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Original Article

Pediatric abusive head trauma: ThinkFirst national injury prevention foundation

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ABSTRACT

Background: Pediatric abusive head trauma (AHT) represents 80% of nonaccidental trauma deaths, remaining a lead cause of death among infants and young children. Furthermore, neurosurgical intervention can ameliorate damage from secondary injury, but we are currently unable to alter the impact of the primary injury. Thus, prevention through increased public awareness is imperative. This study identifies injuries and predictors of outcomes in pediatric AHT and highlights the importance of partnering with our community through ThinkFirst, a national injury prevention foundation, to educate parents and caregivers about prevention.

Methods: This single-institution retrospective review identifies injuries and predictors of outcomes in pediatric AHT and highlights the importance of partnering with our community to raise awareness and educate parents and caregivers about prevention.

Results: The number of pediatric AHT cases continues to steadily increase over time ($P < 0.001$), and over 70% of these patients are <1 year of age ($P < 0.001$). Patients suffering AHT have a mortality rate of nearly 10%. In addition to morbidity and mortality, the economic burden of caring for abused children is high as they often require high levels of care, long hospital stays, and extensive rehabilitation. Furthermore, Medicaid pays for nearly 80% of these patients.

Conclusion: The population of patients with AHT is unique, and one that will benefit from continued efforts at increased multidisciplinary and public awareness. Prevention of AHT through awareness is critical. Through partnering with ThinkFirst, a national injury prevention foundation, we aim to educate parents and caregivers about prevention.

Keywords: Abusive head trauma, Nonaccidental trauma, Pediatric, ThinkFirst

INTRODUCTION

Pediatric abusive head trauma (AHT) is defined by the Centers for Disease Control as "an injury to the skull or intracranial contents of an infant or child younger than 5 years caused by inflicted blunt impact, violent shaking, or both."[44] The estimated incidence of pediatric AHT is 20–40/100,000 infants younger than 1 year of age, and this incidence is relatively consistent worldwide.[3,24,26,29,41,48,52] AHT represents 80% of pediatric nonaccidental trauma (NAT) deaths, and AHT is the leading cause of death among infants and young children with a mortality of 8–25%.[23,34,50,56] Furthermore, there are high rates of morbidity; with one study reporting only 7%

of AHT survivors return to previous neurologic function.[34] Pediatric NAT poses unique challenges in that suspicion is critical for recognition of injuries during initial evaluation, as many of these injuries are missed.[27] As estimates of incidence are based on identified cases, pediatric AHT is hypothesized to be more common than reported. Despite guidelines and management protocols, uncertainty and controversy remain regarding ideal management of these patients.

Neurosurgical intervention can ameliorate damage from secondary injury, but we are currently unable to alter the impact of the primary injury. Thus, prevention through increased public awareness is imperative. This study identifies injuries and predictors of outcomes in pediatric AHT and highlights the importance of partnering with our community, in a region where rates of AHT are increasing exponentially, to raise awareness and educate parents and caregivers about prevention.

MATERIALS AND METHODS

This is a single institution, retrospective study of patients suffering AHT from January 1, 2016, to December 31, 2019. All pediatric patients age 4 and younger who presented to our institution with AHT during this time were included in the study. Patients were obtained through the Trauma Registry. As it can be notoriously difficult to delineate between the two, our hospital's forensics team investigates each possible NAT at the time of presentation and determines whether accidental or nonaccidental events occurred. To further ensure only patients who were victims of NAT were included in the study, all patients obtained from the Trauma Registry were then verified by the authors as NAT. Patients with head trauma that was not determined to be abusive or nonaccidental in nature were excluded from this study. We obtained a waiver of consent for this retrospective institutional study.

Data collected and analyzed included demographic information, injury information, treatment information, and outcomes measures. Outcomes measured included morbidity and mortality data, length of stay, disposition, and cost of hospitalization. A subgroup analysis was also performed on patients with intracranial hemorrhage or injury, excluding those patients with only skull fractures. Payer information was also included. Data were analyzed using SPSS Statistics for Macintosh, Version 26.0 (Armonk, NY: IBM Corp., 2019). The Kolmogorov–Smirnov test for normality was performed, and since data were not normally distributed, nonparametric statistical tests were used. Univariate analysis was performed using the Spearman's Rho, Mann–Whitney U, Kruskal–Wallis, and Chi-square for Independence tests as appropriate. Multivariate analysis using regression modeling was also used to identify predictors of outcomes.

RESULTS

Our institution is the only level 1 pediatric trauma center in the region. Twenty percent of our patients are living in poverty, and 35% live in single parent households. There were 209 patients meeting inclusion criteria. The incidence of AHT is increasing over time ($P < 0.001$); [Figure 1]. The majority are <1 year of age ($P < 0.001$); [Figure 2], and AHT is the leading cause of death at our institution in patients <2 years of age. Older age is associated with higher frequency of epidural hematoma (EDH), occurring in 6.7% of patients <1 year, and increasing to 25% of patients age 4 ($P = 0.023$). No other injuries are associated with patient age. The majority of patients presented with initial Glasgow Coma Scale (GCS) 15 (67%), followed by GCS 3 (13%) [Figure 3]. There is a nearly 10% mortality rate associated with pediatric AHT [Figure 4]. Loss of consciousness (LOC) was reported in 55% of patients. Skull fractures (46%) and subdural hematoma (SDH) (44%) were the most common radiographic findings. Regarding neurosurgical interventions, 11% of patients
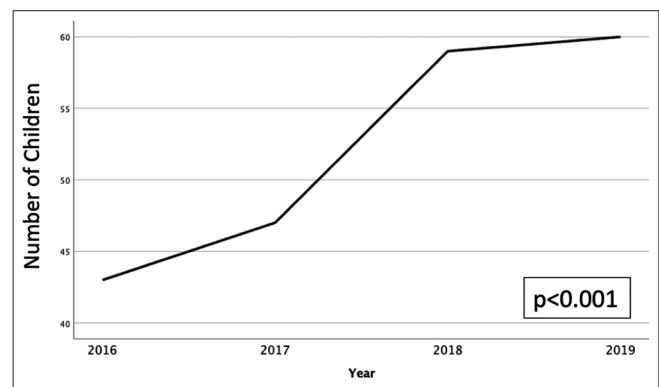
Figure 1: The number of pediatric abusive head traumas is increasing over time from 2016 to 2019. The increase in pediatric abusive head traumas over the years 2016–2019 at our institution.
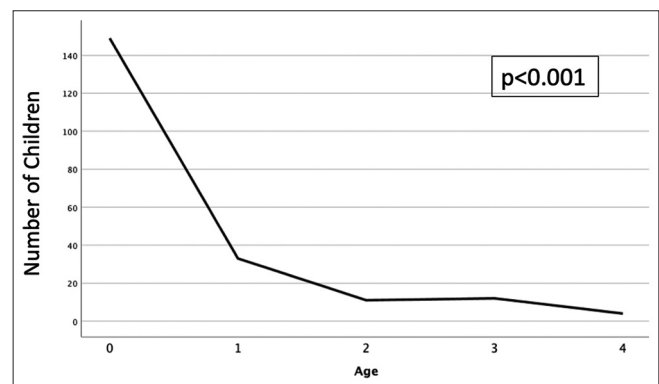
Figure 2: The number of pediatric abusive head trauma decreases with older age. Over 70% of pediatric abusive head traumas occur in children <1 year of age, and rates of abusive head trauma decrease with older age.
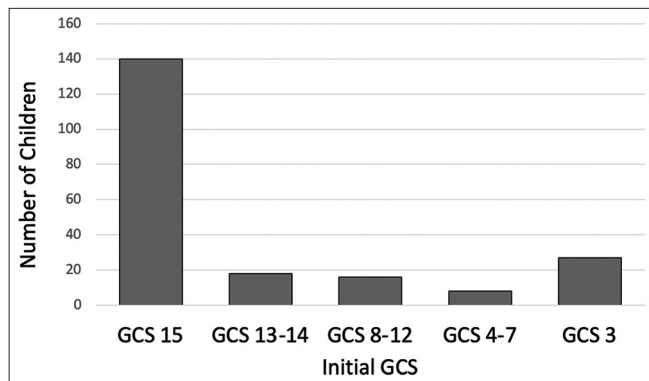
Figure 3: Initial GCS score on arrival. Initial GCS score on arrival with the majority of patients at our institution presenting with GCS 15. This is presumably at least in part due to our institution's low threshold to screen for and initiate a nonaccidental trauma workup. GCS: Glasgow Coma Scale
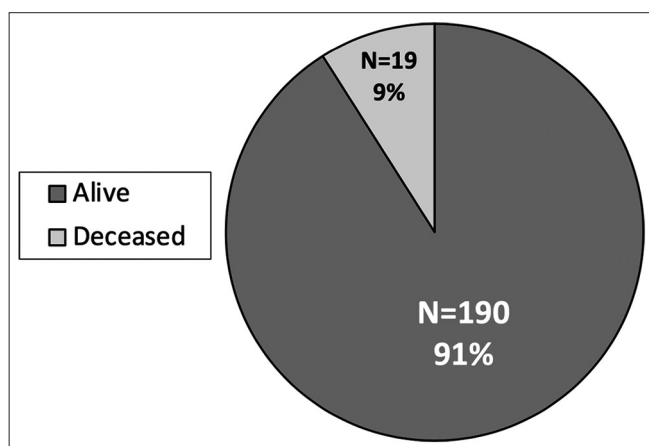

Figure 4: Rate of survival: high rate of mortality in pediatric abusive head trauma. There is a high rate of mortality in pediatric abusive head trauma with nearly 10% of abused children not surviving hospitalization. There are a total of 209 patients with 190 alive and 19 deceased children. All children who did not survive hospitalization presented as a Glasgow Coma Scale score of 3.

underwent an intervention with 8% receiving an external ventricular drain (EVD)/intracranial pressure (ICP) monitor and 6% having a craniotomy/craniectomy performed. In addition to the devastating neurologic and psychologic effects, AHT also creates a large financial burden. The median cost per patient is $88,441 with an interquartile range of $43,000–227,000. Annually, AHT costs our hospital alone nearly $5.5 million dollars, and the majority of AHT patients are paid for by Medicaid (78.5%). A complete report of descriptive data is shown [Tables 1 and 2]. A graphical representation of primary payor information is also shown [Figure 5].

Several injuries were associated with concurrent presence of other injuries. Patients with reported LOC had significantly

Table 1: Demographics, injuries, and outcomes of pediatric patients suffering from abusive head trauma.

Characteristic	N (of total)
Total	209
Year	
2016	43
2017	47
2018	59
2019	60
Age	
Less than 1 year	149 (71.3)
1 year	33 (15.8)
2 years	11 (5.3)
3 years	12 (5.7)
4 years	4 (1.9)
Gender	
Female	93 (44.5)
Male	116 (55.5)
Race	
Hispanic or Latino	106 (50.7)
Caucasian/NonHispanic	61 (29.2)
African American	35 (16.7)
Other	7 (3.3)
Injury Information**	
LOC	116 (55.5)
Skull fracture	96 (45.9)
Contusion/IPH	30 (14.4)
EDH	20 (9.6)
SDH	91(43.5)
Trauma SAH	20 (9.6)
Diffuse TBI, NOS	12 (5.7)
Intracranial injury, NOS	21 (10.0)
GCS in ED	
GCS 15	140 (67.0)
Mild injury, 1314	18 (8.6)
Moderate injury, 912	14 (6.7)
Severe injury, 48	10 (4.9)
GCS 3	27 (12.9)
Post ED Disposition	
Operating room	9 (4.3)
ICU	77 (36.8)
Stepdown unit	23 (11.0)
Floor	96 (45.9)
Other	4 (1.9)
NSU Procedure	23 (11.0)
EVD or ICP monitor	17 (8.1)
Craniotomy/craniectomy	12 (5.7)
Burr holes for SDH drainage	3 (1.4)
Shunt placement	4 (1.9)
Cranioplasty	4 (1.9)
Discharge Status	
Alive	190 (90.9)
Dead	19 (9.1)
Discharge mRS	
mRS 0: No dysfunction	40 (19.1)
mRS 12: Slight dysfunction	135 (64.6)

(Contd...)

Table 1: *(Continued).*

Characteristic	N (of total)
mRS 34: Moderate disability	10 (4.8)
mRS 5: Severe disability	5 (2.4)
mRS 6: Dead	19 (9.1)
Disposition	
Home (with nonabusive family)	97 (46.4)
Child protection agency	85 (40.7)
Transfer	8 (3.8)
Morgue	19 (9.1)
Primary payor	
Medicaid	164 (78.5)
Other Government	9 (4.3)
Commercial	33 (15.8)
Self-pay	3 (1.4)

ED: Emergency department, EDH: Epidural hematoma, EVD: External ventriculostomy drain, GCS: Glasgow Coma Scale, ICP: Intracranial pressure, ICU: Intensive care unit, IPH: Intraparenchymal hemorrhage, mRS: modified Rankin Scale, NOS: Not otherwise specified, NSU: Neurosurgery, SAH: Subarachnoid hemorrhage, SDH: Subdural hematoma, SNF: Skilled nursing facility, TBI: Traumatic brain injury. **Some patients reported to have more than one injury, so total percentages of all injuries do not add to 100%

Table 2: Number of ventilator days and ICU, stepdown, and total length of stay.

	Number of Patients	Mean (SD)	Median (IQR)
Ventilator days	48	7.6 (8.84)	5 (3–8)
ICU days	90	7.4 (11.61)	4 (2–8)
Stepdown days	56	6.6 (7.95)	3.5 (2–6)
Total length of stay	209	9.1 (11.72)	5 (3–10)

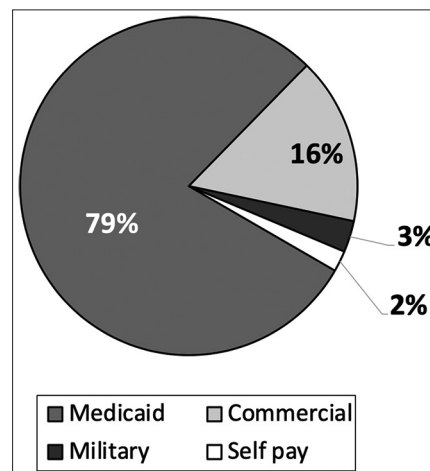ICU: Intensive care unit, IQR: Interquartile range, SD: Standard deviation

Figure 5: Primary payor information. Medicaid is the primary payor for nearly 80% of pediatric abusive head trauma at our institution. As hospital charges are not normally of $88,441 and an interquartile range of $43,247–226,937 per abused child per visit. This further supports the severity of many of these injuries.

higher rates of SDH (*P* < 0.001), contusions/intraparenchymal hemorrhage (IPH) (*P* = 0.001), EDH (*P* = 0.020), and traumatic SAH (*P* = 0.020). Patients with LOC were significantly less likely to have a skull fracture (*P* = 0.002). Patients with a skull fracture were significantly less likely to concurrently also have SDH (*P* < 0.001), diffuse traumatic brain injury (TBI) not otherwise specified (*P* = 0.007), and traumatic subarachnoid hemorrhage (SAH) (*P* = 0.014). The presence of SDH, EDH, or traumatic SAH was not associated with presence of another one of these injuries. Furthermore, reported LOC (*P* < 0.001), SDH (*P* < 0.001), traumatic SAH (*P* < 0.001), and diffuse TBI not otherwise specified (*P* < 0.001) were associated with the lower initial GCS. Skull fractures were associated with higher initial GCS (*P* < 0.001). There was no association between EDH (*P* = 0.366) and contusions/IPH (*P* = 0.351) with initial GCS.

In addition, several injuries were associated with increased likelihood of undergoing a neurosurgical intervention. Lower initial GCS was significantly associated with increased likelihood of undergoing any intervention (*P* < 0.001) as well as both EVD/ICP monitor (*P* < 0.001) and craniotomy/craniectomy (*P* < 0.001). In addition, there was a significant association between receiving EVD/ICP and craniotomy/craniectomy (*P* < 0.001). Patients with traumatic SAH (*P* < 0.001) and SDH (*P* = 0.002) were more likely to undergo an intervention. Although not reaching statistical significance, there was a trend towards increased interventions in patients with contusions/IPH (*P* = 0.089). EVD/ICP monitors were associated with the presence of

traumatic SAH (*P* < 0.001) and SDH (*P* = 0.019). Although not statistically significant, there was a trend towards higher rates of EVD/ICP monitor placement in patients with contusions/IPH (*P* = 0.065). Craniotomy/craniectomy was more likely in patients with SDH (*P* = 0.002) and contusions/IPH (*P* = 0.010). There was a trend toward increased craniotomy/craniectomy in patients with traumatic SAH, but this did not reach statistical significance. Patients with skull fractures were significantly less likely to undergo a neurosurgical intervention (*P* = 0.004), EVD/ICP monitor (*P* = 0.015), or craniotomy/craniectomy (*P* = 0.022). Interestingly, there was no association between EDH and undergoing an intervention (*P* = 0.548), EVD/ICP monitor (*P* = 0.590), or craniotomy/craniectomy (*P* = 0.812).

Nearly 10% of patients presenting with AHT did not survive. All of these patients presented with an initial GCS 3 and imaging findings more consistent with global diffuse anoxic brain injury. Increased mortality was associated with traumatic SAH (*P* < 0.001), and patients with skull fractures had decreased rates of mortality (*P* = 0.001). Higher mortality was seen in patients undergoing any neurosurgical

intervention ($P < 0.001$), EVD/ICP monitor ($P < 0.001$), and craniotomy/craniectomy ($P = 0.005$). There is a high rate of morbidity and dysfunction in survivors of AHT with only 21% returning to neurologic baseline discharging with modified Rankin Score (mRS) of 0; however, the majority of patients were discharged with slight dysfunction, considered mRS 1–2 (67%) [Figure 6]. As expected, lower initial GCS is associated with worse functional outcome at discharge ($P < 0.001$). LOC ($P = 0.002$) and SDH ($P = 0.001$) are associated with worse functional outcomes.

Multivariate analysis for predictors of outcome

Multivariate analysis was used to identify the most significant predictors of outcomes. Lower initial GCS ($P < 0.001$) and SDH ($P = 0.017$) are most predictive of undergoing a neurosurgical intervention. Similarly, lower initial GCS ($P < 0.001$) and SDH ($P = 0.005$) are most predictive of craniotomy/craniectomy, and lower initial GCS ($P < 0.001$) is the most predictive variable regarding EVD/ICP monitor placement. Initial GCS ($P < 0.001$), SDH ($P = 0.020$), and lack of a skull fracture ($P = 0.045$) are most predictive of lower functional outcome at discharge.

Multivariate analysis identified lower initial GCS ($P < 0.001$) and SDH ($P = 0.001$) as the largest predictors of longer ICU stay. Lower initial GCS ($P < 0.001$), diffuse TBI not otherwise specified ($P = 0.003$), and traumatic SAH ($P = 0.029$) are most predictive of longer days in stepdown. Variables most predictive of longer total length of stay are lower initial GCS ($P < 0.001$), diffuse TBI not otherwise specified ($P = 0.003$), SDH ($P = 0.011$), and lack of skull fracture ($P < 0.020$). Interestingly, length of stay in any unit was not associated with whether a neurosurgical intervention was performed or any specific intervention.

Multivariate analysis of hospital charges revealed that undergoing a neurosurgical intervention ($P < 0.001$), cranioplasty ($P < 0.001$), longer ICU stay ($P < 0.001$), longer

Figure 6: Discharge mRS of survivors. There is a high rate of morbidity and disability among survivors of abusive head trauma with only 20% returning to baseline neurologic function. mRS: modified Rankin Score

total length of stay ($P < 0.001$), not surviving ($P < 0.001$), craniotomy/craniectomy ($P = 0.017$), and EVD/ICP monitor placement ($P = 0.045$) are most predictive of increased charges. Lower initial GCS or any specific injury was not predictive of hospital charges.

Subgroup analysis of AHT patients with radiographic evidence of intracranial hemorrhage or injury aside from skull fracture alone

There were 161 patients with AHT injuries aside from skull fracture alone. The age, gender, and racial characteristic compositions are largely unchanged regardless of including or excluding skull fracture alone. In this subgroup analysis, there are 34% of patients with skull fracture and concurrent intracranial hemorrhage or radiographic evidence of TBI. As expected, there are increased in the percentage of patients SDH (from 44% to 66%), contusion/IPH (14% to 22%), EDH (10% to 15%), and traumatic SAH (10% to 13%). Interestingly, there percentage of patients with LOC is increased in this subgroup despite excluding patients with LOC alone, suggesting that patients with LOC alone are likely to have sustained an intracranial injury as well.

DISCUSSION

The term AHT and the understanding of findings, circumstances, and biomechanics associated with AHT have evolved over time. In 1860, Auguste Ambroise Tardieu was the first to report the causal relationship between intracranial injury and physical abuse; however, his work was largely dismissed.[36] Although what is now considered AHT has been reported for over 150 years, it was not until Kempe *et al.* coined the term battered child syndrome in 1962 to describe these patients.[32] A decade later in the early 1970s, Caffey introduced the additional terms of parent-infant traumatic stress syndrome and whiplash shaken infant syndrome. Subsequently, the term shaken baby syndrome (SBS) was largely adopted into the medical literature to describe the clinical features of these patients.[10] SBS has been previously defined as a triad of SDH, retinal hemorrhage, and encephalopathy.[11] Recognizing that, although shaking is one mechanism of injury, head trauma caused by abusive behavior encompasses a wider array of traumatic injuries. In 2009, the American Academy of Pediatrics shifted away from the term SBS towards AHT. The intention of this terminology change was to broaden focus from shaking as the sole mechanism and increase awareness that abusive behavior of any mechanism often involves injury to the head, since not all AHT occurs from shaking babies and not all AHT babies present with the SBS triad.[12]

The incidence of AHT continues to increase over time with the majority of patients being <1 year of age.[16,46] Similar to
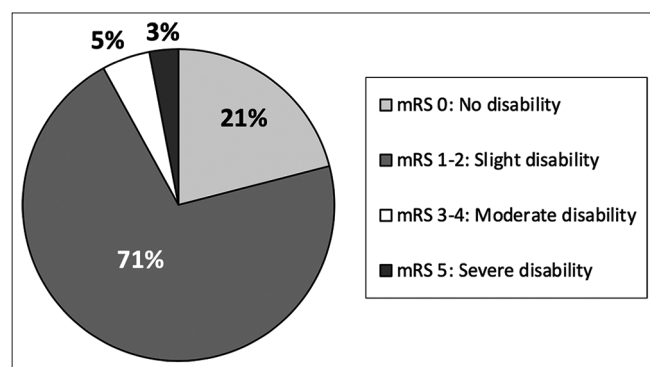
that reported in literature, our data also reflect a slight male predominance.[21,24,29,43,45,48] As noted above, providers need to have a high level of suspicion to recognize and diagnose these injuries, and it is critical for providers to perform meticulous examination to identify bruising, external trauma, or other injuries in patients suspected of AHT. Oftentimes, patients may present with nonspecific symptoms, such as vomiting, altered mental status, or seizures, which do not immediately suggest AHT, or the patient history may change, be incorrect, and even absent of any report of trauma.[6,18,23,27,50,56] In addition to brain injury, these patients often have associated injuries to the skeletal system, especially long bone and rib fractures, spinal cord, retina, and soft tissue or visceral injuries necessitating thorough examinations with even small suspicion of possible abuse.[27]

NAT can be challenging to diagnosis, especially AHT, with many children presenting with nonspecific symptoms, such as irritability or vomiting, and unreliable or absent history.[27,56] One study reported more than 30% of patients diagnosed with AHT had been previously evaluated by a physician for injuries related to maltreatment.[7] Risk factors for unrecognized or "missed" NAT include very young age (<6 months), white race, and two parent "intact" household.[27] Unfortunately, rates of recurrent NAT are high with more than 26% suffering repeated abuse within 1 year and 40% within 2 years of the initial event.[13] Recurrent NAT is often more severe with increasing rates of morbidity and mortality with each additional event.[22] Independent risk factors for recurrent NAT include younger age (<2.5 years), rural residence, and having one to two "minor" injuries (dislocation, open wound, and superficial injury) when previously evaluated following an abuse event.[13,53] Children with multiple returning visits to the emergency room should raise a red flag. One study reported that rate of mortality increase from 10% to >25% in those suffering recurrent NAT.[13] Another study found that up to 80% of NAT deaths occur from recurrent abuse in children previously evaluated for more "minor" injuries not recognized as NAT.[27] This sheds light on an enormous arena for improvement on the part of physicians. As our Children's Hospital is located in an area with a disproportionately high rate of NAT compared to other regions in California and the United States, our institution has a very low threshold for screening and initiating NAT workup. Accordingly, our institution identifies and intervenes on children who are victims of NAT earlier when injuries may not be as severe to prevent a significantly worse injury or death that often seen with recurrent NAT.

Classically, SDH is well known consequence of trauma, and presence of a SDH in an infant is strongly associated with AHT and warrants a NAT evaluation.[31,40,46] Other radiographic findings frequently observed in patients with AHT include EDH, IPH, and skull fractures.[31,40,45] In the literature, SDH is seen in up to 90% of AHT patients; however, only 44% of our total cohort of patients have SDH. Thus, we performed a subgroup analysis to explore this disparity. In our subgroup analysis, we excluded patients with LOC only or skull fracture only without radiographic evidence intracranial hemorrhage or TBI with 66% of patients suffering from SDH. There are studies that report a SDH rate of as low as 61%.[51] This variation in percentage of AHT with SDH may be due to wide variation in screening and management of NAT.[49] As described above, our institution has a low threshold to initiate a NAT workup due to the disproportionally high incidence of NAT in our area compared with other regions of both California and the United States. Thus, we also identify patients with less severe injuries that may be missed with less comprehensive screening, particularly if providers are not as cognizant.

Multiple injuries are often present concurrently, which reiterates the need for meticulous examination to assess for additional bruising, external trauma, or other signs of injury in any patient suspected of AHT or NAT. Up to 85% of patients with SDH have retinal hemorrhages that can be identified with thorough examination.[42] We found that presence of a skull fracture decreased the likelihood of another intracranial injury, whereas a history of LOC was associated with other intracranial injuries. Although injury mechanisms are more complex, biomechanical studies support that skull fractures often result from focal blows to the cranium, cracking in areas experiencing the greatest tensile deformation. The energy from the trauma is absorbed and dissipated by the fracturing of the skull itself.[20] On the contrary, intracranial injuries are generated by global forces through angular velocity and acceleration, which commonly leads to coup/contrecoup injuries as well as the shear stress and strain that tears blood vessels. In these cases, the energy of the trauma is absorbed and dissipated by the intracranial contents.[37] This explains why patients with a skull fracture typically present with higher initial GCS, fewer intracranial injuries, and lower mortality rate. Moreover, a traumatic force large enough to cause LOC is generally associated with higher global forces, and thus, LOC is predictive of intracranial injuries and, accordingly, lower initial GCS scores. Trauma, however, creates complex forces, which explains individual patterns of injury observed across AHT patients as well in related injuries in the craniocervical junction.

There are several known factors underlying the biomechanics of injury to the craniocervical junction in the pediatric population. Having a high head to body weight ratio, especially when the child's head comprises 25% of its body weight, places the craniocervical junction, and therefore the high cervical cord, at a high risk for flexion and extensions injuries. The injury is further exacerbated when coupled with underdeveloped neck muscles and ligamentous laxity in this patient population.[36] Subsequent hypoxic-ischemic injury

has also been noted to occur more frequently in the AHT compared to accidental head trauma patient population, children with hypoxic-ischemic injury were found more likely to experience seizures and often time required invasive respiratory support measures, such as intubation.[25] In addition, trauma-induced apnea associated with AHT has been thought to be a major contributing factor to poor outcomes in the AHT patient population; the resultant hypoxic-ischemic injury being more important than mechanism or intracranial radiographic findings.[28]

There are two phases of neurologic injury in victims of AHT. The primary injury is the immediate physical damage incurred by the abusive behavior itself. Following this trauma, secondary injury ensues as cerebral edema, hypoperfusion, hypoxia, ischemia, and oxidative stress develop and exacerbate neuronal damage and death.[1,19,39] Furthermore, a strong inflammatory response is ignited by presence of intracranial hemorrhage, particularly SDH, which also contributes to secondary injury.[39] At present, neurosurgeons are not able to reverse damage from the primary injury; instead, intervention aims to mitigate secondary injury.

Often invasive neurosurgical procedures are performed as a life saving measure to prevent herniation and salvage uninjured brain in patients already severely injured from the primary traumatic event.[15] This is reflected by the lower initial GCS and, consequently, high rate of mortality in patients undergoing a neurosurgical intervention. Not surprisingly, undergoing either a craniotomy/craniectomy or EVD/ICP monitor is associated with the other procedure also being performed. Thus, often once the neurosurgeon and, when applicable, family decide to commit to life-saving interventions, all measures are taken. Unsurprisingly, EDH was not found to be associated with increased likelihood of neurosurgical intervention. EDH is not often an important part of AHT; EDH is frequently observed in traumatic injuries as opposed to inflicted injuries.

Neurologic and functional outcomes following AHT are variable, relating to the severity of the initial injury.[15] Compared to estimates in the literature, our outcomes are among some of the better reports. As noted above, it is estimated that 8–25% of AHT victims do not survive, and we found a mortality rate of 9%.[23,34,50] Furthermore, regarding functional outcomes among survivors, we found 84% with none or slight disability (mRS 0–2) and 7% with moderate to severe disability (mRS 3–5), whereas the literature describes 60% or more patients with a moderate or greater degree of disability.[4,17] As 67% of our patients presented with GCS 15, this may be explained by increased awareness and recognition of these injuries in less severely injured patients as our region has a high rate of AHT and NAT.[47] At our institution, survivors of NAT are discharged and rehomed to foster care.

According to our data, length of stay is most predicted by the patient's underlying injury, and accordingly, the neurologic status at initial presentation. Whether a patient underwent a neurosurgical procedure is not associated with length of stay, and this includes procedures that inherently imply a patient has a longer hospitalization, such as cranioplasty and shunt implantation. Hospital charges, however, are most predicted by length of stay as well as whether a patient had a neurosurgical intervention. Interestingly, not surviving was predictive of increased hospital charges. Although nonsurviving patients do not accrue costs through long hospital stay, these severely injured patients are most likely to undergo potentially lifesaving, also costly, interventions.

These findings reiterate that once the primary injury has occurred, neurosurgical intervention function to potentially decrease further damage from secondary injury, but they are not able to reverse the effects of the initial trauma. Despite many guidelines and management protocols relating appropriate triage and care of AHT patients once they arrive to the hospital, prevention is the most critical component of caring for these patients. Thus, it is imperative that neurosurgeons and other providers partner with the community, where the initial traumas occur, to educate and increase awareness about AHT.

Shaking and other abuse often results from desperate rage when the baby keeps crying and cannot be calmed or soothed. Infant crying is frequently reported as the inciting event of shaking, and interestingly, a study by Barr *et al.* found that the incidence of AHT by age closely mirrors the normal crying pattern curve for infants.[5] Furthermore, another study by Theodore *et al.* reported that 2.6% of surveyed parents of children 2 years and younger used shaking as a method of discipline.[54] Reductions in AHT may be achievable with a system-wide implementation of a comprehensive parental education prevention program. A study by Barr *et al.* found that parental education on understanding of early increased crying and how to properly address crying in infants was associated with a 35% reduction in infant AHT admissions that were significant for patients that were <24-month-old.[5] The results of these important studies indicate that implementation of parental education has the potential to decrease incidence of AHT in the pediatric population, thereby reducing the significant socioeconomic burden and suffering associated with this terrible condition. This suggests an area of potential intervention by educating the community and new parents on the potentially devastating effects of shaking an infant.

Research has persistently found that socioeconomic status of the caretaker is a factor for AHT.[9,30,33] One study found that rates of AHT are significantly higher during times of recession or economic hardship compared with before

recession, suggesting that stress plays a role in violence and AHT.[8] Another study examined the effect of paid family leave (PFL) on AHT by comparing rates of AHT in California after implementation of the PFL policy with seven other states without a PFL policy, and found a significant decrease in the rates of AHT in patients <1 and <2 years of age.[35] However, as the incidence of AHT is increasing globally, evaluation for suspected AHT should not be dictated by socioeconomic class alone, and higher socioeconomic status is not a substitute for meticulous examination.[30]

Among other studies, a recent review by Lopes and de Albuquerque Williams investigated strategies to reduce NAT, including initiatives to reduce infant crying, regulate the caregiver's emotional responses to crying, and raise awareness about pediatric AHT.[38] The latter being the focus of the current manuscript. One such way of increasing awareness is partnering with ThinkFirst, a nonprofit, national injury prevention foundation, whose mission is to prevent brain, spinal cord, and other traumatic injuries through education, research, and advocacy organized [Figure 7].[14,55] ThinkFirst was organized by the American Association of Neurological Surgeons and the Congress of Neurological Surgeons more than 30 years ago to yield an avenue for neurosurgeons to impact their communities, and due to positive response from the community, it has grown to a national level with many local chapters and specific programs aimed at preventing neurologic trauma in various demographics.[14] Importantly, ThinkFirst's power and effectiveness do not come from sporadic safety notices or presentations about prevention; instead, it comes from building and engraining a culture and lifestyle of safety among members of the community. Each ThinkFirst chapter operates independently, collaborating with local hospitals, health centers, schools, and other organizations to deliver and establish the concept of living safely and understanding how to prevent injury before it happens.

ThinkFirst has a program tailored to educating and raising awareness about AHT, most specifically to prevent SBS. With this mission in mind, we have started ThinkFirst for Your Baby to provide a comprehensive review of infant safety-with a focus on prevention of AHT. At our institution, AHT is the leading cause of death among patients <2 years of age, and

Figure 7: ThinkFirst: National injury prevention foundation. ThinkFirst is a nonprofit organization found over 30 years ago by the American Association of Neurological Surgeons and the Congress of Neurological Surgeons to partner with the community to raise awareness. ThinkFirst's mission is to prevent brain, spinal cord, and other traumatic injuries through education, research, and advocacy.

the incidence continue to rise. ThinkFirst aims to reduce the incidence of AHT by educating expectant parents on topics ranging from child development, stress coping mechanisms and most importantly, specific ways to comfort a crying baby while keeping oneself calm throughout the process. The senior author of this paper is the first physician in the United States trained to provide ThinkFirst for Your Baby seminars and partners with Loma Linda University Children's Health to provide this free program within our community. A free course is offered to caregivers in the community to combat the exponential increase in AHT in the region. Courses provide detailed teaching and understanding for the care of infants, providing resources to caregivers, and emphasizing the disastrous consequences that are possible when a baby is shaken. By partnering with ThinkFirst, we can build on this existing framework and create new initiatives to further impact the community and prevent not only SHS but all AHT by educating and increasing public awareness through example. To reiterate, prevention of AHT is critical, and prevention is where neurosurgeons have the greatest opportunity to fight AHT. ThinkFirst is an exciting new initiative at our institution with evaluation of the efficacy of the program currently underway.

CONCLUSION

AHT has devastating neurologic consequences, and it continues to be a leading cause of death among infants and young children. Although a significant amount of research is being conducted in the area of pediatric TBI to elucidate its underlying the pathophysiology and discover novel treatment modalities for this patient population; prevention remains the best medicine. The population of patients with AHT is unique, and one that will benefit from continued multidisciplinary efforts to increase public awareness and educate parents and caregivers to prevent AHT.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Conflicts of interest

There are no conflicts of interest.

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