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ORIGINAL ARTICLE

Head injury pattern in children can help differentiate accidental from non-accidental trauma

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Abstract
Objectives Our aim was to define the radiographic findings that help differentiate abusive head trauma (AHT) from accidental head injury.
Methods Our trauma registry was queried for all children ≤5 years of age presenting with traumatic brain injury (TBI) from 1996–2011.
Results Of 2,015 children with TBI, 71 % had accidental injury and 29 % had AHT. Children with AHT were more severely injured (ISS 22.1 vs 14.4; $p < 0.0001$) and had a higher mortality rate (15 vs 5 %; $p < 0.0001$). Patients with AHT had higher rates of diffuse axonal injury (14 vs 8 %; $p < 0.0001$) and subdural hemorrhage (76 vs 23 %; $p < 0.0001$). Children with accidental injury had higher rates of skull fractures (52 vs 21 %; $p < 0.0001$) and epidural hemorrhages (11 vs 3 %).
Conclusions AHT occurred in 29 % of children and resulted in increased mortality rates. These children had higher rates of subdural hemorrhages and diffuse axonal injury. Physicians initially evaluating injured children must maintain a high index of suspicion for abuse in those who present with subdural hematoma or diffuse axonal injury.

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Keywords Child abuse · Abusive head trauma · Subdural hemorrhage · Diffuse axonal injury · Non-accidental trauma

Introduction

The battered-child syndrome was first described by Kempe et al. [1] in 1962. Since that time, abused children are now recognized to represent 1–3 % of all children presenting with traumatic injury. Child abuse, or non-accidental trauma (NAT), presents significant and unique challenges to the clinicians who must be able to identify or at least suspect this mechanism of injury at the time of patient presentation. We have previously demonstrated that head injury is the leading cause of morbidity and mortality in the NAT population [2]. Furthermore, NAT accounts for 7 % of all trauma admissions at our institution and is the leading cause of trauma deaths in our hospital [2].

Previous investigators have attempted to describe the initial presentation and neuroradiographic findings associated with abusive head trauma (AHT) [3–7], but many of these studies are plagued by small numbers or discordant results and conclusions. The aim of our current work is to better define the radiographic findings associated with AHT as well as further characterize this vulnerable population, in order to improve the identification of these patients during their initial trauma evaluation. We hypothesized that children with AHT would have a higher mortality than children with accidental head injury and the radiographic findings on initial head computed tomography (CT) would help differentiate accidental injury and AHT.

Materials and methods

We queried the trauma database at Children's Hospital Colorado, a level I regional pediatric trauma center, over a 16-year period (January 1996–December 2011) for all children 5 years of age and younger with a diagnosis of traumatic brain injury (TBI). Data were obtained from the trauma database and include demographic information (age and sex) as well as injury specific information including cause of trauma, injury severity score (ISS), Glasgow Coma Scale score on presentation to the emergency department (GCS), hospital length of stay (LOS), and in hospital mortality. Differentiation of AHT from accidental injury is determined by the Child Advocacy and Protection Team (CAP) at our institution. The CAP team is a multidisciplinary team, which is asked to evaluate children if abuse is suspected by the healthcare providers. The CAP team is made up of child abuse pediatricians, medical social workers, nurses, psychologists, and sociologist–attorney. When asked to consult on a patient, the CAP team is asked to make a determination as to the likelihood of abusive injury.

The results of the initial head CT obtained were then reviewed, and the specific type of head injury was recorded based on the final radiology report. Head injuries identified included subdural hematoma (SDH), subarachnoid hemorrhage (SAH), epidural hematoma (EDH), diffuse brain edema/diffuse axonal injury (DAI), and skull fracture. Because it is well established that children sustaining AHT are younger than children sustaining accidental injury, we also examined the subset of children less than 2 years of age in both AHT and accidental injury groups. Statistical analysis was performed using student's t test and χ^2 analysis where appropriate. Data are recorded as mean ± SD with p values of <0.05 considered significant. Statistical analysis was performed in Prism 6.0b (by GraphPad Software, Inc, La Jolla, CA, USA).

Results

During the 16-year study period, a total of 2,015 children 5 years of age and under presented to our trauma center with a diagnosis of TBI. With the help of the Child Protection Team, 580 (29 %) head injuries were found to be secondary to AHT. The remaining 1,435 (71 %) were classified as accidental head injury. Overall, children with AHT were younger (0.7 ± 0.8 vs 2.2 ± 1.6 years; $p < 0.0001$), more severely injured [median ISS 25 (IQR 17–26) vs 13 (IQR 9–17); $p < 0.0001$), had a lower median GCS on presentation [14 (IQR 6–15) vs 15 (IQR 12–15); $p < 0.0001$), a longer hospital LOS (median 5 days vs 1 day, $p < 0.0001$), and had a significantly higher mortality rate (15 vs 5 %; $p < 0.0001$) when compared to children with accidental injury (Table 1). Males made up 62 % of patients in both groups ($p = 0.6$).

Table 1 Patient demographics

	AHI	AHT	p value
n	1,435	580	
Age in years (SD)	2.2 (1.6)	0.7 (0.8)	<0.0001
Male (%)	890 (62 %)	365 (63 %)	0.61
ISS, median (IQR)	14 (10.3)	22 (8.3)	<0.0001
GCS on presentation, median (IQR)	15 (12–15)	14 (6–12)	<0.0001
LOS median (IQR)	1 (1–3)	5 (2–9)	<0.0001
In hospital mortality (%)	68 (5 %)	85 (15 %)	<0.0001

AHI accidental head injury, *AHT* abusive head trauma, *IQR* interquartile range

Table 2 Radiographic findings (all children)

	AHI	AHT	p value
n	1,435	580	
Skull fracture	761 (52 %)	125 (22 %)	<0.0001
DAI	116 (8 %)	81 (14 %)	<0.0001
EDH	164 (11 %)	15 (3 %)	<0.0001
SDH	335 (23 %)	443 (76 %)	<0.0001
SAH	250 (17 %)	121 (21 %)	0.08

AHI accidental head injury, *AHT* abusive head trauma, *IQR* interquartile range

Radiographic findings present on initial head CT were analyzed based on patient group (Table 2). The distribution of skull fractures, DAI, EDH, and SDH differed between the two groups. Patients with accidental injury were more likely to suffer skull fractures (52 vs 22 %; $p < 0.0001$) and EDH (11 vs 3 %; $p < 0.0001$) than were those who suffered AHT. Patients who suffered AHT were more likely to suffer from DAI (14 vs 8 %; $p < 0.0001$) and SDH (76 vs 23 %; $p < 0.0001$) than were those with AHI. Rates of SAH did not differ between the two groups (17 % in the AHI group vs 21 % in the AHT group; $p = 0.08$).

The majority of children who suffered AHT were less than 24 months old (533/580, 92 %), while only 50 % (716/1,435) of the accidental injury patients were less than 24 months of age. On repeat analysis of only those patients less than 24 months of age, the same trends were observed as were seen with the entire cohort (Table 3). Children less than 24 months old with AHT had a higher incidence of SDHs (76 vs 25 %; $p < 0.0001$) as well as DAI (14.0 vs 8.8 %; $p < 0.01$) when compared to children with accidental injury. Also, similar to the entire study population, children less than 24 months with accidental injury had significantly more skull fractures (53 vs 23 %; $p < 0.0001$)

Table 3 Radiographic findings (children <24 months)

	AHI	AHT	*p* value
n	716	533	
Skull fracture	378 (53 %)	121 (23 %)	<0.0001
DAI	63 (9 %)	75 (14 %)	0.004
EDH	87 (12 %)	13 (2 %)	<0.0001
SDH	178 (25 %)	407 (76 %)	<0.0001
SAH	127 (18 %)	110 (21 %)	0.21

AHI accidental head injury, *AHT* abusive head trauma, *IQR* interquartile range

and EDHs (12 vs 2 %; $p < 0.0001$) when compared to those children with AHT. The incidence of SAHs did not differ between the two groups (18 % in accidental injury group vs 21 % in AHT group; $p = 0.2$).

Discussion

The recognition of children who have sustained non-accidental head injury poses a unique challenge to the trauma surgeon who is typically among the first healthcare providers to evaluate these patients. High levels of emotion involved in caring for these children may confound the evaluation as well as potentially act as a barrier to identifying AHT [8]. It may also be difficult to accurately determine whether the child has truly sustained a non-accidental injury due to the lack of witnesses and unclear mechanisms of injury. Head injury is the most common injury sustained in NAT [2]. Previous investigators have attempted to define the type of injuries that are pathognomonic of NAT including subdural hemorrhage, retinal hemorrhage, rib fractures, cerebral atrophy and ventriculomegaly [3, 9–12]. There have also been attempts to develop injury-scoring systems to define children who have sustained NAT [13]. While the majority of the available literature seems to accept that the presence of any unexplained SDH or SDH not related to a comorbid condition in a young child should raise the suspicion of NAT, the data supporting this conclusion are difficult to interpret. Previous studies suffer from low patient numbers or often report contradictory results [5, 6]. The current report draws conclusions from a large cohort of patients with TBI and AHT, helping to clarify the current literature.

In the current study, we have attempted to better define the head injury pattern in those children with AHT. We identified 580 children with AHT and 1,435 children with accidental injury over a 16-year study period. Children sustaining AHT demonstrated a greater frequency of subdural hematoma or diffuse brain injury, and a decreased incidence of skull fractures and EDH relative to children suffering accidental injury. Children sustaining AHT were also found to be more severely injured, as measured by ISS, and had higher mortality rates, as we have previously reported [14]. This is likely due to the higher frequency of DAI and cerebral edema in the AHT population. We also suspect the AHT children have a more delayed presentation to the hospital after the initial traumatic injury, which may contribute to the increased mortality rate. Our findings are consistent with other previously published smaller series [5], which have also found a higher incidence of SDH and DAI in patients with AHT compared to those with accidental injury. In our review, children with AHT often sustained subdural hematoma (76 %) while children with accidental injury had a significantly lower rate of SDHs (25 %). This observation is also sustained in children less than 2 years of age. Thus, while the presence of a SDH does not confirm AHT, it should significantly raise the index of suspicion, as it is highly suggestive of AHT. In conjunction with our previous observation that rib fractures are predictive of NAT in children less than 2 years of age [9] as well as anemia (hematocrit <30 g/dl) and thrombocytosis (>400,000 platelets/ml) [14], we are beginning to identify specific injury patterns that should be considered NAT until proven otherwise. Similarly, when present, global insults such as DAI and cerebral edema are more suggestive of AHT rather than accidental injury, especially in the absence of a verifiable rapid acceleration—deceleration injury. Interestingly, skull fractures were more common in children who suffered accidental injury. This likely reflects the fact that many cases of AHT arise from shaking which results in a repetitive deceleration injury to the brain without actual blunt force injury to the skull [15]. However, some of these children still suffer blunt force to the skull given that nearly one quarter of children with AHT had concomitant skull fracture. For this reason, these results should be used with caution; CT findings alone cannot be used to differentiate AHT from accidental injury [16].

While we have identified radiographic patterns of injury in children suffering AHT relative to accidental injury, these findings alone cannot serve as a definitive diagnosis but should instead be used by healthcare professionals to heighten suspicion of AHT and mandate further evaluation, particularly in children less than 2 years of age. In many cases, the diagnosis of non-accidental trauma is made only after an exhaustive investigation of the events and care givers, careful physical examination to identify supporting findings such as retinal hemorrhage or bruising, and radiographic exams, like plain X-ray or bone scan, that reveal occult fractures in various stages of healing [17]. Future work will aim to use the data presented here, as well as our previous work [9, 14] that identifies other factors

associated with NAT, to develop a scoring system to help providers identify children at the highest risk of NAT. This scoring system will ultimately need to be validated in a prospective fashion; however, initial work will be directed at identifying which factors carry with them the highest risk of NAT.

Although this work represents the largest reported series of AHT in children, there are several limitations. We report a single center experience with a very active and specialized Child Advocacy and Protection team, but we must acknowledge there are likely children who escaped our detection of AHT. In addition, our institutional experience may not be reflective of the overall NAT population, considering our role as the only Regional Level I Pediatric Trauma Center for the state of Colorado and large areas of neighboring states. As this is a large catchment area, many children who are likely less severely injured are cared for in outside hospitals and never get referred to our trauma center. This may at least in part account for the excessive mortality seen in our patient population, since we are more likely to receive and care for the most seriously injured group of children and a small but unknown number of children with AHT may be admitted to other hospitals and either not diagnosed correctly, or are diagnosed but remain hospitalized but not at a trauma center.

AHT continues to be the leading cause of death in children less than age 5 years at our Level I Regional Pediatric Trauma Center. Furthermore, survivors of NAT have substantial short and long-term morbidity. In any young child presenting with head injury in the absence of an independently witnessed event, non-accidental trauma must be considered, particularly with the radiographic findings of subdural hematoma and/or diffuse axonal injury. A high level of suspicion with detailed history, careful physical examination, and adjunctive radiographic studies should allow early engagement of child protective services, social work, and the respective authorities to not only protect the victim but also to protect others within the home at risk of intentional injury.

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