma. These infants were predominantly white (60.3%), presented to an ACS Level I Pediatric trauma center (53.5%), and had a median ISS of 9.0 (IQR 6). The most common mechanism of injury was fall (48.6%) followed by NAT (14.5%). The most common injury was TBI (50.8%), with 43.6% of head injuries categorized as severe (AIS-Head Grade > 3). The next most common injuries were lower (13.7%) and upper extremity (9.5%) fractures. The overall mortality was 2.1% with a median LOS of 2 (IQR 2) days (Table 1).

### B. Non-Accidental Trauma Infants

There were a total of 2,172 infants presenting after NAT. The majority of NAT infants were white (60.2%), however black infants were over-represented when compared with AT infants (23.6% vs. 18.3%, $p < 0.0001$). The most common injury was TBI (64.5%) followed by lower extremity (27.5%) and upper extremity fractures (20.4%). The incidence of TBI (64.5% vs. 48.5%, $p<0.0001$), lower extremity fracture (27.5% vs. 11.3%, $p<0.0001$), and upper extremity fracture (20.4% vs. 7.7%, $p<0.0001$) were more common in infants with NAT compared to AT mechanisms.

NAT infants had a higher median ISS (10 vs. 9, $p<0.0001$) and a longer median hospital LOS (4 vs. 2 days, $p<0.0001$). Urinary tract infections (0.9% vs. 0.2%, $p<0.0001$) and pneumonia (1.5% vs. 0.2%, $p<0.0001$) were more frequently observed in those infants with NAT. There was a higher observed mortality (6.1% vs. 1.4%, $p < 0.0001$) in NAT infants (Table 2).

### C. Primary outcome: mortality

A total of 317 (2.1%) infants died over the study period. The most common mechanism was NAT (41.6%) followed by falls (13.2%). The incidence of NAT was more frequent in those infants that died compared to those that lived (41.6% vs 13.9%, $p<0.0001$). The median ISS was 26 (IQR 14) for those infants that died compared with 9 (IQR 6, $p<0.0001$) for those that lived. TBI, central axis fractures and visceral injuries were all more common in those infants that died (Table 3). However, lower extremity fractures were more common in those infants that lived (13.8% vs. 8.5%, $p<0.0001$). For 113 (35.6%) infants, support was withdrawn prior to death.

A multivariable logistic regression revealed that hypotension within 24 hours (OR 8.93, CI 5.34–14.92, $p<0.001$) and NAT mechanism (OR 2.48, CI 1.80–3.41, $p<0.001$) had the highest association with mortality (Table 4). In addition, both ISS (OR 1.12, $p <0.0001$) and Severe (Grade > 3) AIS-head (OR 1.62, $p = 0.0135$) were also associated with an increased risk of mortality within the model.

## Discussion:

In this study, we have demonstrated using a large, nationwide dataset that infants who are victims of NAT have more severe injuries, a higher rate of TBI, increased incidence of in-hospital complications, and overall increased mortality when compared to AT infants. Furthermore, black infants were disproportionately represented in the NAT population (23.6% vs. 18.3%, $p < 0.0001$). When adjusting for significant covariates, NAT was found to be a strong independent risk factor for overall infant mortality.

A 2011, study using the Kid's Inpatient Database looking specifically at intentional vs. unintentional blunt abdominal trauma showed longer hospitalizations and higher mortality for pediatric patients with NAT. However, subgroup analysis of the infant patients failed to show any difference in mortality, which differs from our findings [16]. It is likely that this difference can be attributed to the exclusion of TBI in their study, as over 60% of patients that died in our study had a head injury.

NAT being the second most common mechanism of injury is particular concerning when you consider that we showed increased LOS, increased UTI, increased PNA and higher ISS for NAT infants compared to AT infants. While our study focused specifically on infant trauma patients, many comparisons can be drawn from existing pediatric trauma literature, as the infant population represents the largest age subset within the NAT pediatric population. In a retrospective review of the National Pediatric Trauma Registry in 2000, DiScala et al. showed longer LOS, increase ICU admissions, and higher ISS for pediatric patients who suffered an intentional injury, though they did not show an independent association between NAT and these findings using a multivariable logistic regression as was demonstrated in our study[8]. In 2011, a retrospective review of the Kids Inpatient Database showed longer LOS and increased hospital charges with NAT. Similarly, multiple single institution studies have shown an association between NAT, more severe injuries, and increased mortality [10, 13, 14], which is consistent with our findings. However, to our knowledge, no one has shown this increase in mortality while also adjusting for overall injury severity and adjusting for serious TBI in a national dataset.

While the longer LOS for NAT infants that we observed in our study could be related to injury severity, it could also be explained by other factors. Lee et al. in 2017 showed that up to 36% of children who were the victims of abuse stayed beyond the time of medical necessity [15]. This could explain the longer LOS in our data as well, but, unfortunately, we cannot make that determination with the data available. However, we also demonstrated a longer ICU LOS in NAT patients, which suggest that at least some portion of the increase LOS is related to injury severity. Future prospective research is needed to better delineate why NAT is associated with increased LOS and how to further mitigate this. No one to our knowledge has demonstrated the association with increased complication rates (UTI, sepsis, pneumonia) and NAT. The causative factor behind the increase in complication rates is unclear, but it is likely multifactorial including delayed presentation to the hospital and more severe injuries. Furthermore, we observed a longer LOS for NAT patients, which could have increased the risk of nosocomial infections and/or complications. However, the incidence of these complications is quite low in both groups, and this association should be accepted with caution.

Although white infants made up the largest portion of overall and NAT-infants, black infants were disproportionately represented as victims of abuse, supporting the findings of previous demographic studies looking at NAT [4]. However, there is some evidence that white infants with TBI are less likely to be evaluated for NAT or referred to child protective services, indicating that this overrepresentation of black infants with NAT could be secondary to provider bias [20]. It is unclear whether this represents variable reporting or a real difference, but providers need to be aware of potential bias when it comes to diagnosing NAT, especially since there has been a reported connection between infant death from preventable injuries and race, regardless of socioeconomic status [21].

As a retrospective database study there are inherent limitations including the potential for selection bias or miscoding errors. In addition, the TQIP database only records those infants that are admitted as trauma patients thus does not include minor traumatic injuries or patients presenting to non-TQIP centers. Furthermore, TQIP only evaluates index hospitalization outcomes and tracks child abuse by event codes which may misrepresent the true incidence and patient population of NAT as there is no way to differentiate suspected from confirmed NAT. There is also no way to track those infants that were victims of abuse but were unsuspected. In addition, the database lacks pertinent information such as socioeconomic status [4, 12, 16, 17] and prior history of abuse [22, 23], which could potentially impact outcomes. We were also unable to determine birth history or prior medical history information from the TQIP database which have been shown to be risk factors for NAT [8].

The previous assumption has been that the increased mortality rates in NAT have been related to worse overall injuries. However, we demonstrated that the risk of mortality in NAT is not driven by injury severity alone. This indicates that there is likely an uncaptured variable driving this risk. Providers that evaluate pediatric trauma patients need to be aware that a non-accidental mechanism alone increases an infant's likelihood of mortality, and future studies are needed to help elucidate what is driving this increased risk.

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**Table 1.**

Demographics and outcomes of infant trauma patients

| Demographics/Characteristics | N = 14,965 |
|---|---|
| *Race/Ethnicity, n, (%)* | |
| White | 9031 (60.3%) |
| Black | 2848 (19%) |
| Asian | 317 (2.1%) |
| Hispanic | 2493 (16.7%) |
| *Male, n, (%)* | 8557 (57.2%) |
| *Mechanism of injury, n, (%)* | |
| Fall | 7277 (48.6%) |
| Motor vehicle accident | 627 (4.2%) |
| Bicyclist | 23 (0.2%) |
| Pedestrian struck | 205 (1.4%) |
| Child abuse | 2172 (14.5%) |
| Stab wound | 81 (0.5%) |
| Gunshot-wound | 31 (0.2%) |
| *ISS, median (IQR)* | 9 (6) |
| *Lowest 24hr-SBP, median (IQR)* | 70 (40) |
| *Injury, n, (%)* | |
| Traumatic brain injury | 7607 (50.8%) |
| Spine | 191 (1.3%) |
| Rib | 512 (3.4%) |
| Upper extremity fracture | 1424 (9.5%) |
| Lower extremity fracture | 2048 (13.7%) |
| Pelvis | 90 (0.6%) |
| Liver | 175 (1.2%) |
| Spleen | 63 (0.4%) |
| Burn | 32 (0.2%) |
| *Pediatric ACS-Level Verification, n, (%)* | |
| I | 8004 (53.5%) |
| II | 2364 (15.8%) |
| **Outcomes** | |
| *LOS, days, median (IQR)* | 2 (2) |
| *ICU days, median (IQR)* | 2 (2) |
| *Ventilator days, median, (IQR)* | 4 (2) |
| *Complications, n, (%)* | |
| Urinary tract infection | 42 (0.3%) |
| Pneumonia | 53 (0.4%) |
| Severe sepsis | 11 (0.1%) |

| **Demographics/Characteristics** | **N = 14,965** |
|---|---|
| *Mortality, n, (%)* | 317 (2.1%) |

**Table 2.**

Comparison of demographics and outcomes between NAT and AT infants

| Demographics/Characteristics | NAT (N=2,172) | AT (N=12,793) | P-Value |
|---|---|---|---|
| *Race/Ethnicity, n, (%)* | | | |
| White | 1307 (60.2%) | 7724 (60.4%) | 0.9298 |
| Black | 512 (23.6%) | 2336 (18.3%) | < 0.0001 |
| Asian | 17 (0.8%) | 300 (2.3%) | < 0.0001 |
| Hispanic | 345 (15.9%) | 2148 (16.8%) | 0.3034 |
| *Male, n, (%)* | 1289 (59.3%) | 7268 (56.8%) | 0.0301 |
| *ISS, median (IQR)* | 10 (7) | 9 (6) | <0.0001 |
| *Lowest 24-hr SBP, median, (IQR)* | 74 (29) | 70 (46) | 0.4550 |
| *Injury, n, (%)* | | | |
| Traumatic brain injury | 1400 (64.5%) | 6207 (48.5%) | < 0.0001 |
| Spine | 97 (4.5%) | 94 (0.7%) | < 0.0001 |
| Rib | 403 (18.6%) | 109 (0.9%) | < 0.0001 |
| Upper extremity fracture | 444 (20.4%) | 980 (7.7%) | < 0.0001 |
| Lower extremity fracture | 597 (27.5%) | 1451 (11.3%) | < 0.0001 |
| Pelvis | 1 (0.5%) | 89 (0.7%) | 0.2911 |
| Liver | 82 (3.8%) | 93 (0.7%) | < 0.0001 |
| Spleen | 11 (0.5%) | 52 (0.4%) | 0.5502 |
| Burn | 23 (0%) | 9 (0.1%) | < 0.0001 |
| *Pediatric ACS-Level Verification, n, (%)* | | | |
| I | 1158 (53.3%) | 6846 (53.5%) | 0.8628 |
| II | 363 (16.7%) | 2001 (15.6%) | 0.1933 |
| **Outcomes** | | | |
| *LOS, days, median (IQR)* | 4 (2) | 2 (1) | <0.0001 |
| *ICU days, median (IQR)* | 4 (2) | 2 (2) | <0.001 |
| *Ventilator days, median (IQR)* | 5 (3) | 3 (6) | <0.001 |
| *Complications, n, (%)* | | | |
| Urinary tract infection | 20 (0.9%) | 22 (0.2%) | <0.0001 |
| Pneumonia | 32 (1.5%) | 21 (0.2%) | <0.0001 |
| Severe sepsis | 5 (0.2%) | 6 (0%) | 0.0129 |
| *Mortality, n, (%)* | 132 (6.1%) | 185 (1.4%) | <0.0001 |

**Table 3.**

Comparison of demographics and outcomes between infants that survived vs. died.

| Demographics/Characteristics | Died (N=317) | Lived (N=14,648) | P-Value |
|---|---|---|---|
| *Race/Ethnicity, n, (%)* | | | |
| White | 194 (61.2 %) | 8837 (60.3%) | 0.7192 |
| Black | 70 (22.1 %) | 2778 (19%) | 1 |
| Asian | 1 (0.3 %) | 316 (2.2%) | 0.0309 |
| Hispanic | 39 (12.3%) | 2208 (15.1%) | 0.1677 |
| *Male, n, (%)* | 198 (62.5 %) | 8359 (57.1%) | 0.0752 |
| *Mechanism of injury, n, (%)* | | | |
| Fall | 42 (13.2 %) | 7235 (49.4%) | < 0.0001 |
| Motor vehicle accident | 33 (10.4 %) | 594 (4.1%) | < 0.0001 |
| Bicyclist | 0 (0 %) | 23 (0.2%) | 0.4805 |
| Pedestrian struck | 13 (4.1 %) | 192 (1.3%) | < 0.0001 |
| Child abuse | 132 (41.6 %) | 2040 (13.9%) | < 0.0001 |
| Stab wound | 4 (1.3 %) | 77 (0.5%) | 0.5965 |
| Gunshot-wound | 4 (1.3 %) | 27 (0.2%) | < 0.0001 |
| *ISS, median (IQR)* | 26 (14) | 9 (6) | <0.0001 |
| *Lowest 24-hr SBP, median (IQR)* | 61 (23) | 74 (93) | 0.0040 |
| *Injury, n, (%)* | | | |
| Traumatic brain injury | 200 (63.1 %) | 7407 (50.6%) | < 0.0001 |
| Spine | 22 (6.9 %) | 169 (1.2%) | < 0.0001 |
| Rib | 45 (14.2 %) | 467 (3.2%) | < 0.0001 |
| Upper extremity fracture | 32 (10.1 %) | 1392 (9.5%) | 0.9532 |
| Lower extremity fracture | 27 (8.5 %) | 2021 (13.8%) | 0.0051 |
| Pelvis | 5 (1.6 %) | 85 (0.6%) | 0.025 |
| Liver | 16 (5 %) | 159 (1.1%) | < 0.0001 |
| Spleen | 10 (3.2 %) | 53 (0.4%) | < 0.0001 |
| Burn | 1 (0.3 %) | 31 (0.2%) | 0.6949 |
| *Pediatric ACS-Level Verification, n, (%)* | | | |
| I | 179 (56.5 %) | 7825 (53.4%) | 0.2897 |
| II | 52 (16.4 %) | 2312 (15.8%) | 0.7721 |
| **Outcomes** | | | |
| *LOS, days, median (IQR)* | 2 (2) | 2 (2) | 0.31 |
| *ICU days, median (IQR)* | 3 (2) | 2 (2) | <0.0001 |
| *Ventilator days, median (IQR)* | 3 (2) | 5 (7) | <0.0001 |
| *Complications, n, (%)* | | | |
| Urinary tract infection | 1 (0.3 %) | 41 (0.3%) | 1 |
| Pneumonia | 8 (2.5 %) | 45 (0.3%) | < 0.0001 |
| Severe sepsis | 4 (1.3 %) | 7 (0%) | < 0.0001 |

| Demographics/Characteristics | Died (N=317) | Lived (N=14,648) | P-Value |
|---|---|---|---|
| *Withdrawal of Care, n, (%)* | 113 (35.6%) | 0 (0%) | < 0.0001 |

**Table 4.**

Multivariable logistic regression of mortality risk for trauma infants

| Variable | OR | CI | P-value |
|---|---|---|---|
| Non-accidental trauma | 2.48 | 1.80–3.41 | <0.0001 |
| Hypotension (SBP≤70) | 8.93 | 5.34–14.92 | <0.0001 |
| Injury severity score | 1.12 | 1.11–1.14 | <0.0001 |
| Severe (grade>3) AIS-head | 1.62 | 1.11–2.38 | 0.0135 |