# ASSOCIATED RISK OF HEAD TRAUMA IN CHILD MALTREATMENT

A thesis submitted to the University of Arizona College of Medicine – Phoenix
in partial fulfillment of the requirements for the Degree of Doctor of Medicine

Shivani Misra
Class of 2020

Mentor: David Beyda, MD

# Associated risks of head trauma in child maltreatment

S Misra, MSIV[1,2,7], DM Notrica, MD[1,2], L Kirsch, MD[1], C Kelly, MSW[1,3], J Greenberg MA[1], LW Sayrs, PhD[1,2], J. Bryce Ortiz[2,4], Tabitha R. Green[2,4,5], Rachel K. Rowe[2,4,6], Jonathan Lifshitz, PhD[2,4,6]

[1]Phoenix Children's Hospital, Phoenix, AZ

[2]University of Arizona College of Medicine-Phoenix, Phoenix, AZ

[3]Arizona State University School of Social Work, Center for Child Well-Being, Tempe, AZ

[4]BARROW Neurological Institute at Phoenix Children's Hospital, Phoenix, AZ

[5]Department of Biological Sciences, University of Bath, Bath, UK

[6]Phoenix Veteran Affairs Healthcare System, Phoenix, AZ

[7]Corresponding author information: Shivani Misra, MSIV: smisra@email.arizona.edu

No disclosures

## ABSTRACT

Background- Almost 70% of infant deaths are associated with head trauma, making traumatic brain injury a leading cause of death and disability in infants. Those who survive have lifelong physical, developmental, and emotional sequelae. As such, efforts to characterize and understand the factors that lead to head trauma in infants is critical.

Methods- This was a single-institution, retrospective review of suspected AHT patients from 2010-2017. Data were collected on demographics, hospitalization, injury, family characteristics, socio-behavioral characteristics, physical examination, laboratory findings, imaging, discharge, and other follow-up information on fatal and non-fatal head trauma. Statistical analysis involved descriptive statistics, logistic regression, and receiver operating characteristics.

Results- Key risks associated with AHT included bruising (OR: 6.1; 95%CI: 3.5–10.5), multiple fractures (OR: 9.5; 95%CI: 4.2–21.5), unknown method of injury (OR: 3.9; 95%CI: 2.2–7.0), self-reported history of substance abuse (OR: 8.8; 95%CI: 3.0–26.0), prior Child Protective Services reports (OR: 2.1; 95%CI: 1.1-3.9), prior police involvement (OR: 5.3; 95%CI: 2.7-10.4), domestic violence (OR: 1.3; 95%CI: 1.3-5.5), and unknown number of adults in the home (OR: 4.2; 95%CI: 2.4-7.4). The regression model captured 57% of the variance, was 73% sensitive, and was 90% specific using ROC.

Conclusions- We propose to broaden the classification of AHT to include inflicted injury and non-inflicted injury, along with a new category called “traumatic injury from an unexplained event.” An expanded classification system for AHT would capture abuse, neglect, and undetermined patients, making AHT more useful in surveillance, screening, treatment, and prevention of head injury in very young children.

## INTRODUCTION

Child maltreatment is characterized by the infliction of intentional injury (abuse) and/or non-inflicted injury (neglect). In 2016, 7.5 million children believed to have been harmed or at risk of harm were reported to public child protective service agencies in the United States[72]. Of those children, an estimated 3.5 million were involved in cases that warranted further investigation, and 676,000 were subsequently deemed victims of maltreatment[72]. Among these victims, those under the age of 3 were disproportionally represented (70%), with the highest rate of maltreatment occurring in the first year of life. Medical providers play an important role in the identification of victims, as they referred 9.5% of child maltreatment cases to child protective agencies nationally[1]. The vulnerability of this age range (0-3 years) cannot be understated. Not only are these children at the greatest risk of death from maltreatment, but the negative developmental consequences of non-fatal maltreatment also manifest in functional domains later in life.[2-4]

Non-accidental trauma (NAT) is a term used to describe any injury that arises from maltreatment. NAT injuries can occur from neglect or abuse. A recent, single-institution study estimated that non-accidental injuries constitute approximately 45% of all pediatric traumatic deaths.[5] NAT is the second-leading cause of death in the pediatric population behind motor vehicle accidents.[6] Injury patterns specific to inflicted NAT are well described.[7,8] These include radial and metaphyseal fractures, rib fractures, long bone fractures, multiple fractures, and head injuries.[9-11] These injuries and other clinical indications, such as bruising, patterned bruising, burning, and scars often co-occur with NAT.[10-12] Studies have shown that more than half of fatal traumatic brain injury (TBI) cases are the result of NAT.[13-14]

AHT can lead to lifelong disabilities in survivors and significantly impacts society. 80% of AHT survivors display serious lifelong physical, developmental, and emotional sequelae.[4,6,25] One study showed that AHT in early life was associated with significantly increased rates of various mental disorders such as major depressive disorder, drug use, suicide attempts, sexually transmitted infections, and various high-risk behaviors.[26] Another study identified long-term financial and economic consequences as risk factors, such as lower rates of employment and earning, as well as fewer assets as adults.[2] Furthermore, long-term outcomes following AHT are dependent on many factors, including injury characteristics, family dynamics, and individual characteristics. Age at injury appears to be a critical factor in how an individual recovers from AHT, with younger individuals associated with impairments in long-term functional outcomes in domains such as communication and problem solving.[27] Besides the effects on individuals, AHT has significant impacts on society. A recent study estimated that the costs of an individual AHT case can exceed $3 million in terms of medical costs, lost wages, disability, and government and educational services.[28] Clearly AHT is a debilitating condition. However, AHT often goes undiagnosed. Failure to diagnose AHT on the initial presentation significantly increases the probability of repeated abuse and death.[23,24]

In an attempt to prevent AHT, knowledge campaigns have been developed and implemented to address caregiver triggers and knowledge; however, the effect of these interventions is not well established.[29] One identified, well-recognized pathway of AHT is infliction of injury by caregivers who are triggered by infant crying.[29] This inflicted pathway, however, does not account for all head trauma in very young children. Other causes include injuries from neglect, another form of maltreatment. Little is known about the mechanisms of injury or the psychosocial and family risk factors associated with non-inflicted head trauma in

infants and young children.[25,30-32] However, research on maltreatment reveals a variety of patient, caregiver, family, and environmental characteristics that may put children at higher risks for injury, including child prematurity, low birth weight, maternal age, parental depression, education level, unemployment, substance abuse, domestic violence and aggression, poverty, large family size, single parenting, and lack of social connectedness.[25,33-35] Few studies have linked these factors empirically to pediatric injury and head trauma specifically, whether inflicted or non-inflicted.[8,36-38] Yet, identifying the etiology of head trauma early has important implications for timely medical intervention and appropriate identification and coordination of effective interventions to protect infants and young children.[29] The purpose of this research was to analyze patient and injury characteristics associated with inflicted head trauma to develop a pre-admission screening algorithm that can be implemented in the clinic in order to more accurately identify AHT.

## METHODS

In this study, we performed a single-institution, retrospective review of a cohort of pediatric patients with suspected AHT. We examined patient, caregiver, injury, and other characteristics associated with pediatric head trauma to improve screening and surveillance. Phoenix Children's Hospital (PCH) is a large, urban institution and the only level I trauma center in Arizona. During the study period, PCH referred cases of suspected AHT to an institution-based Child Protection Team (CPT) for further evaluation, follow-up by social service agencies, and forensic determination of physical abuse for all children who either presented in the emergency department (ED) or were admitted to the hospital. Members of the team include attending physicians, nurse practitioners, and social workers. The CPT classifies all reported patients into one of three categories: probable abuse, probable not abuse, and undetermined. For

all suspected AHT patients, data on demographics, hospitalization, injury, family characteristics, socio-behavioral characteristics, physical examination, laboratory findings, imaging, discharge, and other follow-up information were collected from patient charts and maintained in the PCH forensic registry under PCH IRB 09-055. Data were extracted from the registry and analyzed under PCH IRB 17-015. All patients with incomplete data were excluded from analyses case-wise based on the respective variables. SPSS version 18 was utilized for all data analyses. Statistical significance was set at $p<0.05$ for all statistical tests.

Fatal and non-fatal head injury alone or in combination with other injuries were included (n=804). Descriptive and non-parametric statistics were used to assess differences between head injuries classified as probable AHT, not probable AHT, and undetermined. Simple logistic regression was used to estimate unadjusted odds ratios (OR) for covariates of interest for inclusion in multiple logistic regression models. Multiple logistic regression was used to estimate adjusted odds ratios (AOR) for main effects while controlling for any potential confounders (a priori or from univariate). The final model assessed risk factors for AHT utilizing a dichotomous variable (i.e., probable/not probable AHT). Undetermined patients were excluded from the model. Area under the receiver operating characteristic curve was calculated to determine model sensitivity and specificity.

## RESULTS

Head injuries in 804 patients (10% of the total trauma population) qualified as suspected AHT, and 72 patients were also characterized as experiencing child neglect. There were major differences for suspected AHT patients vs. the general trauma population (Table 1). Specifically,

75% of AHT patients were under 1 year of age and 87% were under 2. By contrast, 63% of the trauma population was over 4 years of age.

Table 1. Characteristics of suspected AHT cohort vs. all trauma at PCH, 2010-2016

| | **2010-2016 Suspected AHT N=804 n (%)** | **2010-2016 Total Trauma Population N=16,138 n (%)** | **p-value** |
|---|---|---|---|
| **Age** | | | < .001 |
| <12 mo | 603 (75) | 1654 (10) | |
| 12-35mo | 132 (12) | 1260 (8) | |
| 36-47mo | 35 (4) | 3176 (20) | |
| >48 mo | 34 (4) | 10048 (63) | |
| **Gender** | | | < .001 |
| Male | 469 (59) | 6315 (39) | |
| Female | 331 (41) | 9823 (61) | |
| **Race** | | | < .001 |
| Caucasian | 275 (34) | 6839 (42) | |
| Hispanic | 338 (42) | 4516 (28) | |
| African-American | 54 (7) | 1156 (7) | |
| Native American | 91 (11) | 1203 (8) | |
| Other | 41 (5) | 4811 (30) | |
| **Insurance** | | | <.001 |
| Private | 170 (21) | 5613 (35) | |
| Public | 609 (76) | 9470 (59) | |
| None | 18 (2) | 941 (6) | |

All 804 patients classified as suspected AHT presented with a head injury. However, only 640 patients (80%) had at least one abnormal finding from a computed tomography (CT) scan of the head. The head CT for 163 patients yielded normal/unremarkable results, and 2 were unable to be imaged (Table 2). Of 731 total findings in the head injury cohort were the following rates

of diagnosis: 61% skull fracture, 30% subdural hematoma, and 23% intracranial bleed. Additionally, 19% of findings included further classification and description of the intracranial hemorrhage (e.g., subarachnoid hemorrhage (29%), extra-axial hemorrhage (57%), location and size of the hemorrhage, edema, swelling, contusions, thickening, and evidence of older bleeding). There were 56 CT findings among the 50 patients with fatal injuries. Of these, 5 patients were dead on arrival (DOA) and not imaged; 2 patients died from organ failure; 1 patient died from a bowel perforation, and the remaining 42/50 (80%) had fatal brain injuries. Two of the fatal brain injuries occurred from submersion, and the remaining 40 resulted from blunt force trauma. All 40 were classified as probable AHT. Multiple fractures occurred in 12 patients (24%) and healing fractures occurred in 11 (22%). Table 2 shows that fatal head injuries had higher proportions of hypoxic ischemic encephalopathy (10%) and lower proportions of skull fracture (10%) than the non-fatal head injuries.

Table 2. Abnormal head imaging findings for fatally and non-fatally injured suspected AHT patients

| **Head Imaging Findings [1] (CT)** | **All Head Injury Imaging N=731 (%)** | **Fatalities with Head Imaging N=56 (%)** |
|---|---|---|
| Skull fracture* | 448 (61) | 6 (10) |
| Epidural hematoma | 50 (<1) | 1(<1) |
| Subdural hematoma | 216 (30) | 15 (27) |
| Intracranial hemorrhage (brain bleeds) | 170 (23) | 9 (16) |
| Other brain injury and bleeding | 142 (19) | 19 (34) |
| Hypoxic ischemic encephalopathy | 5 (<1) | 6 (10) |

[1]640 patients had 731 findings. 42 patients with fatal injuries had 56 findings. Patients may have more than one abnormal finding.
* Indicates significant differences between groups; p-value < 0.05.

*Characteristics of inflicted and non-inflicted head trauma*

Table 3 presents perinatal injury and family characteristics for the 804 suspected AHT patients compared by determination. Of 804 patients presenting with fatal or non-fatal head injury, 276 (34%) were determined probable AHT, 343 (43%) were deemed not probable AHT, and 185 (23%) were undetermined. The median age was 7 [3-16] months for probable AHT. For all 50 fatal head injuries, 36 (72%) were determined probable, 2 (<1%) not probable, and 12 (24%) were undetermined. Of 42 head fatalities, 38 (90%) were under the age of 5, but a somewhat larger proportion of children (33%) fell into the 2-5 age range for fatalities as compared with non-fatal injuries. The median interquartile [IQR] age for a fatally injured patient was 21 [2-42] months.

There was a higher proportion of Native American ethnicity for fatally injured (21%) compared to non-fatally injured patients (all determinations). The proportions of fatal injuries among other reported ethnicities were comparable with a determination of probable AHT. Table 3 also shows that the majority of patients live with a biological parent who is either single or has a live-in partner. The relatively high proportions of "other" suggest family arrangements not accounted for by conventional demographic measures of family composition.

Less than 25% of patients with probable AHT had married parents, compared to 43% whose AHT status was undetermined. Unreported parental marital status (55%) was highest among patients who were determined probable not AHT. Live-in partner marital status represented 67% of fatal injuries. The highest proportion of patients whose length of stay (LOS) was greater than 72 hours was the probable group (48.5%) versus 49.8% in the 13-24 hour range for patients who were determined not probable AHT. For fatalities, the LOS was similar to the

probable AHT group. Almost 40% of patients with probable AHT did not report a method of injury (MOI unknown), which was comparable to the proportion of undetermined patients reporting unknown MOI. Falls were the most frequently reported MOI for fatal injuries (31%) compared to unknown MOI (45%).

Both prior domestic violence (DV) and Child Protective Services (CPS) reports demonstrated a similar pattern. For DV, the rate of patients deemed probable AHT (19%) was comparable to the rate of DV in undetermined patients (20%). By contrast, DV occurred at a much lower rate (7%) in patients with a determination of not probable AHT. The difference was not statistically significant between DV reported for fatally injured patients (14%) and for all head injuries (19.2%). The rate of patients determined probable AHT with prior CPS reports (34%) was comparable to the rate of prior CPS reports in undetermined patients (30%), the rate being much lower for not probable AHT (13%). Though not statistically significant, CPS reports occurred in 52% of fatally injured patients.

There were high rates of unreported alleged perpetrator. For probable AHT patients with any fatal or non-fatal head injury, the perpetrator was the mother or father in 39.5% of cases, and significant other accounted for 13.8% of alleged perpetrators. The alleged perpetrator in fatal injuries was unknown for 12% of patients.

Table 3. Family, injury, and psychosocial characteristics of abusive head trauma

| | **All Head Injuries** | | | **Head Fatalities** |
|---|---|---|---|---|
| **Characteristic** | **Probable AHT** | **Probable Not AHT** | **Undetermined AHT** | **All Determinations** |
| | n = 276 (%) | n = 343 (%) | n=185 (%) | n = 42 (%) |
| **Age** | | | | |
| Median [IQR] months | 7 [3-10] | 7 [3-16] | 8 [3-12] | 21 [2-42] |

| | | | | |
|---|---|---|---|---|
| 0 – 12m* | 196 (71.0) | 283 (82.5) | 133 (73.9) | 17 (40.5) |
| 13m – 24m | 35 (12.7) | 31 (9.0) | 23 (12.8) | 7 (16.7) |
| 2y – 5y | 33 (11.9) | 23 (6.7) | 20 (11.1) | 14 (33.3) |
| ≥ 5y* | 12 (4.3) | 6 (1.7) | 3 (1.7) | 4 (9.5) |
| **Gender** | | | | |
| Male | 151 (54.7) | 209 (60.9) | 109 (60.9) | 23 (54.8) |
| Female | 125 (45.3) | 134 (39.1) | 71 (39.2) | 19 (45.2) |
| **Race/Ethnicity** | | | | |
| Caucasian | 103 (37.3) | 114 (33.2) | 58 (32.2) | 16 (38.1) |
| Hispanic* | 95 (34.4) | 165 (48.1) | 77 (42.8) | 12 (28.6) |
| African-American | 22 (8.0) | 16 (4.7) | 16 (8.9) | 1 (2.4) |
| Native American | 44 (15.9) | 27 (7.9) | 20 (11.1) | 9 (21.4) |
| Asian | 1 (0.4) | 2 (0.6) | 2 (1.1) | 0 (0.0) |
| Other | 11 (4.0) | 18 (5.2) | 7 (3.9) | 4 (9.5) |
| **Insurance** | | | | |
| Public | 215 (78.2) | 244 (71.1) | 149 (83.2) | 30 (71.4) |
| Private | 53 (19.3) | 89 (25.9) | 28 (15.6) | 5 (11.9) |
| None/unknown | 7 (2.5) | 9 (2.6) | 2 (1.1) | 7 (16.7) |
| **Caregiver Marital Status** | | | | |
| Married* | 64 (23.2) | 94 (27.4) | 45 (42.9) | 6 (14.3) |
| Divorced | 5 (1.8) | 0 (0.0) | 1 (1.0) | 0 (0.0) |
| Single | 67 (24.3) | 37 (10.8) | 30 (28.6) | 3 (7.1) |
| Live-in partner | 57 (20.7) | 24 (7.0) | 25 (23.8) | 28 (66.7) |
| Other/Unreported* | 83 (30.1) | 188 (54.8) | 4 (3.8) | 5 (11.9) |
| **Transfer** | | | | |
| Yes* | 134 (61.2) | 91 (26.5) | 64 (54.7) | 28 (66.7) |
| **MOI** | | | | |
| Unknown | 109 (39.5) | 49 (14.2) | 56 (31.1) | 19 (45.2) |
| Fall | 59 (21.4) | 118 (34.4) | 55 (29.7) | 13 (31.0) |
| Other | 107 (39.1) | 176 (51.4) | 112 (60.8) | 9 (21.4) |
| **Length of Stay** | | | | |
| Median [IQR] hours | 72 [43-192] | 24 [18-43] | 42 [23-66] | 42 [18-76] |
| 1-12 | 9 (3.4) | 36 (11.0) | 11 (6.4) | 1 (2.4) |
| 13-24* | 37 (14.1) | 163 (49.8) | 52 (30.2) | 13 (31.0) |
| 25-36 | 14 (5.3) | 34 (10.4) | 13 (7.6) | 3 (7.1) |
| 37-48 | 43 (16.4) | 49 (15.0) | 43 (25.0) | 6 (14.3) |
| 49-60 | 6 (2.3) | 2 (0.6) | 6 (3.5) | 1 (2.4) |
| 61-72 | 26 (9.9) | 13 (4.0) | 20 (11.6) | 5 (11.9) |
| 73+* | 127 (48.5) | 30 (9.2) | 27 (15.7) | 13 (31.0) |
| **Glasgow Coma Score** | | | | |

| | | | | |
|---|---|---|---|---|
| Severe (<8)* | 42 (19.5) | 9 (3.1) | 10 (7.3) | 42 (100) |
| Moderate (8-12) | 18 (8.4) | 3 (1.0) | 5 (3.7) | 0 (0.0) |
| Minor (≥13) | 155 (72.1) | 276 (95.8) | 122 (89.1) | 0 (0.0) |
| **Altered/ Loss of Consciousness** | | | | |
| Yes* | 63 (34.6) | 22 (7.3) | 21(13.5) | 22 (52.4) |
| No | 36 (19.8) | 213 (70.5) | 57 (36.8) | 0 (0) |
| Unknown | 83 (45.6) | 67 (22.2) | 77 (49.7) | 20 (47.6) |
| **Alleged Perpetrator** | | | | |
| Mother | 39 (14.1) | 3 (0.9) | 12 (6.7) | 8 (19.0) |
| Father | 70 (25.4) | 0 (0.0) | 6 (3.3) | 7 (16.7) |
| Significant Other | 38 (13.8) | 1 (0.3) | 2 (1.1) | 9 (21.4) |
| Relative | 11 (4.1) | 1 (0.3) | 2 (1.1) | 3 (7.1) |
| Caregiver (unrelated) | 13 (4.7) | 1 (0.3) | 2 (1.1.) | 2 (4.8) |
| Other/unknown | 32 (11.6) | 4 (1.2) | 11 (6.1) | 5 (11.9) |
| **Prior CPS report** | | | | |
| Yes | 95 (34.4) | 45 (13.1) | 54 (30.0) | 22 (52.4) |
| **Prior Police Involvement** | | | | |
| Yes | 68 (24.6) | 30 (8.7) | 26 (14.4) | 9 (21.4) |
| **Substance Use** | | | | |
| Yes | 25 (9.1) | 7 (2.0) | 6 (3.3) | 5 (11.9) |
| **Mental Illness** | | | | |
| Yes | 10 (3.6) | 15 (.4) | 5 (2.8) | 0 (0.0) |
| **Domestic Violence** | | | | |
| Yes | 53 (19.2) | 24 (7.0) | 1 (20) | 6 (14.3) |

* Indicates significant differences between groups; p-value < 0.05

***Predictors of inflicted vs. non-inflicted head trauma***

The final model with adjusted odds ratios from the multiple logistic regression is reported in Table 4.

**Table 4. Multiple LOGIT for head trauma (inflicted versus non-inflicted)**

| Variables in the Equation | B | S.E. | Sig. | Exp(B) | 95%CI |
|---|---|---|---|---|---|
| Multiple fracture | 2.148 | .451 | .000 | 9.5 | 4.2-21.5 |
| Substance abuse | 2.277 | .656 | .001 | 8.8 | 3.0-26.0 |
| Bruise | 1.722 | .313 | .000 | 6.1 | 3.5-10.5 |
| Police involvement | 1.352 | .390 | .001 | 5.3 | 2.7-10.4 |
| Unknown # of adults | 1.474 | .324 | .000 | 4.2 | 2.4-7.4 |
| MOI unknown | 1.445 | .339 | .000 | 3.9 | 2.2-7.0 |
| Domestic violence | 1.004 | .407 | .014 | 2.7 | 1.3-5.5 |
| Glasgow Coma Score < 15 | 0.966 | .303 | .001 | 2.7 | 1.6-4.5 |
| Prior CPS report | 0.702 | .328 | .032 | 2.1 | 1.1-3.9 |
| Constant | -3.631 | .380 | .000 | 0.026 | ---- |

Reference categories are the absence of the characteristic. Results include fatalities.

The regression model captured 57% of the variance (R-SQUARE=0.57) and 89% under the ROC curve (95%CI=.86-.92). The model demonstrated 73% sensitivity and 86% specificity. About 14% of the time, the model incorrectly classified a patient as AHT when the patient was not AHT. If the model characteristics were used to screen patients for probable AHT, it would incorrectly assign AHT to patients who were not AHT about 14% of the time. The model incorrectly ruled out a patient as AHT approximately 27% of the time. If used for screening, 1 in 4 true AHT patients would not be correctly identified.

*Injury characteristics*

Similar to prior research on sentinel injuries in AHT, multiple fractures and bruising were predictive.[39] Very young children with multiple fractures are ten times more vulnerable to inflicted head injury (ExpB=9.5[p<.001]). Bruising of any kind increases the odds of AHT 6-fold (ExpB=6.1[p<.001]). Not surprisingly, a Glasgow Coma Score (GCS) of less than 15, which

indicates some form of head injury, was also predictive (ExpB=2.7[p<.001]). Specific injuries, such as subdural hematoma, subarachnoid hemorrhage, metaphyseal fractures, and long bone fractures were not predictive of AHT. These symptoms are associated with a range of conditions, including fall, making them less predictive of AHT in our model. An unknown MOI increased the risk of AHT almost 4-fold.

*Psychosocial characteristics*

Unknown number of adults in the home was a strong predictor of AHT (ExpB=9.5[p<.001]), as was domestic violence (ExpB=2.7[p<.02]), substance abuse (ExpB=8.8[p<.001]), prior child welfare involvement (ExpB=2.1[p<.04]), and prior police involvement (ExpB=5.3[p<.001]).

## DISCUSSION

In this study we used a retrospective review to understand risk factors for AHT in a pediatric population at a single institution. Few associated risk factors were found to predict AHT in our study cohort of all head injuries. Significant injury characteristics included an unknown MOI, GCS score, bruising, and multiple fractures. Predictive family and caregiver characteristics included an unknown number of people in the home, exposure to domestic violence, prior history of police involvement, CPS involvement, and substance abuse. Understanding the risk factors that can predict AHT can lead to novel diagnostic approaches for this form of trauma.

*Injury characteristics*

Caregivers commonly report falls as the method of injury for pediatric ED visits. Reported falls constituted over 37% of all injury-related pediatric ED visits in a recent study[40]

and 32% of fatal injuries in our study cohort. As found in other studies[8,38] fall mechanisms reported in our sample by caregivers included falling off countertops, tables, and beds; falling onto toys; furniture falling onto the child; children running into furniture; sibling carelessness; and caregiver falling while holding the infant. Despite their prevalence in our cohort for both inflicted and non-inflicted AHT, reported falls were not a predictor of AHT. Caregivers also described an infant fall from a bed or couch resulting from negligent supervision, which is well-established in existing literature as a significant contributor to both child injuries[41] and fatalities in a variety of settings.[42] However, negligent conditions leading to unintentional falls for very young children were not characteristic of probable AHT; these falls were captured by the undetermined category as "suspicious" wherein inflicted injury could not be ruled out. In contrast to reported falls, an unknown/unobserved/unreported MOI was associated with 46% of in-hospital deaths and increased the risk of determined AHT 5-fold. Parents frequently reported that they did not observe the cause of their child's head injury, and their description of the event often changed or evolved. Disingenuous accounts of MOI are frequently perceived as a protective mechanism for caregivers against law enforcement and public child welfare system involvement. Differentiating between falls resulting in an injury that did or did not mandate a report to CPS has been a major challenge of AHT screening in the ED. In addition, clinicians often find it too difficult to rule out that the injury could *not* have occurred from a fall. More research is needed to better understand the complex family and socio-demographic circumstances (e.g., family composition, economic hardship, substance abuse, and prior involvement with police or child welfare agencies) that may increase the risk of unintentional falls in order to develop appropriate interventions.

*Family characteristics*

Family and home characteristics had a significant impact on AHT risk. Unknown number of adults in the home was a strong predictor of AHT. This suggests that children who experience AHT live in households that contain fluid family groups, impermanence, and/or disorganization. Similarly, other studies show that children who live in homes with a greater total number of individuals are more likely to be victims of fatal and non-fatal child maltreatment.[43] In our cohort, household composition often included extended fictive kinship relationships, multiple adults sharing housing, and multigenerational and blended households. The relatively high rate of "other" reported for family composition suggests both the volume of the condition, and the need for improved measures to capture demographic information during ED visits. Violence in the home, particularly intimate partner violence, has been well established as a risk factor for child maltreatment.[44-45] In our study, a family history of domestic violence was reported in about 20% of AHT cases. Although injury to the child as a result of a domestic violence episode was described rarely in our study, the impact of violence in the home on children is most likely indirect (e.g., the stressors of witnessing violence). Indeed, living in a home where violence occurs which places young children at significant risk for future behavioral health and adverse social outcomes later in life.[46-48] However, the established relationship between the aggression that underpins domestic violence and child maltreatment is more complex. A pattern of parental negative affect and dysregulation of difficult emotions associated with experiencing domestic violence may perpetuate physical abuse.[49,50] Historically, the approach to child maltreatment in the medical setting has been an event involving a perpetrator who lost his or her temper. This characterization underscores the need for additional empirical research to understand the complex association between domestic violence and AHT.

*Inflicted and non-inflicted head injuries*

Inflicted physical abuse, though often fatal, constitutes a small portion of all head trauma in children. In examination of maltreatment across all U.S. jurisdictions, neglect that is investigated and subsequently substantiated constitutes the largest component of maltreatment.[60] Neglect is an act of omission and can be further classified as physical, emotional, medical/dental, or educational, and can be due to inadequate supervision or exposure to violence. Both physical abuse and neglect can result in head injuries in infants and young children, some of which are fatal. Despite its prevalence, neglect and fatal head injuries resulting from neglect have received minimal attention as a source of pediatric morbidity and mortality. Left untreated, abuse and neglect patterns can escalate from mild and moderate and from near-fatal to fatal injury.[61]

*ED screening for head injuries*

Considerable progress has been made in screening and surveillance of AHT and other inflicted head trauma in very young children. Still, AHT remains a leading cause of death in this population. Improved screening and surveillance may require reclassification of AHT to explicitly include inquiries into inflicted and non-inflicted head trauma. Focusing on inflicted injuries alone has resulted in under-surveillance of AHT due to unclear MOI, inconclusive forensic evidence, and failure to identify children living in household conditions associated with neglect and higher risk of unintentional injury.

Trauma centers should also consider adding an unexplained event category in AHT assessment. Many traumatic head injuries warrant classification as suspicious for AHT but lack the forensic evidence for a conclusive determination. Therefore, a trauma center may classify the event as "undetermined" or dismiss the event entirely. An "unexplained" category could mitigate this issue. The "brief resolved unexplained event" (BRUE) category has been utilized in cardiopulmonary (apneic) events in infants to facilitate screening and surveillance.[62] This

classification alerts clinicians that further patient examination is warranted, including consultation with specialists to facilitate in-depth medical and social screenings. Based on our results, we suggest that trauma centers consider expanding AHT to include a classification similar to BRUE: "traumatic injury from an unexplained event" (TUE). PCH is currently reconfiguring its forensic registry to include TUE and is working with the Child Protection Team to implement it.

The TUE should include one or more of the following characteristics:

- Any injury in a young (<4 years old) or non-ambulatory child, including a head injury;
- Any injury in an ambulatory or non-ambulatory child where the MOI is unobserved, unknown, or unreported;
- Any injury in an ambulatory or non-ambulatory child where the MOI changes materially over time or among caregivers;
- Any injury in an ambulatory or non-ambulatory child where the examining pediatrician/ nurse practitioner cannot rule out NAT because the injury does not match the MOI based on a fully disrobed exam and/or radiologic imaging.

TUEs may serve to decrease real or perceived bias in maltreatment assessment. When clinicians know their determination may be used for forensic purposes, they may be less inclined to label an event as AHT without medical certainty. Utilizing TUE eliminates high-stakes value judgements from the decision-making process since almost all traumatic injuries in children below a certain age are screened. Both non-inflicted and unexplained event categories may provide emotional distance for clinicians and decrease the emotional burden for involved families.

A recent study from Teeuw and colleagues demonstrated that combined screening procedures, a top-to-toe examination of the child, and a checklist in the ED led to more accurate diagnoses of AHT in children.[63] An expanded classification system may also encourage the development of more effective prevention strategies. Currently, considerable effort is spent working with medical evidence to support a classification of AHT, working with police and child welfare workers to confirm an inflicted injury, and following-up to ensure patients are discharged to a safe environment. These efforts may be warranted for the few patients with inflicted head injuries, but an expanded classification system enables providers to: 1) more quickly classify patients where evidence is lacking and 2) focus on preventing repeat injuries. No classification—whether current or expanded—precludes mandatory reporting to DCS or a changes to a forensic determination.

It should be noted that AHT is a trauma classification, and the conditions classified as trauma vary by trauma center. Some centers include drownings, severe rashes, rapid weight loss, dehydration, failure-to-thrive, and medical neglect, while others exclude these conditions unless they are comorbid with an acute injury. Each institution could adopt a classification for AHT that already aligns with its trauma screening and surveillance goals.

*Prevention*

Although screening is becoming more widely accepted in medical settings and its value in detecting AHT has been recognized, evidenced-based interventions based on screenings have lagged.[64,65] Beyond reporting, some hospitals also collect data in forensic/trauma registries, screen for adverse childhood experiences or domestic violence, screen parents for trauma, offer parents some training on injury prevention, provide parent education and parent programs, provide in-home nursing support and parent training for medically fragile children, and make

referrals to local child welfare agencies.[65] Interventions, including online resource directories, new programs embedded in practice (e.g., Reach Out and Read, Healthy Steps for Young Children, Medical-Legal Partnership, Health Leads, Triple P, and video coaching), or collaboration with home-visiting programs from local child welfare agencies have demonstrated limited impact.[65] A summary paper published by the National Scientific Council on the Developing Child found that interventions like those described above have resulted in only modest reductions in child maltreatment:

> [T]he inconsistent nature and magnitude of the child impacts, however, underscore the need for new strategies in the health care setting to fully address the diversity of challenges facing families with young children.[65]

Recent efforts have utilized neuroscience to create an innovative parent-coaching model for medical settings called "serve and return." In this model, caregivers are coached on reciprocal and interactive engagement with young children to "rewire" brain architecture in building stable and responsive circuitry.

Many AHT prevention programs focus on increasing awareness regarding the dangers of inflicted trauma and educating caregivers about triggers and normal developmental stages of infants and children. However, the effectiveness of these programs is unclear. An early study found that AHT educational programs provided in maternity wards showed that about 50% of participants in the program were less likely to abuse their child.[66] Moreover, parents who receive training on AHT are likely to remember the training[67] and believe that others should also receive the training.[68] However, recent studies found that educational programs do not reduce the rate of AHT.[69] More research is needed to understand the effectiveness of AHT prevention programs and to create successful programs that will decrease the rate of AHT.

*Barriers*

Admittedly, there are barriers to addressing the complex causes of inflicted and non-inflicted head trauma in very young children. In the medical setting, clinicians may be more comfortable screening patients than providing interventions. Recently, trauma-informed practice has become a focus of the integrated care model[70], serving to diminish clinical bias, support the integration of psychosocial risk factors into screening and assessment, and champion the use of motivational interviewing as an evidence-based brief intervention.[26] Recent changes to health care financing will also go a long way to support delivery of enhanced services, but more could be done to improve the concept of the medical home.[65]

Integrated care has also helped shape community-based interventions designed to support at-risk families in the prevention of abuse and neglect.[66] This approach offers opportunities for enhanced prevention across a wider population of at-risk children and their families. However, more effective interventions and further training for clinical professionals are needed. As clinicians become more comfortable with integrated care, they may find that collaborating with nurses, social workers, and injury prevention specialists can ease clinical burden. A systematic collaboration across disciplines will also increase consistency, further reduce bias in the medical work-up for AHT and support effective family interventions.

*Study limitations*

This was a single-institution study from a large, urban, regional pediatric trauma center, and the results may not be generalizable to other settings. Our referral process for determination did not rely on a single set of clear guidelines or a well-defined screening algorithm. As a result, children may have been under-surveilled. This research identified risks but could not fully validate these risks in the absence of a randomized design. Selection bias could pose a significant

risk for our research. Only children identified by the PCH Child Protection Team were included in the study. As a result, there could be a significant risk of type I error, namely by excluding children who should have been identified. Previous injuries and time between presenting injuries may be a contributing factor in predicting AHT, but these factors were not measured in this study.

In our study, injuries that may have resulted from some form of caregiver neglect rarely, if ever, resulted in a determination of AHT; these injuries were more frequently classified as undetermined. No sibling–associated injury connected with a lack of supervision was classified as AHT. AHT was reserved strictly for inflicted injuries where a possible adult perpetrator with agency (and intent) could be specifically linked to the injury. Injuries that did not meet this criterion were not classified as AHT under our single institution's CPT classification scheme. As a result, almost a third of patients who suffered serious and potentially fatal head trauma were classified as undetermined and not included in the predictive model.

Child maltreatment is a multiplicative phenomenon in that the risk of maltreatment increases multiplicatively as the number of risk factors increases.[56] We did not test any fully specified multiplicative models. Many interactions were tested but did not prove statistically significant.

## CONCLUSIONS

Many fatal or near-fatal head injuries can be prevented if environmental risk factors or early signs of abuse and neglect were recognized and subsequently addressed.[71] Non-accidental trauma constitutes the overwhelming majority of fatal and non-fatal head injuries for children under the age of 5. Our results suggest that the ED screening process for AHT, such as the one at this institution, demonstrates considerable specificity (i.e., the process reliably rules a patient as

having probable inflicted head trauma). However, the process lacks sensitivity and is thus not reliable for excluding patients with AHT deemed probable not abuse. In addition, almost a third of all head trauma at our institution during the study period was undetermined, suggesting that a more inclusive classification scheme for AHT determination is needed.

In a 7-year time period, 80% of children (n=42) who suffered fatal non-accidental injuries died of head injuries. Of these, 40 were classified as probable AHT by blunt force trauma. The determination rate of probable abuse for fatalities was considerably higher than for all head injuries, where only a third were determined as probable abuse. Injuries resulting from neglect, or those that do not meet a conclusive forensic evidentiary basis, should not preclude medical determination and preventive intervention strategies. Both inflicted and non-inflicted head injuries in very young children put this population at risk for serious injury and death. Current screening tools at pediatric trauma centers—in the absence of a single universal guideline for AHT determination—vary widely, are too limited, and need improvement.

EDs are on the front lines of treating head trauma; therefore, pediatric trauma centers should continue to develop reliable screening and surveillance tools. There are several family risk factors for early childhood head trauma: substance abuse, domestic violence, unknown number of adults in the household, unknown method of injury, and prior involvement with child welfare or police. In addition, pediatric trauma should also develop prevention strategies to reduce the risk of head trauma, re-injury, and death, regardless of whether the injury was inflicted. Pediatric trauma centers may also consider implementing universal screening for AHT for children under the age of 5. Universal screens should capture inflicted head trauma, non-inflicted head trauma, and TUE. An expanded screening classification system would improve surveillance by capturing 100% of head injuries in very young children. Equally, screening could

be utilized as the basis of preventive intervention strategies with individual families or in community programs. This schema may help to destigmatize non-inflicted AHT and better characterize environmental risks, such as untreated substance abuse, domestic violence, and family impermanence associated with head trauma in young children.

Index: Abbreviations

AHT: Abusive head trauma

BRUE: Brief resolved unexplained event

CPS: Child Protective Service

CPT: Child Protective Team

CT: Computed tomography

DCS: Department of Child Safety

DOA: Dead on arrival

DV: Domestic violence

ED: Emergency Department

GCS: Glasgow Coma Scale

LOS: Length of stay

MOI: Method of injury

NAT: Non-accidental trauma

PCH: Phoenix Children's Hospital

ROC: Receiver operating characteristic

TBI: Traumatic brain injury

TUE: Traumatic injury from unexplained event

References


1. Block, R.W. and V.J. Palusci, *Child abuse pediatrics: a new pediatric subspecialty.* J Pediatr, 2006. **148**(6): p. 711-2.
2. Currie, J. and C.S. Widom, *Long-term consequences of child abuse and neglect on adult economic well-being.* Child Maltreat, 2010. **15**(2): p. 111-20.
3. Springer, K.W., et al., *Long-term physical and mental health consequences of childhood physical abuse: results from a large population-based sample of men and women.* Child Abuse Negl, 2007. **31**(5): p. 517-30.
4. Glaser, D., *Child abuse and neglect and the brain--a review.* J Child Psychol Psychiatry, 2000. **41**(1): p. 97-116.
5. Snyder, C.W., et al., *Paediatric trauma on the Last Frontier: an 11-year review of injury mechanisms, high-risk injury patterns and outcomes in Alaskan children.* Int J Circumpolar Health, 2014. **73**: p. 25066.
6. Shein, S.L., et al., *Risk factors for mortality in children with abusive head trauma.* J Pediatr, 2012. **161**(4): p. 716-722 e1.
7. Worlock, P., M. Stower, and P. Barbor, *Patterns of fractures in accidental and non-accidental injury in children: a comparative study.* Br Med J (Clin Res Ed), 1986. **293**(6539): p. 100-2.
8. Paul, A.R. and M.A. Adamo, *Non-accidental trauma in pediatric patients: a review of epidemiology, pathophysiology, diagnosis and treatment.* Transl Pediatr, 2014. **3**(3): p. 195-207.
9. Ward, A., et al., *Non-accidental Trauma Injury Patterns and Outcomes: A Single Institutional Experience.* Am Surg, 2015. **81**(9): p. 835-8.
10. Sugar, N.F., J.A. Taylor, and K.W. Feldman, *Bruises in infants and toddlers: those who don't cruise rarely bruise. Puget Sound Pediatric Research Network.* Arch Pediatr Adolesc Med, 1999. **153**(4): p. 399-403.
11. Carter, K.W. and S.L. Moulton, *Pediatric abdominal injury patterns caused by "falls": A comparison between nonaccidental and accidental trauma.* J Pediatr Surg, 2016. **51**(2): p. 326-8.
12. Osifo, O.D., P.E. Iribhogbe, and E.E. Ugiagbe, *Epidemiology and pattern of paediatric and adolescent trauma deaths in a level 1 trauma centre in Benin city, Nigeria.* Injury, 2012. **43**(11): p. 1861-4.
13. Keenan, H.T., et al., *A population-based study of inflicted traumatic brain injury in young children.* JAMA, 2003. **290**(5): p. 621-6.
14. Palusci, V.J. and T.M. Covington, *Child maltreatment deaths in the U.S. National Child Death Review Case Reporting System.* Child Abuse Negl, 2014. **38**(1): p. 25-36.
15. Tardieu, A., *A medico-legal study of the sevices and ill treatments conducted on children.* Ann Hyg Publ Med Leg, 1860. **13**: p. 361-398.
16. Roche, A.J., et al., *The work of Ambroise Tardieu: the first definitive description of child abuse.* Child Abuse Negl, 2005. **29**(4): p. 325-34.

17. Burhans, C. and H. Gerstenberger, *Internal hemorrhagic pachymeningitis in infancy: report of five cases.* Journal of the American Medical Association, 1923. **80**(9): p. 604-609.
18. Caffey, J., *Pediatric X-ray diagnosis.* Southern Medical Journal, 1946. **39**(3): p. 274.
19. Kempe, C.H., et al., *The battered-child syndrome*, in *C. Henry Kempe: A 50 Year Legacy to the Field of Child Abuse and Neglect*. 2013, Springer. p. 23-38.
20. Caffey, J., *The whiplash shaken infant syndrome: manual shaking by the extremities with whiplash-induced intracranial and intraocular bleedings, linked with residual permanent brain damage and mental retardation.* Pediatrics, 1974. **54**(4): p. 396-403.
21. Duhaime, A.C., et al., *The shaken baby syndrome. A clinical, pathological, and biomechanical study.* J Neurosurg, 1987. **66**(3): p. 409-15.
22. Christian, C.W., et al., *Abusive head trauma in infants and children.* Pediatrics, 2009. **123**(5): p. 1409-11.
23. Sheets, L.K., et al., *Sentinel injuries in infants evaluated for child physical abuse.* Pediatrics, 2013. **131**(4): p. 701-7.
24. Piteau, S.J., et al., *Clinical and radiographic characteristics associated with abusive and nonabusive head trauma: a systematic review.* Pediatrics, 2012. **130**(2): p. 315-23.
25. Program, A.C.F.R., *Twenty-Third Annual Report*, in *Arizona Department of Health Services*. 2016.
26. Norman, R.E., et al., *The long-term health consequences of child physical abuse, emotional abuse, and neglect: a systematic review and meta-analysis.* PLoS Med, 2012. **9**(11): p. e1001349.
27. Keenan, H.T., et al., *Longitudinal Developmental Outcomes after Traumatic Brain Injury in Young Children: Are Infants More Vulnerable Than Toddlers?* J Neurotrauma, 2018.
28. Miller, T.R., et al., *Lifetime Cost of Abusive Head Trauma at Ages 0-4, USA.* Prev Sci, 2018. **19**(6): p. 695-704.
29. King, W.K., E.L. Kiesel, and H.K. Simon, *Child abuse fatalities: are we missing opportunities for intervention?* Pediatr Emerg Care, 2006. **22**(4): p. 211-4.
30. Boop, S., et al., *Abusive head trauma: an epidemiological and cost analysis.* J Neurosurg Pediatr, 2016. **18**(5): p. 542-549.
31. Lopes, N.R.L. and L.C.A. Williams, *Pediatric Abusive Head Trauma Prevention Initiatives: A Literature Review.* Trauma Violence Abuse, 2018. **19**(5): p. 555-566.
32. Hillis, S.D., et al., *The association between adverse childhood experiences and adolescent pregnancy, long-term psychosocial consequences, and fetal death.* Pediatrics, 2004. **113**(2): p. 320-327.
33. Zhou, Y., E.J. Hallisey, and G.R. Freymann, *Identifying perinatal risk factors for infant maltreatment: an ecological approach.* Int J Health Geogr, 2006. **5**: p. 53.
34. Hymel, K.P. and C.A. Hall, *Diagnosing pediatric head trauma.* Pediatr Ann, 2005. **34**(5): p. 358-70.
35. Ross, A.H., S.M. Abel, and D. Radisch, *Pattern of injury in child fatalities resulting from child abuse.* Forensic Sci Int, 2009. **188**(1-3): p. 99-102.
36. Miyamoto, S., et al., *Risk factors for fatal and non-fatal child maltreatment in families previously investigated by CPS: A case-control study.* Child Abuse Negl, 2017. **63**: p. 222-232.
37. Hurme, T., et al., *Risk factors for physical child abuse in infants and toddlers.* Eur J Pediatr Surg, 2008. **18**(6): p. 387-91.
38. Kotch, J.B., G.O. Muller, and C.H. Blakely, *Understanding the origins and incidence of child maltreatment.* 1999.
39. Morad, Y., T. Wygnansky-Jaffe, and A.V. Levin, *Retinal haemorrhage in abusive head trauma.* Clin Exp Ophthalmol, 2010. **38**(5): p. 514-20.
40. Damashek, A., S. Drass, and B.L. Bonner, *Child Maltreatment Fatalities Related to Inadequate Caregiver Supervision.* J Interpers Violence, 2014. **29**(11): p. 1987-2001.

41. Damashek, A., M.M. Nelson, and B.L. Bonner, *Fatal child maltreatment: characteristics of deaths from physical abuse versus neglect.* Child Abuse Negl, 2013. **37**(10): p. 735-44.
42. Cherry, R. and C. Wang, *The link between male employment and child maltreatment in the US, 2000–2012.* Children and youth services review, 2016. **66**: p. 117-122.
43. Featherstone, B., et al., *Poverty, inequality, child abuse and neglect: Changing the conversation across the UK in child protection?* Children and Youth Services Review, 2017.
44. Evans, S.E., C. Davies, and D. DiLillo, *Exposure to domestic violence: A meta-analysis of child and adolescent outcomes.* Aggression and violent behavior, 2008. **13**(2): p. 131-140.
45. Kitzmann, K.M., et al., *Child witnesses to domestic violence: a meta-analytic review.* J Consult Clin Psychol, 2003. **71**(2): p. 339-52.
46. Jouriles, E.N., et al., *Children Exposed to Intimate Partner Violence: Conduct Problems, Interventions, and Partner Contact With the Child.* J Clin Child Adolesc Psychol, 2018. **47**(3): p. 397-409.
47. Mammen, O.K., D.J. Kolko, and P.A. Pilkonis, *Negative affect and parental aggression in child physical abuse.* Child Abuse Negl, 2002. **26**(4): p. 407-24.
48. Smith, A.L., et al., *Emotional dysregulation and negative affect mediate the relationship between maternal history of child maltreatment and maternal child abuse potential.* Journal of Family Violence, 2014. **29**(5): p. 483-494.
49. Stith, S.M., et al., *Risk factors in child maltreatment: A meta-analytic review of the literature.* Aggression and violent behavior, 2009. **14**(1): p. 13-29.
50. Drake, B., M. Jonson-Reid, and L. Sapokaite, *Re-reporting of child maltreatment: does participation in other public sector services moderate the likelihood of a second maltreatment report?* Child Abuse Negl, 2006. **30**(11): p. 1201-26.
51. Loman, L.A., *Families frequently encountered by child protection services: A report on chronic child abuse and neglect*. 2006: Institute of Applied Research St. Louis, MO.
52. Pecora, P. and M. Harrison-Jackson, *Child welfare policies and programs.* Social policy for children and families: A risk and resilience perspective, 2006: p. 19-66.
53. Prisons, F.B.o., *Inmate Statistics: Offenses*. 2018.
54. Wolfe, D.A., *Risk factors for child abuse perpetration.* 2011.
55. Goodman, S.H. and H.E. Brumley, *Schizophrenic and depressed mothers: Relational deficits in parenting.* Developmental Psychology, 1990. **26**(1): p. 31.
56. Wells, K., *Substance abuse and child maltreatment.* Pediatr Clin North Am, 2009. **56**(2): p. 345-62.
57. Chung, E.K., et al., *Maternal depressive symptoms and infant health practices among low-income women.* Pediatrics, 2004. **113**(6): p. e523-9.
58. Putnam-Hornstein, E., *Report of maltreatment as a risk factor for injury death: a prospective birth cohort study.* Child Maltreat, 2011. **16**(3): p. 163-74.
59. Parkinson, G.W., R.C. Adams, and F.G. Emerling, *Maternal domestic violence screening in an office-based pediatric practice.* Pediatrics, 2001. **108**(3): p. E43.
60. Foundation, A.E.C., *Children who are confirmed by child protective services as victims of maltreatment by age group.* 2015.
61. University, C.o.t.D.C.a.H., *From Best Practices to Breakthrough Impacts: A Science-Based Approach to Building a More Promising Future for Young Children and Families*. 2016.
62. Tieder, J.S., et al., *Brief Resolved Unexplained Events (Formerly Apparent Life-Threatening Events) and Evaluation of Lower-Risk Infants.* Pediatrics, 2016. **137**(5).
63. Teeuw, A.H., et al., *Screening for child abuse using a checklist and physical examinations in the emergency department led to the detection of more cases.* Acta Paediatr, 2018.

64. Dudley, N., et al., *Patient-and family-centered care of children in the emergency department.* Pediatrics, 2015. **135**(1): p. e255-e272.
65. Erickson, S.J., M. Gerstle, and S.W. Feldstein, *Brief interventions and motivational interviewing with children, adolescents, and their parents in pediatric health care settings: a review.* Arch Pediatr Adolesc Med, 2005. **159**(12): p. 1173-80.
66. Showers, J., *"Don't shake the baby": the effectiveness of a prevention program.* Child Abuse Negl, 1992. **16**(1): p. 11-8.
67. Altman, R.L., et al., *Parent education by maternity nurses and prevention of abusive head trauma.* Pediatrics, 2011. **128**(5): p. e1164-72.
68. Dias, M.S., et al., *Preventing abusive head trauma among infants and young children: a hospital-based, parent education program.* Pediatrics, 2005. **115**(4): p. e470-7.
69. Zolotor, A.J., et al., *Effectiveness of a Statewide Abusive Head Trauma Prevention Program in North Carolina.* JAMA Pediatr, 2015. **169**(12): p. 1126-31.
70. Dubowitz, H., et al., *The SEEK model of pediatric primary care: can child maltreatment be prevented in a low-risk population?* Acad Pediatr, 2012. **12**(4): p. 259-68.
71. Levin, H.S., et al., *Mental state attributions and diffusion tensor imaging after traumatic brain injury in children.* Dev Neuropsychol, 2011. **36**(3): p. 273-87.
72. U.S. Department of Health & Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. (2019). Child Maltreatment 2017. Available from https://www.acf.hhs.gov/cb/research-data-technology/ statistics-research/ child-maltreatment.